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SCIENCENTRIS
From Knowledge to Market

FOREWORD

Over the last few decades, materials are facing a continuous revolution due to significant scientific and technical achievements obtained in cutting edge areas like physics, chemistry or biology. The possibility to design the material´s properties at the molecular level or to enhance their performance using advanced functionalization techniques, are making materials smart, able to respond and adapt to external stimuli, more durable and resistant and, mainly, completely adapted to each specific application.

Research and development on advanced materials for defense is being driven all over the world by the most renowned Universities, Research Centers, Military Institutes and Companies to meet important requirements to improve safety and survivability of platforms and personnel, along with requirements for enhanced maintainability and operability of platforms.

AUXDEFENSE2022 is focused on advanced materials research in the forward-looking enabling R&D domain where the intersection of key technologies in areas such as nano and microtechnology, biotechnology, meta materials, smart materials and structures, and energy generation and storage are being explored.

It is expected that AUXDEFENSE2022 may continue the work started in the previous editions (2018 and 2020), contributing for the important role played worldwide by this scientific event on the integration of the whole set of agents involved on this topic, bringing together scientists, researchers, militaries, students, technicians, entrepreneurs, end-users, companies, among others.

AUXDEFENSE2022 is the meeting point for all those interested on advanced materials for application in the defense field, including about 100 presentations from representatives of 35 countries, from 5 continents.

Guimarães/Portugal, 6 July 2022

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KEYNOTE LECTURE
INTELLIGENT MATERIALS

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ABSTRACT

The central role of science & technology in securing human life is evident from the diverse measures employed by the nations around the world against the raging COVID19 pandemic, which already infected 313 million people and sadly caused 5.5 million deaths. Examples include vaccines, diagnostic tools for screening of billions of people, facemasks, anti-viral surfaces, point of care, and remote monitoring of patients.

In the post-pandemic world, the demand for smart and intelligent materials will accelerate owing to the stressful human living, aging population, unmet clinical needs, and preparedness for perceived future threats. The scientific literature on smart and intelligent hydrogels, fibers, and wearables is rapidly growing.

In the coming years and decades, humans will have access to intelligent materials, devices, and systems to perceive their own mind and manage it as per their own will. A glimpse of the emerging future may be gleaned from the Neuralink (https://www.neuralink.com/), which recently announced a neural interface or in-brain device that could potentially solve neurological challenges. Moreover, further research and innovation will enable humans to access and control external devices via thoughts. This lecture seeks to draw attention to the emerging future underpinned by intelligent materials and systems.

KEYNOTE LECTURE

SMART TEXTILES FOR THE MONITORING OF BODY VITAL SIGNS AND ENVIRONMENTAL THREATS

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ABSTRACT

Novel spinning technologies like microfluidic wet spinning, thermal drawing, or electrospinning have recently enabled the development of multi-material and hybrid fibers. These multicomponent fibers can for example incorporate fluorescent moieties or bioactive materials and can be used as fiber-based sensors to assess vital signs for non-invasive body monitoring. Such sensors can measure physical parameters like the ECG or oxygen saturation in the blood, or chemical quantities in sweat or wound exudate (pH, lactate, different proteins, etc.), as well as harmful agents like volatile organic compounds. The implementation of such technologies requires an easiness to use and possible energy autarchy to ensure a high acceptance of the users. This may be achieved with the development of energy harvesting fibers. Our vision is the development of wearables that are not perceived by the users by integrating these sensing and actuating smart fibers into fabrics and clothing with classical textile technologies like weaving or knitting. Thus, these fiber-based sensors will become a new class of wearables called “disappearables”.

KEYNOTE LECTURE

SMART MINIATURIZED PAPER-BASED DEVICES FOR CHEMICAL AND BIOLOGICAL WARFARE AGENTS

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ABSTRACT

In the sustainability vision of the world, analytical chemistry has the overriding goal to deliver accurate, easy-to-use, and cost-effective analytical devices for the smart detection of the target analytes belonging to several fields including the defense field. Why the electrochemical biosensors are considered sustainable devices? Because i) their possibility to use themselves on-site without the need of skilled personnel, ii) their capability of the measurement with rapid feedback (few seconds/minutes), iii) their analytical features namely high accuracy and sensitivity, iv) their cost-effectiveness and miniaturizations rendering them well suitable for mass-production. Herein, I present our activity related to the development of smart and sustainable analytical tools for chemical and biological warfare agents.

INTRODUCTION

The biosensors are the sensing tools in which the biocomponents are in close contact with the transducers. The electrochemical biosensors are the ones in which the transducer relies on an electrochemical cell and this type of biosensor possesses several advantages concerning other transducers including miniaturization, high sensitivity, and the capability to work in complex matrices. It is not by chance that the biosensor with the biggest impact on our society is an electrochemical biosensor, that is the strip that each diabetic patient uses for glucose monitoring every day. To further improve the sustainability of these sensing tools, our group started to develop paper-based analytical devices to apply in the defense sector. Why the selection of paper to develop sustainable and smart devices? Paper-based devices have the capability of the management of the microfluidic without any external pumps and valves, the reduction of chemical reagents by using a low volume of sample, the easiness to use, and the reduction of sample treatment, the foldability to create easily 3D origami structures. Furthermore, we recently demonstrated that they can detect chemical warfare agents namely mustard agents in the gas phase without the need of the sampling system, overcoming the limitation of plastic-based sensors which can detect directly the target analyte only in liquid samples.

RESULTS AND CONCLUSIONS

Herein, I report three examples of paper-based biosensors developed for chemical and warfare agents namely nerve agents, mustard agents, and botulinum neurotoxins. The toxicity of the nerve agents relies on their capability to inhibit irreversibly a key enzyme of nervous transmission namely acetylcholinesterase. In the development of a miniaturized device to detect this type of chemical warfare agent, we have selected an enzyme belonging to the cholinesterase family namely butyrylcholinesterase. By measuring the residual enzymatic activity after the exposure of the biosensor to the sample, we can estimate the amount of nerve agents present in the sample analyzed at ppb levels. To carry out easily the measurement, we have exploited the porosity of the paper to pre-load the reagents, in that case, the 3D network of the paper works as a reservoir, and we ask for end-users only

to add a few mL of the sample or distilled water to carry out the measurement (Cinti, 2017)
In the case of mustard agents, together with the Bundeswehr Medical Academy, Medical CBRN Defence and Bundeswehr Institute of Pharmacology and Toxicology, Munich, Germany, we have designed an origami paper--based biosensor to detect sulfur mustard. The detection of sulfur mustard was carried out by monitoring the inhibitory effects of these chemical warfare agents on the choline oxidase enzyme. In that case, the configuration designed and the use of paper demonstrated for the first time the use of the paper-based device to detect the chemical warfare agent detection in the aerosol phase, avoiding the need for any additional sampling system. Indeed, being the paper-based device constituted of the electrochemical sensor printed on the filter paper and an addition filter pad with the presence of pre-loaded reagents, the humidity of the aerosol is able to dissolve the reagents delivering the measurement without any additional task for the end-user, with a fast and rapid measure with a detection limit of 0.019 g·min/m3 (Colozza, 2019).
For the detection of botulinum neurotoxins, we have developed the first paper-based antibody-free sensor biosensor for reliable and rapid detection of BoNT/A and BoNT/C, exploiting their cleavage capability toward a synthetic peptide able to mimic the natural substrate SNAP-25 in collaboration with Scientific Department, Army Medical Center, Italy within the National Project BIOAPTABONT funded by Italian Ministry of Defense. In this novel configuration, the peptide is labeled with the electroactive redox label and when BoNT/A and BoNT/C are present in the sample analyzed, they cleave the peptide with the electroactive redox label with the decrease of the response, proportional to BoNT amount. This paper-based biosensor can detect the target analyte with a detection limit equal to 10 pM (Caratelli, 2021). These diverse paper-based biosensors reported demonstrated the capability of the electrochemistry combined with paper-based support and enzymes/peptides to develop smart and sustainable devices for fast, cost-effective, and sensitivity analyses on site by unskilled personnel.

ACKNOWLEDGMENTS

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KEYNOTE LECTURE

SHOCK ATTENUATION CHARACTERISTICS OF METHYLCELLULOSE HYDROGELS: EXPERIMENTATION AND PHENOMENOLOGICAL MODELING

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ABSTRACT

Liquid methylcellulose hydrogels have a definite potential to mitigate strong shocks, of the kind responsible for traumatic brain injury. As such, they can complement the usual armor layers aimed at destroying the threat while transmitting the shock elastic energy without disturbance.

The shock attenuation characteristics of aqueous methylcellulose (MC) gels were characterized experimentally and modeled towards their application in bodily protection systems against traumatic injury. The attenuation of MC gel with 4 different thicknesses (4, 7, 10, and 20mm) and 3 concentrations (5, 10, and 15%Wt) was measured, using an instrumented (Hopkinson) bar and piezoresistive sensors for direct force sensing on the gel.

First, the impulse attenuation was systematically characterized for all combinations of thickness and composition, and the results were analyzed statistically. The impulse attenuation increases with both thickness and MC concentration. A non-linear function was then fitted to the experimental results. The fitted functions increase monotonically with both the thickness and the concentration of the gel layer. However, the slope of each function decreases gradually with the thickness of the layer, thereby indicating an effective thickness beyond which shock attenuation efficiency does not increase significantly. The frequency dependence of the attenuation was determined next and found to be relatively independent of both thickness and gel concentration up to 100 kHz. A phenomenological expression was developed and validated for the shock attenuation of MC gels as a function of their composition, thickness, and spectral content of the shock.

In the next step, (kinetic) energy mitigation was experimentally characterized using a momentum trap setup, thereby completing the picture of the shock energy attenuation by liquid MC hydrogels.

INVITED LECTURE
MATERIALS RESEARCH AND INNOVATION PLANNING IN EUROPEAN DEFENCE

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ABSTRACT

The role of the European Defence Agency as Innovation Hub has been recently discussed within the EDA Steering Board in the configuration of R&T Directors, following a call from the Foreign Affairs Council (conclusions of May 2021) to reinforce EDA's role in fostering defence innovation, including disruptive technologies. The hub will function as a network to identify and promote the development of innovative and disruptive defence technologies, testing and certification services.

The EDA Materials & Structures Capability Technology Group (CapTech) is a well-established forum composed of Member States representatives, supported by industrial and academia stakeholders, and is contributing to this priority axis through the current set up of a long-term research programme, called ICARO (Innovative materials for CApability-driven Research for Outstanding European defence). It is composed of four Strategic Research Clusters (SRCs) whose endpoint is the research development and innovation enhancement in four domains: air, maritime, land and cross-cutting. A total of 9 projects distributed among the four SRCs is expected to be implemented in the upcoming 8 years, enhancing competencies in several fields, such as structural health monitoring, high-temperature materials, advanced additive manufacturing, sustainable materials, ballistic protection.

ICARO is based on the Technology Building Blocks of the Materials CapTech and related roadmaps, which are part of the EDA Overarching Strategic Research Agenda (OSRA).

INVITED LECTURE

DESIGNING AND MANUFACTURING LIGHTWEIGHT MULTIFUNCTIONAL STRUCTURAL MATERIALS

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ABSTRACT

System weight is a key determinant of the performance and operational endurance of mobile vehicles (e.g. drones, automobiles, etc.) and equipment (e.g. armor, golf clubs, etc.). For this reason, there has been an endless pursuit of lightweight material systems through methods such as alloying, composites development, and structural design. The latter, in particular, has been advanced significantly by the advent of additive manufacturing in recent years, due to 3D printing's ability to realize a wide range of complex designs for testing without the need for expensive tooling. There has also been emerging interest in the strategy of using multifunctional materials to replace multiple dedicated materials for lightweight purposes, as well as to increase the functionality of structural materials.

In this talk, I will be sharing my team's experience with designing lightweight, stiff and strong materials from first principles, the challenges faced with fabricating the designs, as well as developments on the material and design front to imbue the structures with additional properties such as negative Poisson's ratio, compressive resilience, and electrochemical storage capabilities.

INVITED LECTURE

SMART PPE FOR BETTER SAFETY AND THE ISSUE OF RELIABILITY

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ABSTRACT

Today's users of PPE rely on the highest quality of integrated textile components, which are produced in compliance with standards from a specific application field. In addition, known production technologies and quality parameters are the basis for repeatable quality of the PPE. Speaking about the human safety increased by smart PPE we are still faced with the lack of reliability in functioning of these smart systems. The reason is related to the IoT systems and reliable (and secure) communication protocols, which again depend from one to another application field. A second open issue that need to be solved is the repeatability of the production processes in the serial manufacturing. A proper approach in solving these two problems can result in accessible smart PPE on the EU market.

This work is presenting the solution for above problems by defining the quality parameters for reliability and repeatability, either by understanding the end users working environments or by using the appropriate testing methods/protocols.

INTRODUCTION

The proposed work is presenting the importance of human safety in relation to the reliability of today available smart PPE prototype. Human safety and protection given by the PPE has to be adequate through the whole time of its usage. Today´s PPEs are made accordingly to standards from the specific application field and all integrated textile components are fulfilling this requirements.

For the defence, the PPEs must be in compliance with STANAG standardize guidelines for the required properties of combat clothing in general (STANAG 2333), of the tropical field (STANAG 4563), for the design for arctic clothing (STANAG 4573), for the waterproofness (STANAG 4364). In addition, the guide for environmental testing (STANAG4370) for project managers, programme engineers and environmental engineering specialists has to be followed in the planning of these products. The goal is to identify potential damaging effects that natural and induced environmental conditions have on the materials and complete combat clothing ensembles.

For firefighting, the PPE must be in compliance with EN 469, while in addition also the testing using the flame manikin tests are welcome (ASTM F1930, ISO 13506, NFPA 1971, NFPA 2112).

There are many smart PPE prototypes that have been developed for the defence and rescuing, but the current situation with the smart PPE for this extremely harsh environments is still more on the R&D side than in the industry. The reliability of the smart PPE depends on its weakest components, which are the battery, secure communication between the PPE and data platform, cable or wireless connections between sensors, price/quality relation of sensors themselves, etc… In addition, after use maintaining protocol of smart PPE needs as well some adoptions to the real operational fields, similar to protocols which are known today (for non-smart PPEs).

RELIABILITY AND SAFETY

Human safety in rescuing requires zero failure smart systems.

For hot harsh environments (like firefighting) this means that all into the PPE integrated components, have to be resistant to the condition of a flash fire explosion (ISO13506), high humidity (read "wetness") and to the variety

of combined mechanical (sometimes also biological and nuclear) and thermal loads. The electronics available today for wearable systems is not resistant to the mentioned environmental impacts.

For extreme cold environmental conditions (STANAG 4573), the main function of the PPE is to provide the satisfied thermal insulation to protect the users against cold induced injuries. In this case the most challenging problem of the electronic components in wearable systems is the durability of the battery. Nevertheless, the minimum durability has to rely with the time of activities performed in cold environment (hiking, guard duty, rescuing, ….).

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INVITED LECTURE

TRIPLY PERIODIC MINIMAL SURFACES SANDWICH STRUCTURES SUBJECTED TO SHOCK IMPACT

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ABSTRACT

Triply-Periodic-Minimal-Surfaces (TPMS) are cellular structures that naturally inspired continuous non-self-intersecting surfaces with controllable mechanical properties. In this work, sandwich composite panels constructed from four different types of TMPS unit cells and metallic facets are numerically investigated and compared to evaluate the dynamic behaviors when subjected to blast loadings. The finite element analysis is employed to characterize the deformation of proposed structures taking into account the rate-dependent properties, elasto-plastic response, and nonlinear contact.

The Johnson-Cook material model is implemented to capture the transient responses of the TPMS sandwich panels under high strain-rate loadings. The numerical model is validated with a two-dimensional analytical one revealing the static sand dynamic crushing strengths. Due to the symmetry, only a quarter of the panel is simulated using simple shell elements, which significantly reduces the computational cost.

A series of studies are conducted to evaluate the influences of different design parameters on the blast resistances of TPMS composite panels. Reaction forces and critical stresses extracted from underneath protected structures are assessed for various key parameters including TPMS type, thickness, number of layers. TPMS sandwich structures clearly demonstrate unique dynamic crushing responses, impact energy mitigation & dissipation mechanisms, which leads to the enhancement of the blast resistance.

INVITED LECTURE

THREE-DIMENSIONAL NEGATIVE POISSON'S RATIO LATTICE STRUCTURES WITH ENHANCED LOAD BEARING CAPACITY

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ABSTRACT

Negative Poisson's ratio (NPR) lattice structures exhibit unusual deformation behavior. They laterally contract, rather than expand, when compressed. The NPR lattice structures, especially those in 3D forms, have attracted considerable attention in recent years because of their intriguing mechanical properties and numerous promising applications, particularly in stringent environments, such as in aerospace and defense fields. The 3D NPR lattice structures exhibit superior dynamic loading and energy absorption capabilities compared to non-NPR materials and structures. However, a remaining barrier to their application is their low load-bearing capability. Despite attempts to address this by implementing an embedding enhanced strategy, no satisfactory and systematic design strategy has been developed. In addition, commonly used basic materials for fabricating the 3D NPR lattice structures are single types of materials such as metals or polymers of which the effect on improving the mechanical properties of 3D NPR lattice structures is limited.

In this presentation, a novel class of 3D NPR lattice structure that has high load-bearing capacity will be presented, and the effects of structural parameters on its mechanical performance will be discussed.

Funding sources

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INVITED LECTURE

TRANSIENT RESPONSE AND FAILURE OF UHMW-PE (DYNEEMA) PANELS SUBJECTED TO EXPLOSIVE DETONATIONS

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ABSTRACT

This work describes an experimental investigation into the response and failure characteristics of ultra-high molecular weight poly-ethylene (UHMW-PE), commonly known as Dyneema©, when subjected to loads arising from high explosive detonations. Panels were manufactured from Dyneema HB26 in a polyurethane matrix, mounted in a clamping frame and subjected to explosive detonations using PE4 at a stand-off distance of 50 mm. The charge mass was varied to obtain a range of responses, including rupture failure. For tests not involving rupture, a high speed stereo-vision system, combined with digital image correlation, was used to determine the transient displacement of the rear face of the panel, obtained insights into the peak deformation and rebound characteristics.

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CALCULATION OF K_H (HUBERTY'S COEFFICIENT) FOR AGAVE FIBERS SPINNING OPTIMIZATION.

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ABSTRACT
The yarn regularity is an important quality factor that depends on the number of fibers in crosssection and coefficient of variation of fiber diameter (CV_d).To determine the transversal regularity of a yarn, the K parameter is defined. This parameter is based on the number of fiber in cross-section of a real yarn and its ideal model.
The closer real K (K_{Real}) to k of ideal yarn(K_{ideal}), the yarn produced is more regular.

INTRODUCTION
Natural fibers obtained from different plants, due to their amazing properties, have been considered. Today, there are hundreds of plants that their leaves, seed or stems used as raw materials for textile industrial. The bio-based fibers are low-cost, high hydrophilicity, lowdensity, biodegradable and renewable, recyclable. They have good mechanical and antibacterial properties [1]. The fibers used in this work, agave fibers, are a part of fibro vascular system of the leaves. They classified as hard fibers and have interesting mechanical properties that give them good technical applications for example geotextile. Purpose of this research is the calculation of Huberty's coefficient, which is one of the most important parameter involved in the optimization of fiber spinnability and until now has been calculated only for cotton and wool [2]. By calculating KH, we can obtain the transvers irregularity of fibers and this irregularity is an important factor in determining the spinnability limit and optimizing the spinning process.

MATERIALS AND METHODS
Agave fibers are extracted from mature leaves harvested from the agave plant. Fibers after washing to remove unwanted materials such as gel, pulps and the remaining leaves; are dried in the ambient temperature for one day (20°C and 65%HR). In the last step, all neps (small tangling of fibers that cannot be unraveled) are removed and the agave fibers are combed and placed in parallel. The agave fibers are a rich source of cellulose and can replace instead of cotton. At the same time, they are very long fibers that can be spun based on wool spinning. Therefore, we need to calculation this coefficient to have a good evaluation of the spinnability.Based on Martindale equation [3], transversal irregularity is equal to:

$$CV_A = \frac{100 \cdot \sqrt{1+0.0004 \cdot CV_d^2}}{\sqrt{\overline{n_s}}} \quad (1)$$

In addition, based on Huberty [3]:

$$K_{real} = \sqrt{\bar{n}_s} \,.\, CV_{total} \qquad (2)$$

(1) (2): $$K_{ideal} = Lim\ K = \sqrt{\bar{n}_s} \,.\, Lim\ CV\ (total) = 100. \sqrt{1 + 0.0004\,.\,CV_d^2} \qquad (3)$$

$$K_{ideal} = 100. \sqrt{1 + 0.0004\,.\,CV_d^2} \qquad (4)$$

As result, K_{ideal} depends only on CV_d, CV_d which is the coefficient of variation of fibers diameter. To measure diameter of agave fibers, we need to have an image of cross-section of fibers. To have a clear picture of the cross section of agave fibers, we use the microtome method. In this method, the fibers are dried vertically inside the resin epoxy and a microtome device cuts them (figure1). Cross-sectional area of fibers are observed by scanning electron microscope (SEM) (Figure2). Then the fibers diameter measurement were calculated based on equation 5 (figure3).

$$\mathbf{d = (d_1 + d_2) / 2} \qquad (5)$$

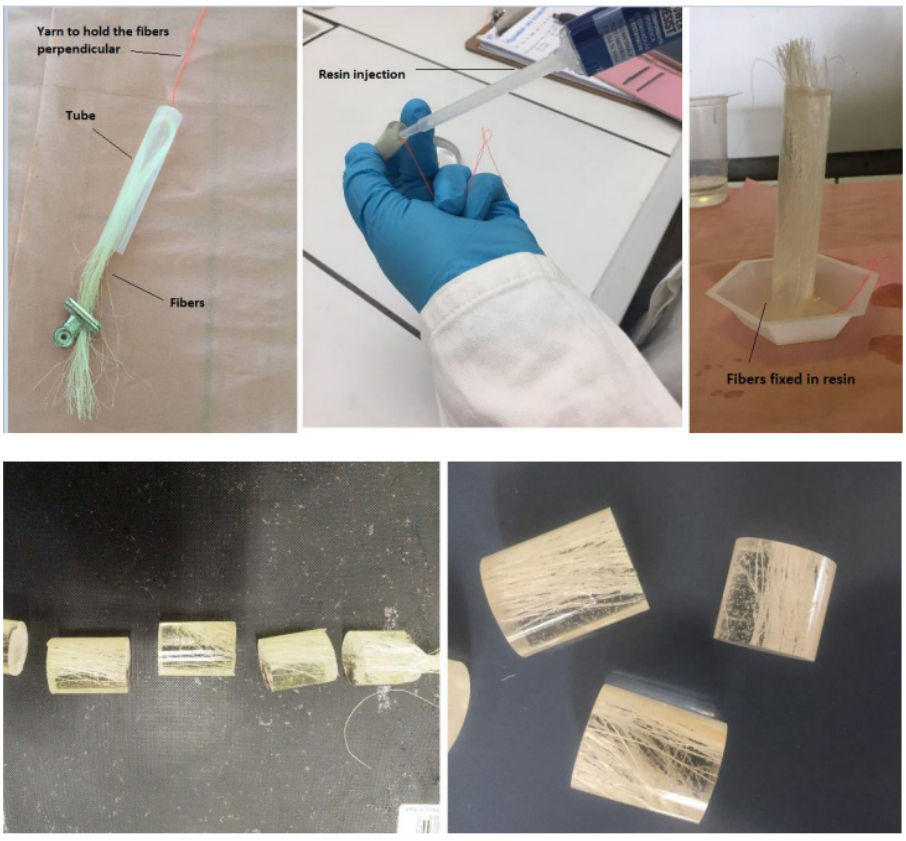

Figure 1: Steps of fixing the fibers inside the resin for cutting

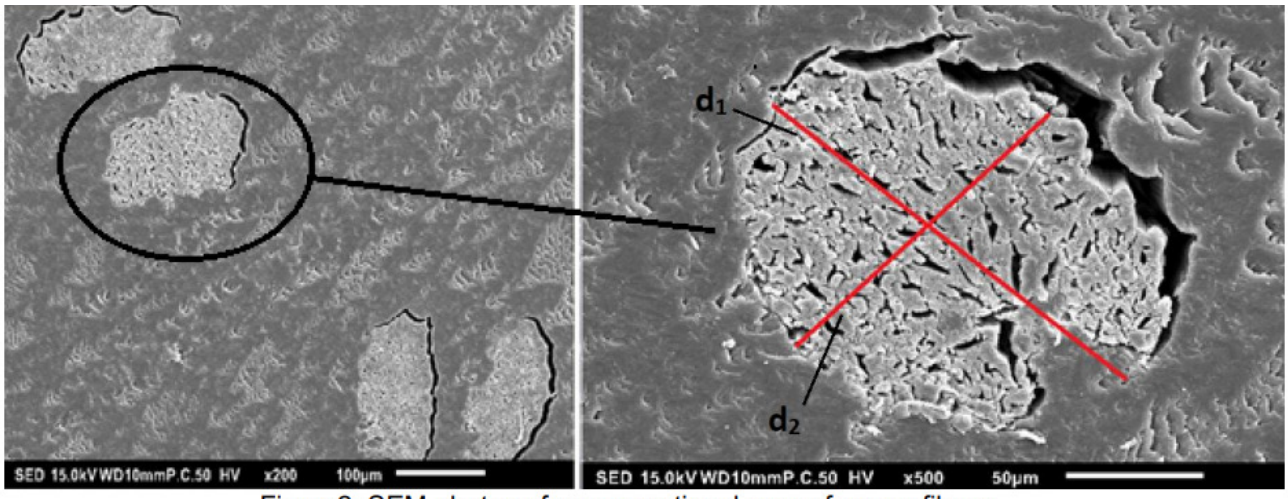

Figure2: SEM photos of cross-sectional area of agave fibers.

RESULTS AND DISCUSSION

From fiber diameter measurement, CV_d for four types of agave fibers grown in France and Senegal was calculated. The value of K_H is shown in table below. Using K_H we can determine the irregularity of agave fibers; it is enough to compare K_{Ideal} with K_{Real}. A K_{real} with bigger value than KI_{deal} is related to the greater irregularity. To have the spinnability limit, we need to K^{Real} close to K_{Ideal}.

Table1: K_{Ideal} and $CV_{l,d}$ for French and Senegalese agave fibers

Agave Fibers	$CV_{l,d}$	K_{Ideal} calculated
Salmiana (FR)	141	299.2
Salmiana (SN)	69.4	171.0
Crassispina (FR)	98.4	220.7
Crassispina (SN)	87.4	201.3

K_{Ideal}. Has been calculated for cotton and wool fibers befor this researche.

Table2: K_{Ideal} calculated for cotton and wool fibers.

Fibers	K_{Ideal} Calculated
Cotton	1.12
Wool	1.06

According to equation, we know that, K_{Ideal} depends on the coefficient of variation of fibers diameter. CV_Djustifies the difference between the values of KI_{deal}. in cotton and wool with agave fibers diameter is more dispersed in agave fibers for example, in Salmiana (FR) max and min diameter are 256.6 µm and 64 µm respectively, but typically cotton and wool fibers are more homogenous in diameter. Agave fibers are technical fibers consisting in fiber bundles. Improving the spinnability of agave fibers needs to decrease K factor by decreasing CV_d. To do that, we must work on the fibrillation of the bundles, this will be the subject of a future presentation.

CONCLUSION

The current paper presents a strong method to calculate Huberty's coefficient for agave fibers as well as all other fibers. This approach will give to spinners a reliable tool to evaluate the spinnability of such fibers instead of using cotton or wool parameters. Due to the wide range of bio sourced fibers, the studies of real spinnability parameters have to be improved for these fibers.

ACKNOWLEDGMENT

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ID 142

STUDY OF MECHANICAL PERFORMANCE OF HYBRID WOVEN FABRICS AS POTENTIAL REINFORCEMENT IN COMPOSITES.

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ABSTRACT

This work compares the porosity, puncture, tensile and stiffness properties of two novel hybrid woven fabrics with two basic woven fabrics (matt and 6 ends Satin). The fabrics were developed using a natural fibre Jute yarn on rapier dobby machine present in a in-house lab. The tests were performed on a universal testing machine and circular bend procedure stiffness tester. The satin weave showed maximum deformation during a puncture test. Moreover, the hybrid weave demonstrated improvement in tensile property during a tensile test. The stiffness of hybrid weave is better as compared to other fabrics.

INTRODUCTION

The fabric can be of different types based on design and construction parameters. The basic types of fabric can be categorized as woven, braided, knitted and non-woven (Grosberg, 1966). The variation in fabric architecture influences the mechanical properties of the woven fabric (Booth, 1961). The crimp of the weave structure is also pivotal in deciding the tensile strength. Theoretically, plain weave has high crimp as compared to satin weave. The more the crimp amplitude in the fabric, the less will be the tensile strength. This causes a less contribution towards the tensile force and inter-yarns get more entangled (Saiman et al., 2014).

Hybridization of yarns in a weave structure by using different fibers can be beneficial in obtaining optimum mechanical performance structures to save cost (Andrew and Arumugam, 2017). The hybrid natural woven fabric can be potentially used in composite for aerospace and construction and low velocity impact applications. In this study, the porosity, puncture resistance, tensile and stiffness properties of natural fiber based woven fabrics from two different novel hybrid woven fabrics, with the combination of longer and shorter yarn floats, and two (2) basic woven structures are studied.

RESULTS AND CONCLUSIONS

The results showed a significant effect of weave structure on the mechanical properties of developed fabrics as shown in Table 1. The porosity is linked with the areal density of the fabric. The Matt weave with lowest areal density shows the highest porosity and sample with highest areal density shows the lowest porosity. The results of puncture and tensile tests are shown in Fig. 1. Multiple peaks are present in the load extension curve during a puncture test showing the breakage of filaments. The Matt weave show least penetration resistance and can be linked to high porous structure. Moreover, the Satin weave with loose structure show highest peak load during a puncture test. It is found that the Matt weave show the least tensile strength in the warp wise direction. However, the hybrid weave (consisting of combination of Matt and Satin weave) shows the maximum peak load due to the presence of a compact part in its weave structure (matt weave). The results can be attributed with the presence of crimp amplitudes in the woven structure. It is found that the more the crimped structure the less will be the tensile strength. Furthermore, the sample with a loose and tight part in its weave structure (Hybrid weave consisting of combination of Satin and Matt weave) shows the highest stiffness. The Satin weave having a loose

structure showed the least stiffness.

Table 1 Mechanical properties of developed woven fabrics

Structure	Porosity	Puncture load (N)	Tensile Stength (N)	Stiffness (gm)
S1 (Hybrid A)	76.2 %	267	1148	18655
S2 (Matt)	82.5 %	132	798	15145
S3 (Hybrid B)	81.0 %	231	1105	11312
S4 (Satin)	79.72 %	275	961	10827

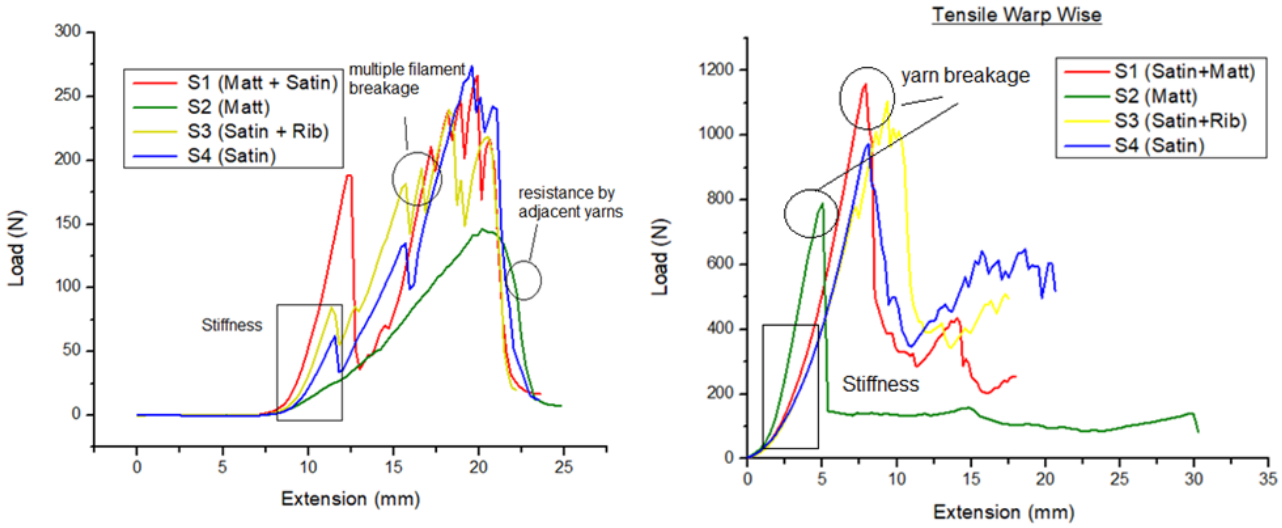

Fig. 1 Load extension curves of a) Puncture test b) Tensile test (warp wise)

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ID144

DESIGN OF PERSONAL PROTECTIVE CLOTHING FOR PORTUGUESE WOMEN FIREFIGHTERS – STUDY OF THE REDESIGN PROCESS BASED ON AN ERGONOMIC STUDY

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ABSTRACT

This work focuses on the redesign of Personal Protective Equipment (PPE) for Portuguese women firefighters in the municipality of Guimaraes. It was observed that women Firefighters use the same type of PPE that are available to men Portuguese Firefighters. Thus, with regard to comfort related to the usability of PPE, the considerations of this work are focused on limiting movements, especially in action situations, compromising the safety of users, leaving them dissatisfied. Users are looking for better comfort in terms of ergonomics, functionality and practicality; they look for solutions that respond to their needs, based on the study of their anthropometric measurements. Such needs, in terms of protective clothing, constitute the main problem of this study. Thus, in addition to analyzing the personal protective clothing of Portuguese female firefighters, the main objective of this research is to propose the redesign of the elements that make up the individual protective clothing of Portuguese female firefighters, in order to enhance their safety, ergonomic and sensory comfort, combining codesign as a product innovation strategy.

INTRODUCTION

In order to offer solutions to problems related to the movement restrictions of this target audience, since the situation causes several problems regarding the comfort and safety of women.

The redesign study was carried out through an exploratory analysis of the PPE used by firefighters, observing its construction form through the analysis of the modeling study. Therefore, in order to carry out the redesign of the equipment, essential factors were considered, such as: analysis of body shape, anthropometric measurements and movements performed by women firefighters from Guimarães - Portugal, during their professional activities. The product was digitally presented through an illustrated and technical drawing, with a differentiated design, presenting a distinct redesign proposal, adding comfort, namely in its ergonomic and anthropometric components.This study presents suggestions for a redesign of the elements that make up the Individual Protection Equipment of Portuguese Women Firefighters of Guimarães, belonging to the Volunteer Fire Brigade of Guimarães, with a greater focus on the elementary details of each piece (pants and coat), considering the exchange active discovery, to improve the working systems of each part of the play in the course of the action. Transversely, it benefited from the collaboration of firefighters, exploring the user's own knowledge, that is, combining co-design as an innovation strategy with an emphasis on user comfort.

RESULTS AND CONCLUSIONS

In the final result of the research carried out, Thus, the current clothing in the firefighters' body was evaluated, verifying the details that complement the piece with the active exchange of findings collected from the user, a way used to adapt and adjust the functioning of parts of the piece during the activities carried out during the actions. With the analysis carried out from the observations during the active exchange with the participants, it was possible to identify improvements in the firefighters' clothing.

It is possible to conclude that studies related to anthropometric analysis combined with ergonomic and sensory comfort are foundations in the development of Individual Protection Equipment for women firefighters. So, the analysis of body measurements and lines, the ergonomic considerations applied in testing positions and movements in activities during simulated actions, were tools used that can contribute to change the way firefighter PPE is designed, produced and tested in the field. future.

In addition, it can be seen that even with the development of the equipment from the measurements of the women, it is essential to know their activities in full action, so that it is possible to analyze the positions and movements carried out, being able to carry out an analysis of the parts of the body. clothing on the body in action, to locate those that most need movement, avoiding their restriction. The participants took active positions, simulating their day-to-day actions, making it possible to identify opportunities for improvement. As this is an PPE, it was essential to evaluate the equipment used by the users during the execution of the action.

ACKNOWLEDGMENTS

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ID145

MODAL ANALYSIS OF VIBRATION OF A MACHINE GUN BARREL

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ABSTRACT

The study analyzed the vibration of the barrel of a machine gun firing 7.62 x 51 mm ammunition with the use of modal analysis based on the presented version of the rifle for special forces. The version of such a rifle differs slightly from the rifles intended for the land forces, namely the barrel length, which is 440 mm. The research methodology was based on three variants of the barrel length, where a replacement model in the form of a unilaterally restrained beam was used, and then the stiffness of the system with additional equipment was considered. The reference point was the standard machine guns used by infantry units of the land forces with a barrel length of 547 mm.

INTRODUCTION

One of the most important groups of firearms is the barrel. It is the barrel that causes the phenomenon of a shot, as a result of which the projectile is ejected from the barrel of the barrel at the right angle to reach and hit the target [1,2]. Therefore, balance issues during the shot are an important problem in the barrel strength analyzes. The work to date has focused on various analyzes, ranging from muzzle velocity analyzes, projectile analyzes with the speed of energy creation and the velocity of the projectile moving along the barrel conduit. [3,4,5]. This has a significant impact on the reaction of the material from which the barrels for firearms are made.

RESULTS AND CONCLUSIONS

Numerical analysis was performed in Abaqus software using modal analysis. In the first stage, 3 (three) barrel lengths were analyzed: L1 = 547 mm, L2 = 440 mm and L3 = 400 mm, as one-sidedly supported beams. The results were analyzed for 8 mod. In the second stage, the impact of additional equipment for three length variants was analyzed. The influence of the gas pusher pipe on the system stiffness was investigated. In the last stage, hybrid numerical methods were used in which the combustion process of the mixture of the propellant and the projectile on the muzzle velocity was modeled for the barrel lengths under consideration (see Fig. 1). The results of the individual frequencies are summarized in Table 1 below.

Table 1 List of vibration frequencies for barrels

Modal	L= 547 mm	L= 440 mm	L= 400 mm
1	87 Hz	134 Hz	165 Hz
2	362 Hz	576 Hz	753 Hz
3	953 Hz	1407 Hz	1805 Hz
4	1773 Hz	2762 Hz	3425 Hz

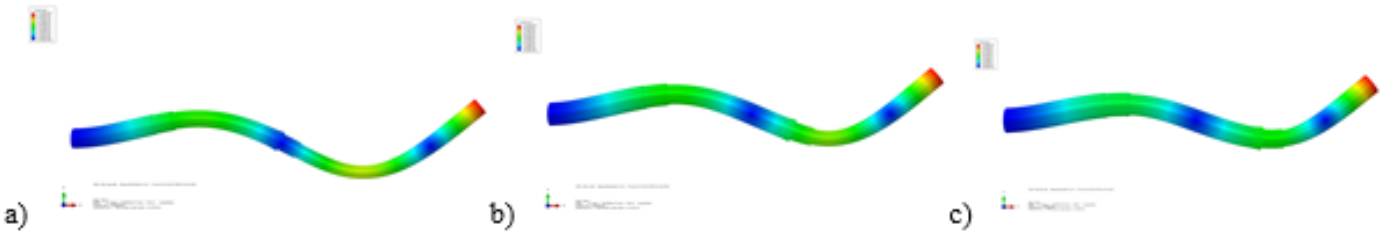

Fig.1 Przykładowe wyniki dla mody 1: a) L= 547 mm, b) L= 440 mm, c) L= 400 mm

CONCLUSIONS

The conducted research on the modal analysis of the rifle barrel shows us the influence of the barrel length on the results. It has been observed that the increase in the frequency of vibrations is related to the shortening of the barrel length, which directly translates into the stiffness of the system and the accuracy of the weapon. Such research allows us to optimize the reliability of the weapon and its accuracy.

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ID146

THE MODULAR, LIGHTWEIGHT AND ERGONOMIC PROTECTIVE SOLUTION FOR THE SOLDIER - VESTLIFE

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ABSTRACT

The demands of protective clothing are strict and mostly contradictory since they require the combination of optimal protection and comfort. VESTLIFE project aimed to develop a newlightweight and modular bulletproof integral solution, which integrates a CBR detection system. As a result, two prototypes were designed and improved over a complex reengineering cycle. To assess the different components and complete systems' performance, tests in controlled and non-controlled environment were performed. In controlled environment tests were performed both in terms of thermal and physiological comfort using a thermo-sweating manikin, as well as ballistic tests. Regarding non-controlled environment several tests to evaluate VESTLIFE prototypes and identify possible limitations were conceived, recreating a set of activities that can be performed by military personnel in operational theatres. A field exercise course was conceived to test the prototypes and evaluate ergonomics and comfort as well as trials with military and civilian users, comprising movements according with prEN16448-1 (Protective Clothing - Body Armour - Part 1:General requirements). Additionally, a physiological assessment was done at CINAMIL.

INTRODUCTION

VESTLIFE project aimed to develop different types of ballistic protection armour with advanced features. The protection system consisted of different levels, mainly soft and hard armour in a modular approach. In parallel, a CBR sensor was integrated enabling possible risks detection. Two prototypes were developed, the Standard vest with a ballistic belt and the Slim vest with a tactical belt. To test its usability and comfort, studies were carried out in controlled environment in a climatic chamber with predefined environmental conditions, considered the most common within the scenarios in which European military forces arecurrently deployed. The vest's degree of usability and comfort was achieved considering the degree of physical activity and the typical environmental conditions of its use. A methodology was envisioned, based in the L.E.A.P. (Load Effects Assessment Program), toassess the prototypes in an "in-field" experience with the purpose of recreating a set of activities that can be performed by military personnel in operations, to identify possible limitations and improvement areas. This course is a standardized military obstacle course that comprises ten sequential timed mobility tasks, each designed to simulate the most common or the most challenging physical tasks encountered during military tactical operations [1].

RESULTS AND CONCLUSIONS

The two prototypes comprised three levels of ballistic protection that were achieved, namely, level IIIA (soft panels with 3layer fabric knitting technology), level III (by means of auxetic composites) and level IV (lightweight 3D printed ceramics). Both types of protection obtained are improved and more lightweight, with the soft panels achieving up to 23.9% weight and up to 30% blunt trauma reduction. Regarding the hard plates, it was registered 24% weight reduction and back face signature reduction up to 30%.The testing methodology to quantify the comfort of the systems developed was based on using an adult-like thermal manikin in a climatic chamber with established environmental conditions, and using an integrated sweating system, thus simulating the human body's physiological sweating (Fig. 1)

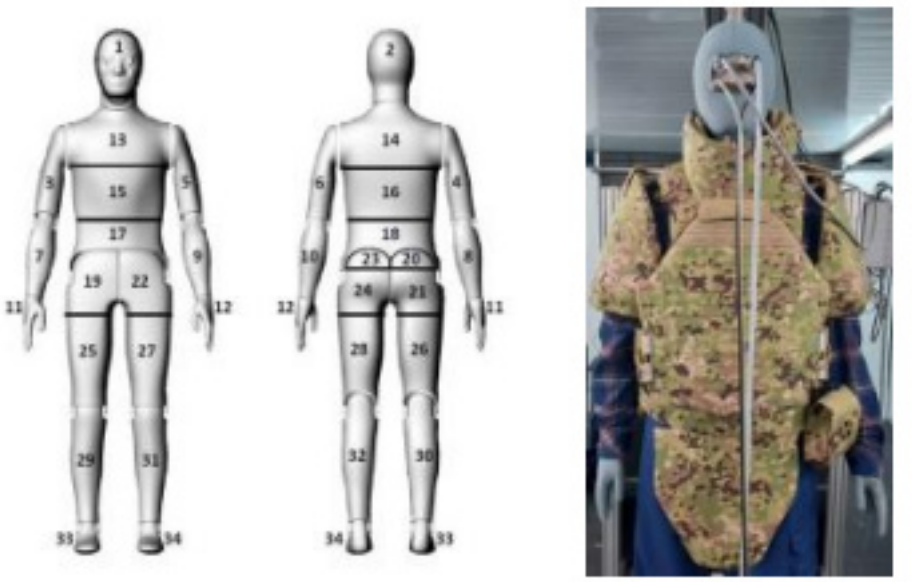

Fig.1 Comfort testing with manikin.

The ergonomic field trials, based on the L.E.A.P. program, were devised to simulate real combat field movements and grouped in 3 stations. Station duration time, Borg scale of perceived effort, heartbeat and body temperature measurements, vertical jump distance, global evaluation (flexibility, volume, weight, agility, velocity, mobility, and general fatigue) and user feedback were obtained, using questionnaires. Additionally, military and civilian testers performed ergonomic movements, Fig. 2, according with prEN16448-1 requirements and replied to a five-levels questionnaire (Excellent; Good; Fair; Poor; Unacceptable).

Fig.2 Illustration of the movements performed by civilian and militar users.

The Military Readiness Lab (CINAMIL) assessment focused on the prototypes physiological responses using a set of three protocols:1) Lab; 2) Task S. Course and 3) Force Platform.

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ID147

EFFICACY OF COOLING VESTS BASED ON DIFFERENT HEAT-EXTRACTION CONCEPTS

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ABSTRACT

The present study aimed to investigate the performance of different cooling concepts in a simulated industrial setting, with participants exposed to warm and moderately humid environment with low air velocity. Under the studied environmental conditions (ambient temperature: 35°C, relative humidity: 50%), the vests provided different levels and durations of cooling.

INTRODUCTION

A wide range of cooling vests for heat-stress mitigation purposes during physical work are available on the market. The decision regarding the optimal cooling vest/concept for a specific environment can be challenging by relying solely on the information provided by the manufacturers. The aim of this study was to investigate how different types of cooling vests would manifest/perform in a simulated industrial setting, in a warm and moderately humid environment with low air velocity.

Ten young males completed six experimental trials, including a control trial (no vest) and five trials with vests of different cooling concepts. Once entering the climatic chamber (ambient temperature: 35°C, relative humidity: 50%), participants remained seated for 30 minutes to induce passive heating, after which they donned a cooling vest and started a 2.5-h of walk at 4.5 km.h-1. During the trial, torso skin temperature (Tsk), microclimate temperature (Tmicro) and relative humidity (RHmicro), as well as rectal temperature (Tre), gastrointestinal temperature (Tgi) and heart rate (HR) were measured. Before and after the walk, participants conducted different cognitive tests and provided subjective ratings throughout the walk.

RESULTS AND CONCLUSIONS

All vests reduced Tre and HR significantly (37.6±0.2°C, 103±12 bpm, respectively) when compared to control trial (37.9±0.3°C, 116±17 bpm, $p<0.05$). Four vests also reduced the torso Tsk (31.7±1.5°C, $p<0.05$) compared to control trial (36.1±0.5°C, $p<0.05$). Cognitive performance remained unchanged between the trials. Physiological responses were also well reflected in subjective reports. Conclusion: Most vests could be considered as adequate mitigation strategy for workers in industry at studied conditions.

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ID148

RAISING THE BAR OF PROTECTIVE COATINGS DURABILITY THROUGH MONITORING THE PROTECTIVE COATING BARRIER PERFORMANCE

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ABSTRACT

Protective coatings are essential for maintaining the integrity and reliability of metallic military assets, and increasing the durability of coatings is of immediate interest. This paper presents examples of monitoring the performance of protective coatings done at the Faculty of Chemical Engineering, University of Zagreb, in the course of developing a novel Quantitative Coating Quality (QCQ) technology. The technology aims to capture temporal patterns of coating behaviour by measuring coating impedance during accelerated testing and in the field. The most basic function of the QCQ device is to measure coating impedance at 0.1 Hz. Impedance values between 6 and 11 on a logarithmic scale are characteristic of rust-free coatings and are indicative of the barrier effect of the coating. It is expected that the quantitative readout will prove to be a valuable input for pre-qualification of coating systems and condition-based maintenance.

INTRODUCTION

Coating impedance testing is described in the standard ISO 16773-2, which allows various cell designs but describes the use of a cylindrical cell filled with liquid electrolyte. This cell requires a separate specimen of a particular coating system to be tested after various periods of accelerated exposure and is also impractical for field measurements.

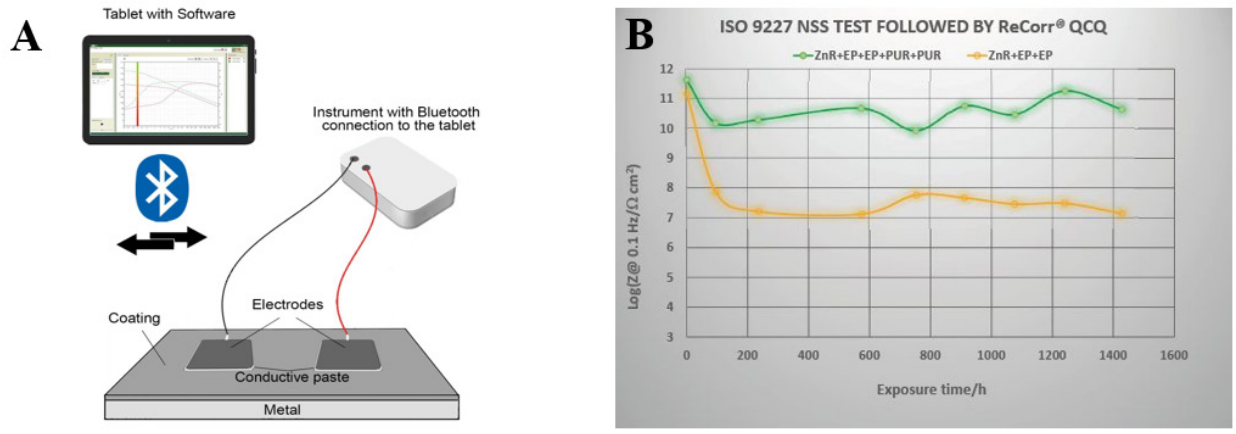

Figure 1. QCQ setup (A) and an example of ISO 9227 neutral salt spray QCQ results (B).

The novelty of the QCQ technology is the application of the flexible polymer electrodes (Figure 1 A) and a conductive paste. The measurement can be performed non-destructively and repeatedly on flat and curved surfaces with any orientation, in the laboratory and in the field.

RESULTS AND CONCLUSIONS

An example of the application of QCQ during a 1440-hour neutral salt spray test (ISO 9227) shows a significant difference in impedance between an excellent and a doubtfully performing coating system (Figure 1 B). Another example (Figure 2) shows a difference in QCQ results for the unexposed epoxy coating and the identical coating exposed to offshore-like conditions for two years. The results for the unexposed and aged, heavily chalked sample, which is susceptible to wetting, are much lower than for the unexposed sample (Figure 2 B).

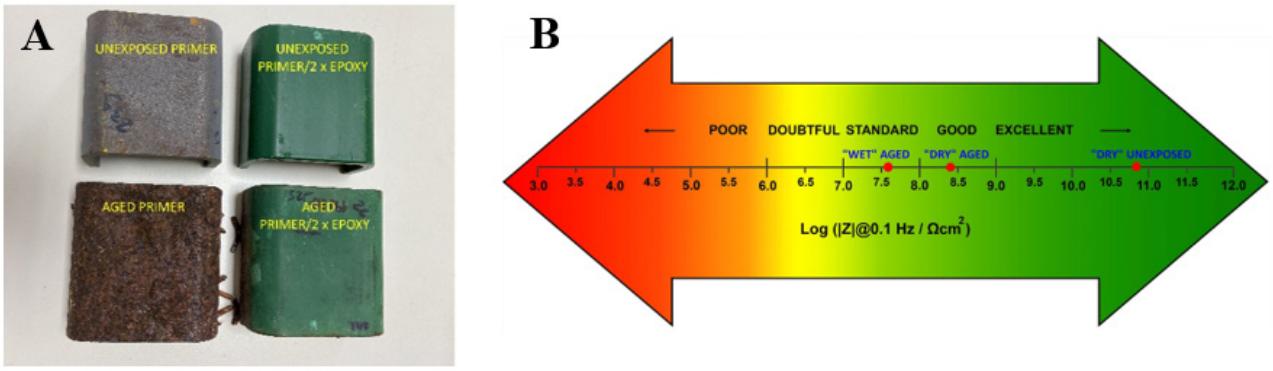

Figure 2. Unexposed and naturally aged samples (A) and their QCQ results (B).

QCQ principles and examples can be found in the references. QCQ is now in the technology transfer phase and is licensed to the faculty spin-off company ReCorrTech.

ACKNOWLEDGMENTS

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ID149
POTENTIAL STRESS BIOMARKERS DETECTION IN SWEAT FOR IN-SITU SENSING

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ABSTRACT

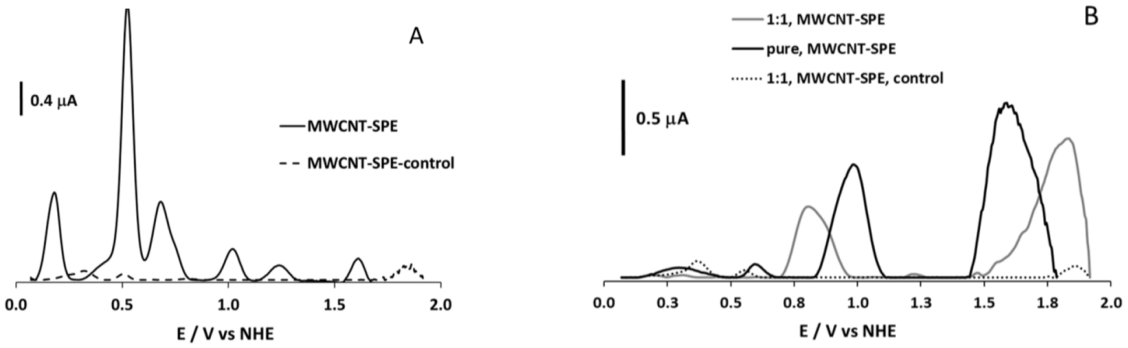
Stress detection through biomarkers is an interesting field to the modern societies, but considered as extremely important for military, since it can be useful for attaining higher missions' performance and to adjust operational conditions. This study is part of a project where civilian, military and a textile manufacturer's association researchers are together aiming to study and early detect stress biomarkers, through non-invasive methodologies (using sweat), with the ability to operate in field and in real-time monitoring, integrated in wearables. The results have shown to be possible to detect molecules in sweat with potential to be considered as stress biomarkers. The levels' variation of sets of molecules in different conditions (physical stress and rest) and good correlation with blood analysis were attained.

INTRODUCTION

Sweat is a potential biological fluid for analytical assessment of diverse potential biomarkers, including stress-related molecules, whose major interest is the opportunity to attain its levels non-invasively and in real-time. Stress detection is considered as extremely important for people with highly stressful occupations, such as emergency workers, firefighters, and military. For military, real-time stress detection can be useful for attaining higher missions' performance and adjusting operational conditions, minimizing risks and post-operations psychological disorders. The current work is part of a project where civilian and military researchers collaborate to study and early detect stress biomarkers, through non-invasive methodologies, using sweat, with the ability to operate in field and in real-time, integrated in wearables. Analysis of biological samples, such as sweat, however, are always associated with challenges, namely regarding the sampling procedures, low molecules' levels and possible interferent. A non-invasive methodology to achieve a molecular profile of sweat was recently achieved, by chromatograph with tandem mass spectrometry (LC-MS/MS), allowing to identify 26 molecules (Nunes, 2021). From these, major neurotransmitters and their metabolites, amino acids, purines and amino acids precursors of amines, carboxylic acids, carbohydrates, and steroid hormones were identified. Different sweat sampling methodologies were tested. The previous knowledge was applied to the sweat analysis of 22 volunteer students from the Portuguese Military Academy, with an average age of 21 years. Also, blood samples from the volunteers were submitted to clinical analysis. The samples were studied both by LC-MS/MS and electrochemical techniques.

RESULTS AND CONCLUSIONS

The results from sweat and blood analysis show that variations can be found between several molecules that can be associated with stress as displayed in Table 1. Electrochemistry analysis, by differential pulse voltammetry (DPV), using multiwalled carbon nanoparticles screen-printed electrodes (MWCNT-SPE) allowed detecting sets of target molecules in simulated conditions and in real samples (Fig. 1) (Nunes, 2022). Variations of levels were also detected between in physical training and rest conditions



Biofluid	Blood		Sweat	
Physical State	Rest	Exercise	Rest	Exercise
Major NTs				
Biological amines and metabolites				
DA	↓	↑	ND	ND
DOPAC	-	-	↓	↑
3-MT	-	-	↓	↑
HVA	-	-	↓	↑
E	Inconclusive	Inconclusive	Inconclusive	Inconclusive
NE	↓	↑	Inconclusive	Inconclusive
5-HT	↓	↑	Inconclusive	Inconclusive
5-HIAA	-	-	Inconclusive	Inconclusive
Other biomarkers				
Amino acids precursors of biogenic amines				
Phe	↓	↑	↓	↑
Tryp	↓	↑	↓	↑
Tyr	↓	↑	↓	↑

Table 1. Some potential biomarkers molecules variation between rest and exercise in blood and sweat (↑ increase, ↓ decrease, - not available, ND-not detected).

Figure 1. Potential biomarkers DPV, using MWCNT-SPE electrodes in A) simulated sweat (lactate, ascorbate/ascorbic ac., creatinine, glucose, dopamine, tryptophan, serotonin, tyrosine, phenylalanine, histidine, cortisol, 0.010mM/PBS/NaCl, standard conditions (ISO) and B) real sweat samples.

This work opens a route for developing a semi-quantitative electrochemical stress sensing device, integrated in wearables, based on the molecule's levels present in sweat that may be useful for stress level monitoring in-situ and in real-time.

ETHICS DECLARATION

Sweat samples were attained from volunteers in compliance with ethical standards (World Medical Association, WMA, DoH). An informed consent was obtained; data was codified and is anonymous and confidential. The study was performed and approved by the Ethical Committee of Universidade NOVA de Lisboa (doc. Ref."Parecer_CE18082020") and Portuguese Army.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by Fundação para a Ciência e Tecnologia (FCT), Portugal, under grant PTDC/SAU-SOC/28390/2017 (STRESSSENSE). This work was supported by the Associate Laboratory for Green Chemistry - LAQV which is financed by national funds from FCT/MCTES (UIDB/50006/2020 and UIDP/50006/2020). The authors also acknowledge the volunteer students for their participation.

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ID150

ADAPTIVE CAMOUFLAGE – AN ITERATIVE APPROACH FOR THE SOLDIER OF THE FUTURE

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ABSTRACT

In order to keep pace with the ever-changing character of warfare, the military must be forward-looking, adaptable and embracing new operational perspectives as much as new equipment and technologies. Not only must it have the best force structure to counter a growing range of threats but it should, most of all, always protect the soldier. The classic approach, in its most basic form, regarding soldier protection is: don't be seen; if you're seen, don't be hurt, but ideally, don't be there. The rapid advancement of sensors and sensorplatforms (satellites and drones, for example) is putting dismounted soldiers and deployed high value assets at greater risk of detection, thus urging the need for not being seen. It is in this context that adaptive camouflage comes into play, providing the armed forces with better protection in known environments and the ability to operate in other environments previously considered too dangerous, against several present and future sensors and sensor systems operating in a wide range of wavelength bands.
Two architectures, LEDs-based and Thermochromics-based, were created through an iterative process of prototype design and development and considering military users' feedback. These architectures encompass the integration of several active and passive adaptation mechanisms into a textile-based soldier camouflage system. A multi-spectral camouflage was one important aim to be achieved, namely, visual (VIS), thermal infrared (TIR) and radar, with military needs on aspects such as sensing, mobility and endurance also being considered. A methodology based on the L.E.A.P. (Load Effects Assessment Program) was devised to assess the prototypes in operational-like conditions, recreating a set of activities that can be performed by military personnel in operational theatres, aiming to identify possible limitations and improvement areas.

INTRODUCTION

Drawing on the advances in materials science, sensor technologies and autonomous systems, the dismounted soldier protection should be improved by making them hard to detect, improving the protective qualities of their uniforms and even removing them from the immediate threat, using autonomous technologies. The scheme in Fig. 1 exemplifies the concern, in a more basic form, regarding soldier protection. To avoid detection on a multi-spectral level, the two proposed architecture solutions are the result of integrating several active and passive adaptation mechanisms into a textile-based soldier camouflage system.

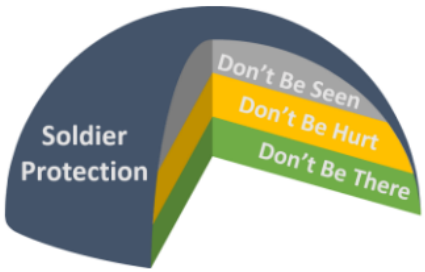

Fig.1 Soldier protection schematic.

The observation method of a recognition mission is comprised by four stages: 1) Alert (Weak and discrete signals trigger an abnormal situation and improved awareness); 2) Detection (triggering a search for abnormalities in the scene); 3) Recognition (analysis of the scene) and 4) Identification. In this last stage it is recognized and established if the abnormal situation is a threat. Camouflage efficiency evaluation primarily measures the ability to postpone the identification stage.

RESULTS AND CONCLUSIONS

A methodology was set for ergonomic field trials, based on the L.E.A.P. program, and simulating real combat field movements, in three stations. Station duration time, Borg scale of perceived effort, heartbeat and body temperature measurements, vertical jump distance, global evaluation (flexibility, volume, weight, agility, velocity, mobility, and general fatigue) and user feedback were registered, by questionnaires. In addition, ergonomic movements, Fig. 2 left, were performed according to prEN16448-1 requirements and replies to a five-levels questionnaire (Excellent; Good; Fair; Poor; Unacceptable) were registered. The field trials methodology (Fig.2, right) entailed building several scenarios based in selected locations and specific movements, while testing the adaptive performance of the prototypes. Sparse, dense, analysis. These field trials also permitted optimization of the camouflage performance, observation of the NIR, TIR, and IR, as well as ergonomics and mobility evaluation.
Operational performance evaluation and radar discretion measurements were also performed.

Fig.2 Graphical representations for ergonomic trials (left) and field trials (right) methodologies.

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ID151

DEVELOPMENT OF A HIGH-PERFORMANCE BLAST ENERGY-ABSORBING SYSTEM FOR BUILDING STRUCTURES

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ABSTRACT
Shock absorbers have been used widely in the automotive and aeronautical industries for many years. Inspired on these devices, the paper describes a blast protective system for building structures that is composed of a shielding element connected to the main structure, at the floor levels, through ductile Energy Absorbing Connectors (EACs). The EACs exploit the external tube inversion mechanism to absorb a significant part of the imparted kinetic energy from the blast wave. Three types of inversion tubes are studied against a blast load of 150kg TNT at 5m stand-off. An analytical model to compute structure behavior is developed and compared with a numerical model in LS-DYNA's Finite Element software.

INTRODUCTION
The concept of the proposed high-performance blast energy-absorbing system is shown in Figure 1. The idea is to ensure that the contact between the protective panel that receives the shock wave and the elements to be protected is avoided. This is accomplished by using floor level Energy Absorbing Connectors (EACs) with a sufficient stroke to accommodate, by shortening, the impulse imparted by the explosion. The yielding of special designed kernel elements in the EACs during the dynamic response to blast loads limits the peak dynamic reaction transmitted to the supporting structure. As a consequence, the associated damage can be substantially reduced with respect to traditional rigid connectors.
The presented protective concept is inspired from highly efficient shock absorbers used in the automotive and aeronautical industries [1, 2, 3]. When applied to Buildings [4, 5, 6], besides protecting critical elements, it creates an empty buffer zone between the outer panel and the main structure (figure 2), that can be filled with materials that guarantee protection against other associated phenomena, e.g., fragmentation, spalling or explosively formed projectiles.

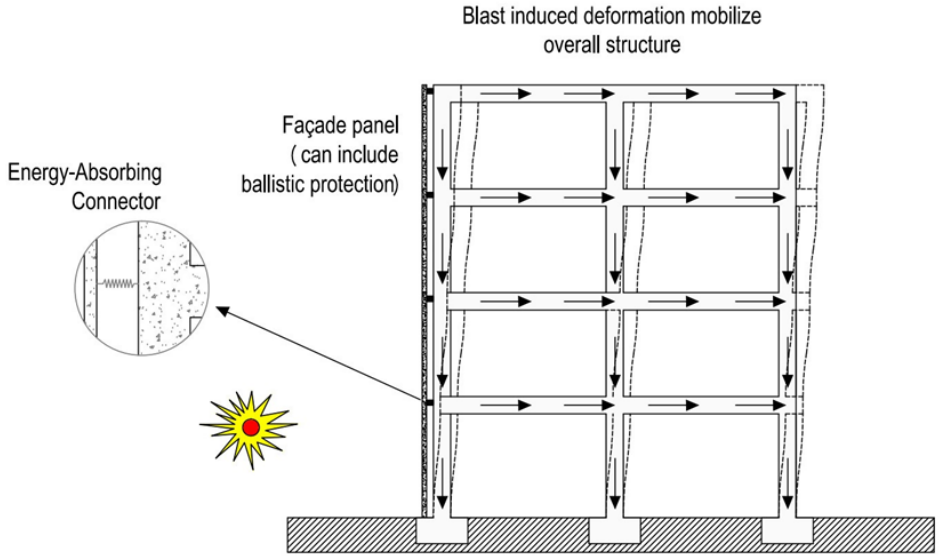

Figure 1: Protective system mobilizing the global response of the structure.

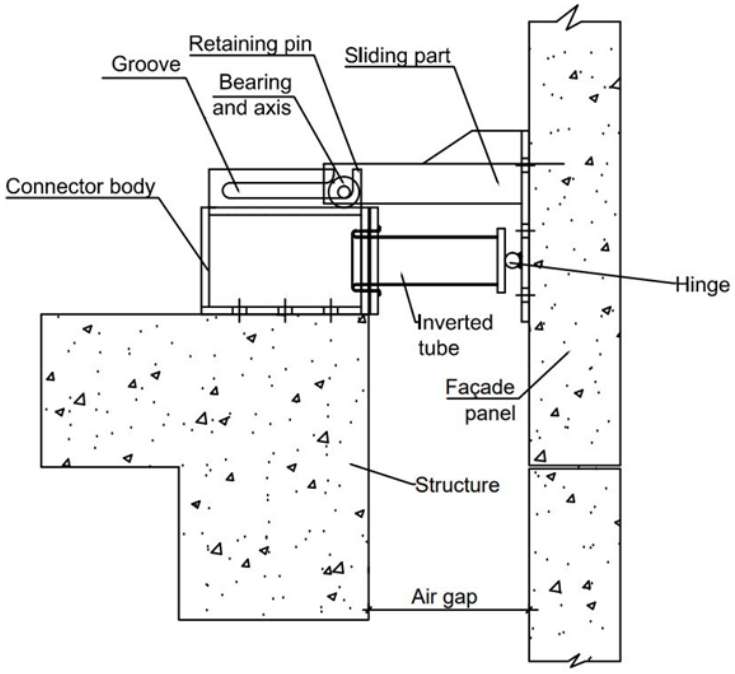

Figure 2: Mounting of the energy absorbing connector (no scale).

RESULTS AND CONCLUSIONS

The results from the theoretical model are collected in table 1.

Table 1 – Stroke demand for analytical model.

Physical entity	Units	Φ42 × 1.5 × 200	Φ54 × 1.5 × 200	Φ64 × 2.0 × 200
Loading time	ms	83	82	42
Peak velocity	m/s	9.9	9.9	9.9
Inversion demand - Energy	mm	214	212	108

The protective system presented in this study exhibits a considerable high performance and can be employed for a large variety of blast threat scenarios, especially when increasing the stand-off is not a possible/viable option and sensitive facilities have to be protected. Assuming that the structure can withstand the transmitted forces, the introduction of the energy absorbing system, when properly designed, clearly reduces the peak horizontal loads transmitted to the supporting structure. Accordingly, a significant reduction of the internal forces in the vertical elements (columns) is expected. Therefore, it seems clear that the first beneficial effect of the EACs is to operate a transformation in the pressure loading curve, smoothing the initial pressure peak. Peak forces imparted to the overall protected structure by explosion decrease depending on the inverter used. For instance, peak forces imparted to the overall protected structure by explosion decrease, in the case of Φ54 × 1.5 connectors about 52% (from 367.1 kN to 4×43.6=174.4 kN).

ACKNOWLEDGMENTS

This work was supported by contract PTDC/ECI-EST/31046/2017 with the Portuguese funding institution FCT - Fundação para a Ciência e Tecnologia.

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ID152
ENGINEERING DESIGN OF AUXETIC TEXTILE STRUCTURES

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ABSTRACT
This work introduces the development of four innovative hybrid auxetic geometries, based on chiral auxetic architecture. These new hybrid auxetic geometries have been designed, and their analytical modeling is carried out using python programming. And thereafter, woven fabrics are produced on an electronic jacquard weaving system based on these hybrid auxetic geometries. All the fabric samples produced were characterized for their auxetic effect by measuring Poisson's ratio on UTM attached with the video extensometer. The plot between Poisson's ratio v/s axial strain of fabric samples, reveals a good agreement between analytical and experimental values. However, the absolute value of experimental NPR shows a significant deviation from predicted values.

INTRODUCTION
Auxetics are basic materials with Negative Poisson's ratio(NPR). Various geometries/ structures provide auxeticity. Auxetic materials are currently available in a variety of materials, including polymers, metals, ceramics, and composites. These can now be woven in two dimensions and three dimensions, and they can also be employed in composite materials to encourage fiber reinforcement in textiles 1–3. Because of their high indentation resistance, synclastic behavior, enhanced energy absorption capability, shear resistance, fracture toughness, formability, and dampening properties, auxetic textile materials can be used for personal protective fabrications and flexible armors, adaptive and deployable structures, energy absorption components, viscoelastic damping materials, and packable materials in defense as personnel, vehicles, and temporary hardened shelters are frequently exposed to the abrasive, sharp edge, ballistic, and explosive threats during military operations 4. And because these applications demand varying degrees of auxeticity, modeling of these auxetic structures is essential 5. A variety of geometries that impart auxeticity have been reported in the literature over two decades. It is claimed that hybrid auxetic structures with improved auxeticity and enhanced mechanical properties can be created by combining and modifying conventional auxetic structures in the case of engineering materials. Therefore, we believe that hybrid auxetic structures are needed for design engineering of woven textiles for different applications. In this research, four innovative hybrid auxetic geometries are developed for creation of their respective woven constructions.

PRINCIPLE OF MODELLING AND FABRIC DEVELOPMENT
Here four different types of hybrid auxetic structures shown in Figure 1 have been designed that possess NPR greater than the conventional auxetic chiral structure, and the relation between the angle of rotation and NPR has been plotted with the help of Python programming. Four basic modifications have been introduced for the conversion of conventional auxetic chiral structure to hybrid auxetic structure as shown in Figure 2, i.e., the introduction of the core structure, inclination of the core with the reference axis, un-equal length of the connecting ribs, and providing an allowance for torque generation. And it was assumed that the connecting ribs of the structure are solid and incompressible, the core is solid and free to rotate about its central axis in the Z direction, The endpoints of the shorter connecting ribs only slide on the reference axis, when extended in the x-direction.

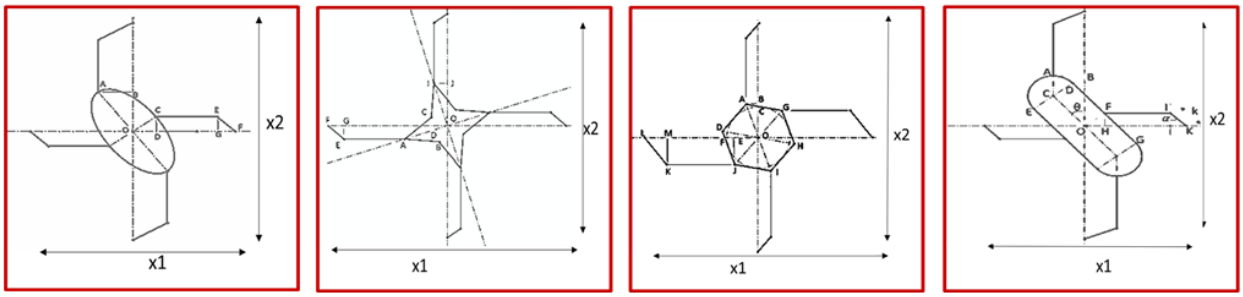

Figure 1 Different types of hybrids auxetic structures developed (a) elliptical (b)star shape(c)hexagonal (d)racetrack

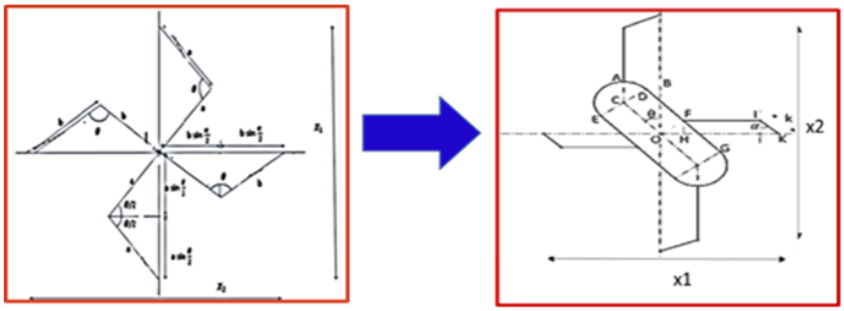

Figure 2 Approach to convert the chiral auxetic structure to hybrid racetrack auxetic structure

Once the analytical modeling of the auxetic structures is done, fabric formation is carried out based on these modified geometries, where 100% cotton and core-spun lycra yarn have been used as warp and weft yarn. The auxetic behavior of the prepared new fabric sample was tested via a video extensometer.

RESULTS AND CONCLUSIONS

From the analytical modeling of the designed hybrid geometries, the following are the expressions derived for the prediction of NPR of the auxetic structure

For elliptical core hybrid auxetic structure

$$\vartheta 21 = \frac{1}{b\ \left(-\frac{b}{k}\right) cos\theta - \mathrm{b}} \left(\frac{k\ \sin\left(\cos^{-1}\left(\left(\frac{b}{k}\right)\sin\theta\right)\right) + l + \ b\cos\ \theta}{\cos\theta} \right)$$

Where a = major axis of the ellipse, b = minor axis of the ellipse, θ= angle between the major axis and y-axis, l= long connecting rib, k = short connecting rib

For racetrack core hybrid auxetic structure

$$\vartheta 21 = (a\sin\theta)\frac{\left(r\cos\theta + l + k\sin\left(\cos^{-1}\left(\frac{r\,sin\theta}{k}\right)\right)\right)}{(-r\sin\theta\ + r\ cos\theta)(a\cos\theta\ + r)}$$

Where a = major axis of the ellipse, r = radius of the semicircle, θ= angle between the major axis and y-axis, l= long connecting rib, k = short connecting rib

For star-shape core hybrid auxetic structure

$$\vartheta 21 = \frac{(-1)(-2a(\cos\beta+\sin\beta)\sin\theta)\left(2k\ \sin\left(\cos^{-1}\left(\frac{a(\cos\beta+\sin\beta)\sin\theta}{k}\right)\right)+2l+2\ a(\cos\beta+\sin\beta)\cos\theta\right)}{\left(2a(\cos\beta+\sin\beta)\sin\theta\frac{a(\cos\beta+\sin\beta)\cos\theta}{k\sin(\cos^{-1}(\frac{a(\cos\beta+\sin\beta)\sin\theta}{k}))}-2\ a(\cos\beta+\sin\beta)\sin\theta\right)(2a(\cos\beta+\sin\beta)\cos\theta)}$$

Where a = side of the star shape, β = half internal angle of the star apex, θ= angle between the major axis and y-axis, l= long connecting rib, k = short connecting rib

For hexagonal core hybrid auxetic structure

$$\vartheta 21 = -\frac{2a\sin\theta}{\left(2\,a\sin(\theta+30)+2a\sin(\theta+30)\frac{a\cos(\theta+30)}{k\sin\left(\cos^{-1}\left(\frac{a\sin(\theta+30)}{k}\right)\right)}\right)}\left(\frac{2\,a\cos(\theta+30)+2l+2k\ \sin(\cos^{-1}\left(\frac{a\sin(\theta+30)}{k}\right)}{2a\ \cos\theta}\right)$$

Where a = side of the regular hexagon, θ= angle between hexagon diagonal and y-axis, l=long connecting rib, and k = short connecting rib

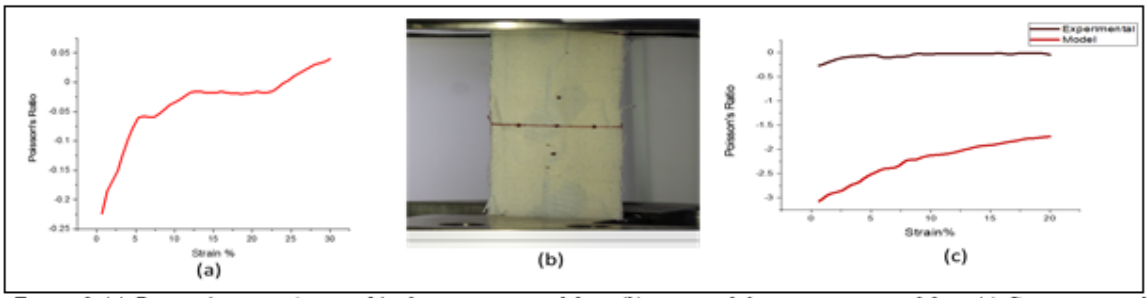

Figure 3 (a) Poisson's ratio v/s strain% of auxetic woven fabric (b) image of the auxetic woven fabric (c) Comparison of experimental and analytical NPR

The above plot shown in figure 3(a) confirms the auxetic behavior of the woven fabric developed by realizing the hybrid auxetic geometry into the fabric structure. It is observed from the plot that initially high value of NPR is obtained whereas on further stretching the auxetic effect decreases due to the interlacement between the warp and weft yarns which restricts the relative movement of the yarns, leading to lower NPR. Also, from the plot shown in Figure 3(c), the experimental NPR value follows the same trend as the analytical values obtained from the model. Although there is a significant difference in the absolute values of the Poisson's ratio obtained from model and experiment, due to the resistance offered by the yarn interlacement which restricts the free movement of the unit cell, the auxetic behavior in both experimental and modeling method appear quite similar which confirms the authenticity of our model approach.

ACKNOWLEDGMENTS

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ID153

PERFORMANCE EVALUATION OF TPMS-PRIMITIVE REINFORCED CONCRETE SLABS UNDER BLAST LOADING

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ABSTRACT

Research on strengthening and retrofitting concrete structures against blast loading has recently received much attention. In this paper, a new type of reinforcement is proposed for concrete panels to enhance their blast-resistant capacity. The reinforcement structure is naturally optimized with continuous non-self-intersecting surfaces, known as TPMS-Primitive scaffold. The Primitive minimal surface - one type of the triply periodic minimal surface (TPMS) structure - is employed as reinforcement of cement-based slabs. Such TPMS-Primitive reinforced concrete slabs are fabricated by using 3D printing formwork technique. The impulsive performance of TPMS-Primitive reinforced concrete slabs under blast loading is numerically investigated. The concrete slabs reinforced with one and two layers of TPMS-Primitive unit cells are designed and examined. Blast numerical models are validated and compared with experimental data of a traditional reinforced concrete slab from a published work. A constitutive model that takes the strain-rate effect into analysis is employed to capture the rate-dependent impulsive behavior of the proposed panels. Taking the advantage of symmetrical geometry, only a quarter of the panel is simulated to save computational time. The finite element (FE) results indicate that both considerable enhancement in damage resistance and a substantial reduction in center deflection are witnessed in the concrete reinforced panels when the rebar lattice is replaced by the TPMS-Primitive scaffold. Through the parametric studies, the proposed reinforcement with two layers of unit cells proves to be more efficient. It is also feasible to fabricate TPMS-Primitive scaffold with the advance in 3D printing technology.

Keywords: TPMS-Primitive reinforcement; Additive manufacturing; Finite element method; impulsive performance; blast loading.combining and modifying conventional auxetic structures in the case of engineering materials. Therefore, we believe that hybrid auxetic structures are needed for design engineering of woven textiles for different applications. In this research, four innovative hybrid auxetic geometries are developed for creation of their respective woven constructions.

ID154

NUMERICAL SIMULATION OF PRESSURE DISTRIBUTION FOR STRUCTURAL DESIGN OF DIABETIC FOOT INSOLES

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ABSTRACT

Custom-made diabetic insole is used to protect foot plantar from getting injury. The insole can distribute the plantar pressure to avoid peak pressure and absorb impact force during walking. Taking the advantage of braced frame structures against lateral loads, this study proposes different internal structures to improve the offloading performance of insole materials which could effectively redistribute excessive plantar pressure from bony prominences. The synclastic effect of the internal structure was illustrated through numerical simulation method.

INTRODUCTION

People with diabetic foot may loss of protective sensation. It is very difficult for them to respond to pressure, wounds, and injuries. Custom-made diabetic insoles are routinely used to protect the foot from getting injury. It aims to distribute the bodyweight pressure through the whole foot plantar and reduce the peak contact pressure so as to minimise the risk of neuropathic ulceration (van Netten et al., 2018). Cushioning materials to absorb the impact force during gait are usually added onto the forefoot and the rearfoot, which are the prominent plantar bony regions suffering from high contact pressure (Hernández-Lara et al., 2022). By using low Young's modulus insole materials, the insole can readily absorb energy and reduce the transmission of elevated plantar loads (Bhagavathula et al., 2022). However, researchers generally focused on the material properties of the insole that the offloading performance induced by the internal structure of insole has been neglected (Werner et al., 2022). In this study, a total of 3 different internal structures of braced frame structures are proposed and inserted into the traditional insole material (Fig. 1)(Montuori et al., 2022). By using finite element analysis (FEA), the influence of the proposed insole internal structure on the redistribution of plantar pressure has been simulated. Based on the 3D model of the insole, 2 insole material properties were measured for the numerical simulation model. The ASTMD575 Standard Test Method for rubber properties in compression was referenced and the Instron 4411 universal mechanical test frame was used. The corresponding compression properties of two traditional insole materials (PeLite® and Poron®) were measured. The specimens were 28.6mm in diameter and 12.5 mm in thickness. The results were then inputted into FE model to simulate the interface pressure distribution at insole compression.

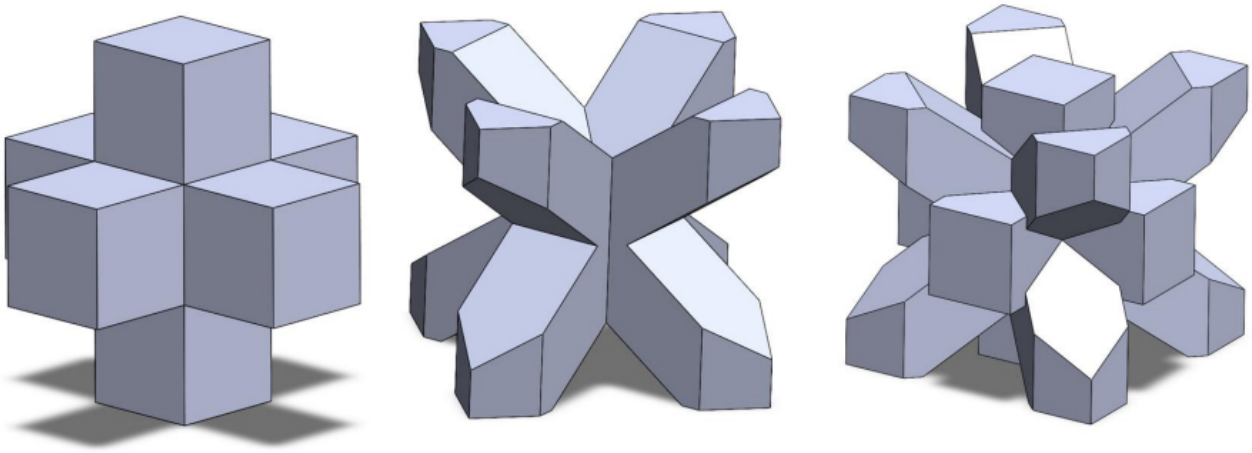

Fig. 1 Design of the internal structure

RESULTS AND CONCLUSIONS

The results from the compression tests are shown in Fig. 2 and Table 1. It is found that the Poron® insole has a lower Young's modulus.

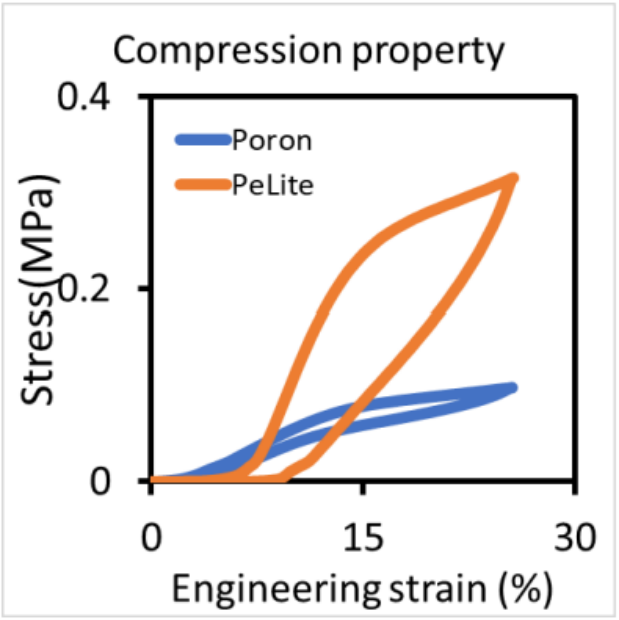

Fig. 2 Compression property results

Table 1 Material properties

Material	PElite	Poron
Hardness (A)	44.6	15.1
Density (g/cm3)	0.16	0.32
Energy absorption (%)	73.00%	78.60%
Young's modulus (MPa)	3.28	0.72

More in-depth analysis and numerical simulations are required to better understand the interface pressure distribution in relation to the internal structures of insole materials.

ACKNOWLEDGMENTS

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ID155
METHODOLOGY AND TESTING OF NEWLY DESIGNED EXPLOSIVE ORDNANCE DISPOSAL (EOD-NG)

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ABSTRACT
The research presents the assumed requirements and protective properties for newly developed explosive ordnance disposal (EOD-NG) in terms of resistance to FSP.22 and FSP.30 fragments.
The results of the study on the influence of shock wave on EOD-NG using Hybrid III anthropomorphic test device (ATD) are also presented. The shock wave was generated by the detonation of Semtex plastic explosive, formed in the shape of a 0.5 kg sphere, at 1 m distance for 2 positions of the explosive charge relative to the ATD: on the ground and at a height of 1 m above the ground.
The use of ATD allowed to determine parameters of damage to the human body as a result of the impact of overpressure wave. The experiments also included a measurement of such parameters as forces and moments on lower extremities, acceleration of head and pelvis. As the most critical parameter, the Chest Wall Velocity Predictor (CWVP) was selected and calculated using pressure measured on ADT chest. It was revealed that the 1 m distance of explosion of a 0.5 kg pure explosive does not exceed most of the allowed parameters.

INTRODUCTION
Threats associated with the increasing usage and detonation of explosives have led to the development of protection device: EOD-NG designed to provide pyrotechnical protection while performing activities related to the neutralization of explosives. Currently used explosive charges cause explosions, followed by the fragmentation, release of large amounts of energy, local increase in pressure and temperature. Injuries to users result from the simultaneous action of risk factors associated with the explosion. Firstly, the pressure, propagating spherically in the form of a sound wave. The closer a person is to the explosion, the greater the pressure is noticed. The type of injury is also related to the size of the explosive, its design and whether the detonation took place in an open or closed space. The blast of the explosion traveling behind the sound wave is coincidently with this factor. Other injuries are caused by debris carried by the blast of the explosion. These are part of the design of the explosive charge or fragments from the environment. Due to their high velocity and blast radius, they are often the primary cause of injury to blast victims, especially those further from the epicenter of the explosion. They cause penetrating injuries to body cavities, soft tissue injuries, and limb injuries. The last of the discussed factors is high temperature, flames and post-explosion gases accompanying the explosion, which cause burns to the body surface and/or respiratory tract.
The mentioned factors, which associate with the explosion, became a reason to start working on the development and testing of new generation of EOD. As a part of research, material solutions of EOD-NG were tested in terms of their effectiveness against fragmentation according to STANAG 2920. The reduction of effects caused by 0.5 kg of Semtex material placed 1 m away from ATD and in two different positions in relation to ATD: on

the ground and 1 m above the ground were tested. The main criteria used to evaluate the blast reduction were: head injury criteria (HIC), lumbar and thoracic spine injury criteria (DRI), thorax (TCC and VC) and internal organs (CWVP) as well as lower limb forces and bending moments.

RESULTS AND CONCLUSIONS

The results from ATD sensors after 0.5 kg of Semtex charge at the distance of 1 m from EOD-NG are shown in Table 1.

Table 1. Results of parameters measurement after 0.5 kg of Semtex charge detonation.

No.	Damage criterion	Unit	Tolerance level for ATD	Distance from ATD: 1 m Explosive charge height:	
				0 m	1 m
1.	Head injury criterion (HIC_{15})	---	250	3.23	9.46
2.	Chest Wall Velocity Predictor (CWVP)	m/s	3.6	1.66	2.61
3.	Frontal compression criterion (TCC $_{frontal}$)	mm	30	2.98	13.16
4.	Viscous criterion (VC $_{frontal}$)	m/s	0.70	0.01	0.11
5.	Dynamic response index (DRIz, (DRIx)	---	17.7 (DRIz), 40 (DRIx)	3.20	4.45
6.	Compressive force (-Fz) - femur	N	6.9	5.30	0.79
	Compressive force (-Fz) -tibia		5.4	5.97	1.04

The studies show that the minimum distance, at which user wearing the EOD suit may approach a 0.5 kg explosive charge, is 1 m. At this distance and this amount of the explosive, damage to the body should be minor according to collected data. Moreover, the obtained test results indicate that by additionally applying modern material solutions it is possible to obtain a wide range of protection against FSP.22 and FSP.30 fragments, ranging from 600 m/s to 1800 m/s velocity, depending on the type and composition of the ballistic composite.

ACKNOWLEDGMENTS

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ID156

A NOVEL MOBILE RADIATION DETECTION SYSTEM FOR SECURITY AND DEFENSE APPLICATIONS

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ABSTRACT

This work compares the detection and localization sensitivity of two gamma radiation detectors with silicon photomultiplier (SiPM) readout in Security and Defense scenarios (e.g. illicit trafficking of nuclear or radioactive material), namely a prototype organic scintillator EJ200 with a thin titanium window to improve beta particles sensitivity, and a commercial inorganic scintillator CsI(Tl). Measurements using a Cs-137 gamma-ray source showed that EJ200 can outperform the detection efficiency of CsI(Tl) at distances above 1 m. The large sensitive area, low power consumption, low price and low weight of EJ200 makes it a good candidate for coupling in small mobile platforms as unmanned aerial vehicles (UAVs). The uncertainties affecting the detection, identification and quantification are addressed and discussed.

INTRODUCTION

Illicit trafficking of radioactive sources and special nuclear materials is a cause of concern worldwide, due to the possible use of these sources and materials in radiological dispersal devices (RDD), radiological exposure devices (RED) and improvised nuclear devices (IND). Whilst INDs causes a high number of casualties, RDDs and REDs devices have the potential to become weapons of massive disruption with huge social and economic consequences. Their detection is currently achieved mainly using static radiation portal monitors (RPMs) installed on some border crossing points, airports and maritime ports, such as shipping container cargo (Connolly, 2021). Portable RPMs can be deployed and mobile radiation detection system can also be used in these places or in other strategic points (potential threats). However, these detection systems are generally expensive, large, heavy, and in some cases the monitoring process is time consuming (e.g. secondary inspection is done by handheld equipment). The use of SiPM readout in scintillators allows more compact and lightweight detectors, which can be coupled to small and highly maneuverable platforms such as multirotors. The result provides an eager opportunity to reproduce multiple instances of detection systems able to be programmed aiming at autonomous operations of surveillance. To the best of our knowledge, SiPM has not been used in organic scintillators, in particular the EJ200, for mobile radiation detection systems (Marques, 2021).

The preliminary experiments were performed using a 0.146GBq Cs-137 source. The cylindrical detectors ϕ51mm×51mm CsI(Tl) and ϕ110mm×30mm EJ200 were placed in a small wheeled box (“sensors box”) with a global navigation satellite system antenna, a multichannel analyzer, a power bank, and a Raspberry Pi 3B, which can be accessed remotely. The static measurements consisted in measuring with both detectors the background, and then with the source at 12 cm height the count rates were measured at source-detector distances 1-5m

(at same height). Radiological measurements were also obtained with the sensors box moving along predefined paths. The source was placed in a fixed position at 1,12m height while the sensors box was manually guided along different paths (parallel straight lines of 10 m length each), with the distances between the source and the paths assuming values between 1 and 5m. Changes in the sampling rate (1-2s) and sensors box speed (0.2-0.5m/s) were also tested. The detectors kept always their orientation (flat face frontal to the source). Finally, the measurements (counts per second) obtained by each detector were analyzed by a maximum likelihood approach (Brouwer, 2020) to estimate the position of the Cs-137 source.

RESULTS AND CONCLUSIONS

The results from the signal to noise ratio (SNR) are shown in Fig. 1. Despite the higher intrinsic detection efficiency of CsI(Tl), at source-detector distances between 1-5m the EJ200 detector presents a SNR almost a factor of 3 greater than CsI(Tl).

When considering the measurements with the sensors box moving predefined paths, the best result of source position estimation was obtained with the EJ200 detector moving at 0,2 m/s and a sampling rate of 1s which matched real source position (small shift of 10 centimeters).

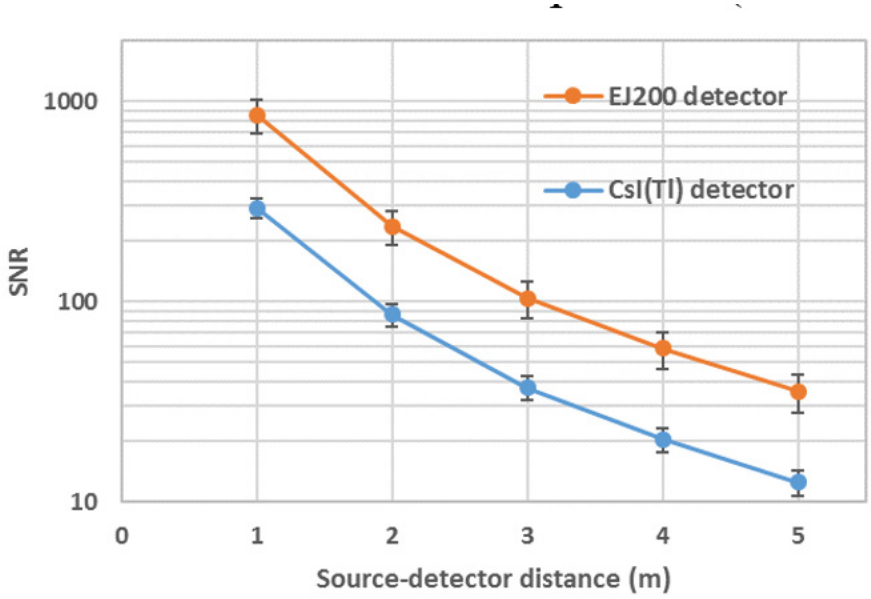

Fig.1 Signal to Noise Ratio (SNR) versus source-detector distance.

This study shows that the cheaper, lower consumption and lighter EJ200 detector with SiPM readout has a greater SNR than a commercially CsI(Tl) detector, which makes it a good candidate for coupling in small platforms as UAVs when considering the fast detection and localization of gamma sources. Further tests will be performed to analyze the detector directionality, gamma energy threshold and dependence (by using other sources as Am-241 and Co-60), beta particles sensitivity, and explore other paths not restricted to line segments.

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ID157

INVESTIGATION AND ANALYSIS OF HEAD PROTECTION PARAMETERS USING WZ. 2005 COMBAT HELMET MODEL

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ABSTRACT

This study examines the overall circumstances surrounding ballistic head protection, as well as the threats that may arise on modern battlefields. We were able to offer development trends for helmets worn in the world's biggest armies after conducting a thorough literature review. The authors concentrated on helmet shell hits, which overloaded the whole helmet-protected head–neck system. The major goal of this research is to look at the protective capabilities of a helmet shell when it encounters a projectile, using contact curvature as an indicator of impact energy concentration. Back face deformation (BFD) was used to evaluate blunt head trauma.
For testing, the Wz.2005 combat helmet was utilized. Our findings are in good agreement with the norm and literature values.

INTRODUCTION

Because the skull is the most vital organ in the human body, it requires special protection.
Helmets [1,2] are employed for this reason, with the goal of decreasing the effects of this socalled traumatic brain injury (TBI) caused by projectile impacts. Helmets have really been worn on the head since ancient and have developed in tandem with technological and material engineering advancements. Previously, solutions relied on a proper steel shell (body). Helmet shells began to be manufactured utilizing current materials solutions in the first part of the twentieth century, once the first fiber composites were produced. [3-4]. Determining the BC of a person's head is a difficult task. Knowing the contact geometric features (the curve of contact between a helmet and a projectile) of a helmet's BFD (the value required in the National Institute of Justice (NIJ) Standard for Ballistic Helmets) involves significant challenges, as does determining the exact diameter of the surface [4]

RESULTS AND CONCLUSIONS

Peak Linear Acceleration evaluation For the location used, Figure 1 shows the linear acceleration history, where the maximum peak linear acceleration can be measured. For the helmet form configuration, PLA (Peak Linear Acceleration) value does not exceed the threshold of 275 m/s2 as set by the standards.

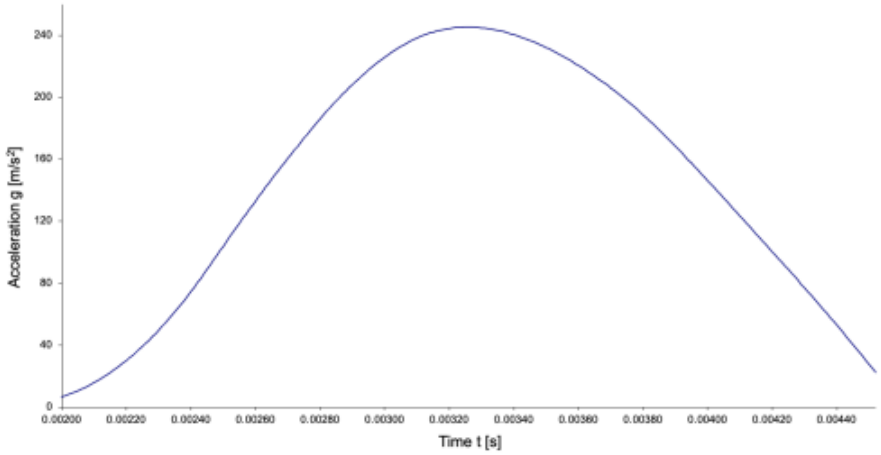

Fig. 1. The acceleration evolution of head model used in z-direction impact location

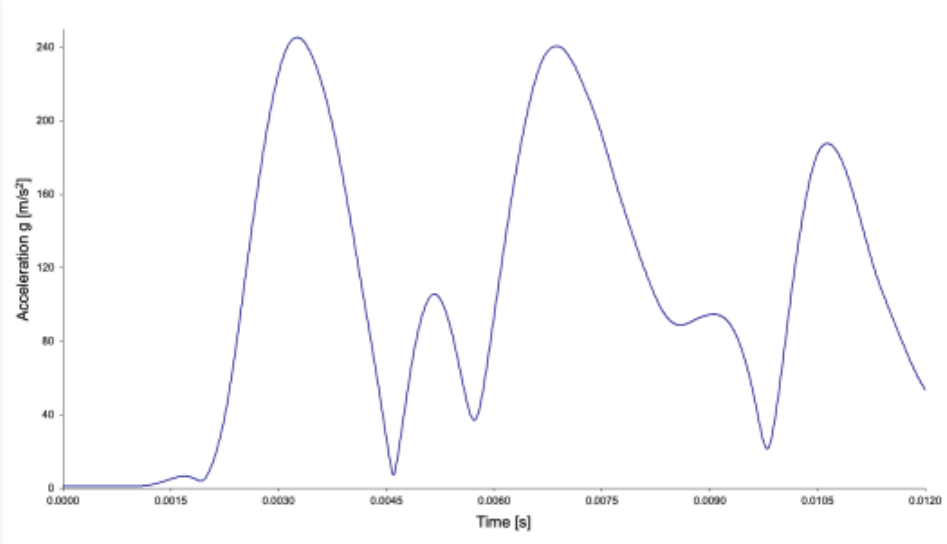

Fig. 2 The maximum deceleration of the center of gravity of the head.

Head Injury Criterion (HIC)

The maximum HIC considering PLA is 953 in the frontal zone while the minimum HIC is 608 for rear impacts according to the NHTSA criteria, the HIC threshold is 1000 which makes our values fall below the threshold.

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ID158

PROJECTILE INFLUENCE ON COMPOSITE IMPACT RESISTANCE AND DAMAGE

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ABSTRACT

The objective of the work presented is to compare the impact resistance and structural damage of one aluminium panel (Al2024 T3) and 3 different solutions, including two composite materials, (Al2024 T3/Rohacell71 WF/ Al2024 T3; T700; Al2024 T3/Kevlar29/Al2024 T3) when impacted by two different metal projectiles (called P1 and P2), with the same impact energy (140J). The impact tests and non-destructive inspection results showed a significant higher damaged area as well as higher impact energy absorption when impacted by the heavier and larger Projectile 2 (P2). Al/Kevlar/Al was able to resist perforation with both projectiles but presented the largest difference in damaged area between P1 and P2 of all materials tested.

INTRODUCTION

Composite materials have been occupying a prominent position in engineering applications in which it is necessary resistance to impact, namely ballistic ones (Bhatnagar 2016). In the aeronautical sector, the use of these materials in structures subject to medium and high energy impacts is accompanied by great concern due to the type of impact, which may be intentional or accidental, but also to the various types of damage associated with this type of events (Bielawski 2017). The damage resulting from an impact can manifest itself in different ways, namely delamination, matrix and fiber failure and fiber/matrix de-bonding, each of which has its own degree of severity for the structural strength of the laminate (Razali 2014). Knowing the impact resistance and damage suffered by these materials when subjected to an impact is extremely important, even more when their performance does not depend only on the impact energy, but also on the characteristics of the projectile and its speed. The materials involved in this study are Al2024 T3, a sandwich solution of Al2024 T3 and Rohacell71 WF which is a closed-cell rigid foam, a UD T700 carbon fiber and MTC801 epoxy resin laminate and an Al2024 T3/Kevlar29/ Al2024 T3 sandwich. These 4 panel solutions, from which the first three are currently applied in aircrafts, were tested with the impact of two metallic spheres (AISI 52100, 57-66 HRC) with different diameter and weight (P1: Ø=12mm, wt=7.05gr.; P2: Ø=19.05mm, wt=28.2gr.). The impact speed was adjusted to ensure a 140J impact for both spheres. To carry out the test, a compressed air cannon was used, capable of firing projectiles at up to 400m/s, while two high-speed cameras and a ballistic chronograph recorded the impact and residual velocity. The damage evaluation after impact was performed using non-destructive inspection techniques, namely X-ray and Ultrasonic Testing.

RESULTS AND CONCLUSIONS

Fig.1 and Fig. 2, depict the damage and impact energy absorbed and are presented in a qualitative manner, normalized with P2 values. Results presented in Fig.1 and 2 must be analyzed in Material-P1/2 pairs (enveloped by the blue boxes)

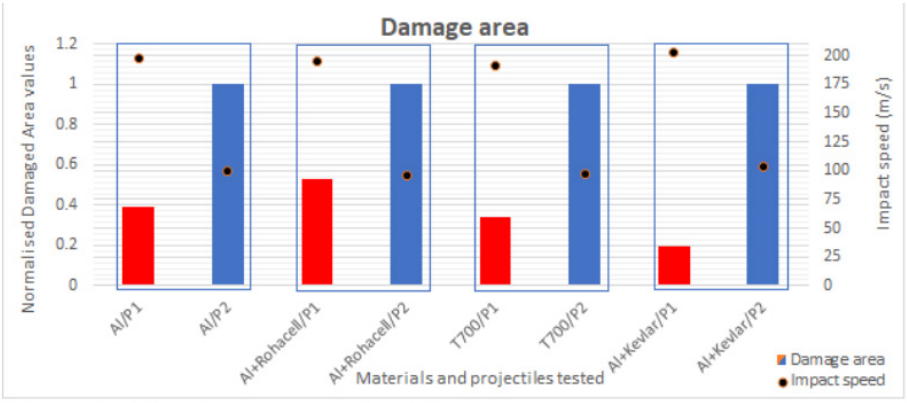

Figure 1 – Specimens normalized damage area.

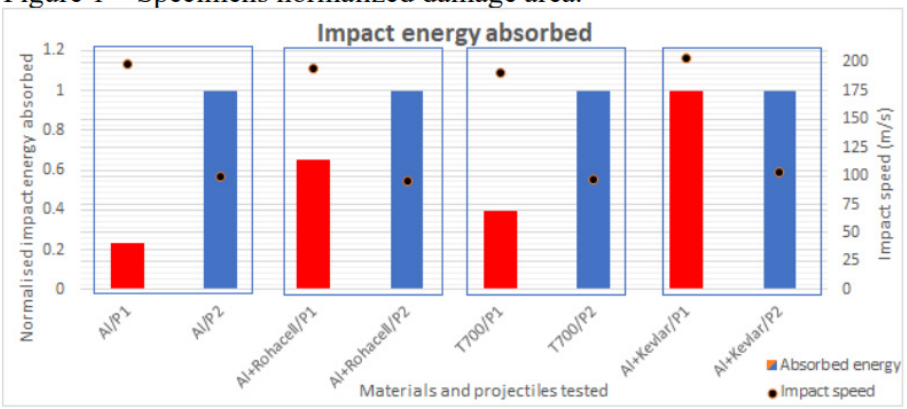

Figure 2 – Normalized impact energy absorption by specimens

Only Al/Kevlar specimens resisted to perforation by P1 and P2, while Al/Rohacell did not suffer perforation only with P2. Remaining specimens presented perforation with both projectiles. Specimens impacted with P2 revealed a higher damage area than with P1, between 50 to 80% higher, and higher values of energy absorption. Al/Kevlar sandwich specimen was able to resist perforation in both P1 and P2 impacts but presented the highest P1/P2 damage area difference. Overall best performance is from AL/Kevlar/Al since it resisted perforation from both projectiles. This study shows that the presence of high strength fibers (e.g. Kevlar) in middle or back layers enhance the energy absorption by dissipation of the impact energy in the form of plastic deformation. Although Rohacell foams register a slight increase in the shear resistance in face of a compressive event, due to the collapse of the closed cells (combination of elastic buckling and plastic bending) (Arezoo 2011), it is not capable to withstand the more localized forces as was proven by P1 impacts.

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ID159

RETAINING THE INTEGRITY OF LIGHT FRAME WALLS AGAINST BLAST LOAD EFFECTS

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ABSTRACT

Light frame walls are used as non-load-bearing partitions in commercial and residential buildings everywhere. Within normal operating conditions little attention is paid towards emergency loads e.g., caused by gas explosions or similar. Blast loading effects are however increasingly used to carry out attacks against automated teller machines (ATMs). Gas explosions have been observed to create openings into the perimeter surrounding the ATM, providing easy access to the room. Cost effective methods to avoid post-explosion openings in the perimeter wall sheathing are therefore considered. Within this experimental investigation the performance of three retrofitting methods were tested. Light frame wall sheathings of plywood and gypsum boards were reinforced with a polymer or polymer composite coating. Based on experimental performance of sheathing of boards, suggestions for the retrofitting practice are provided.

INTRODUCTION

Throughout Europe, the frequency of gas attacks against ATMs has significantly increased in recent years [1-2]. The modus operandi of the attackers is to pump explosive gas into an opening of the ATM and then to ignite it, aiming for easy access to the room and its contents. The blast wave from the gas explosion can easily damage the perimeter wall, providing openings for entering the room as well as creating unwanted projectiles.

Cost-effective measures for countering the aforementioned criminal activities are being considered. Among those, retrofitting of the perimeter wall sheathing with a polymer or composite coating has been proposed. Current experimental investigation focuses specifically on the post-explosion integrity of light frame wall sheathings. Two widely used construction board materials were investigated. The 12 mm thick birch plywood represents ‘strong’ structural boards, while the 13 mm thick gypsum board low-cost brittle materials with much lower strength properties. Plywood and gypsum were both retrofitted with two types of thermoset composite (glass and hybrid fiber fabrics) and one type of polyurea coating, applied in one-sided and two-sided configurations.

In order to clarify specific reinforcement benefits from these retrofitting practices, blast testing of regular (unmodified) and retrofitted sheathing boards was devised. The testing principle and the test set-up was chosen analogous to previously used sub-scale field testing arrangement for concrete columns [3]. Figure 1 shows the open-air test set-up where four simply supported sheathing boards were fixed to a rigid frame for simultaneous blast testing. One unmodified and three retrofitted board specimens were loaded simultaneously with a concentric blast wave by using different mass configurations of pentaerythritol tetranitrate (PETN) explosives. After testing, the visual damage to the boards was inspected, and the residual force-deflection diagrams for surviving boards were measured from three-point bending experiments.

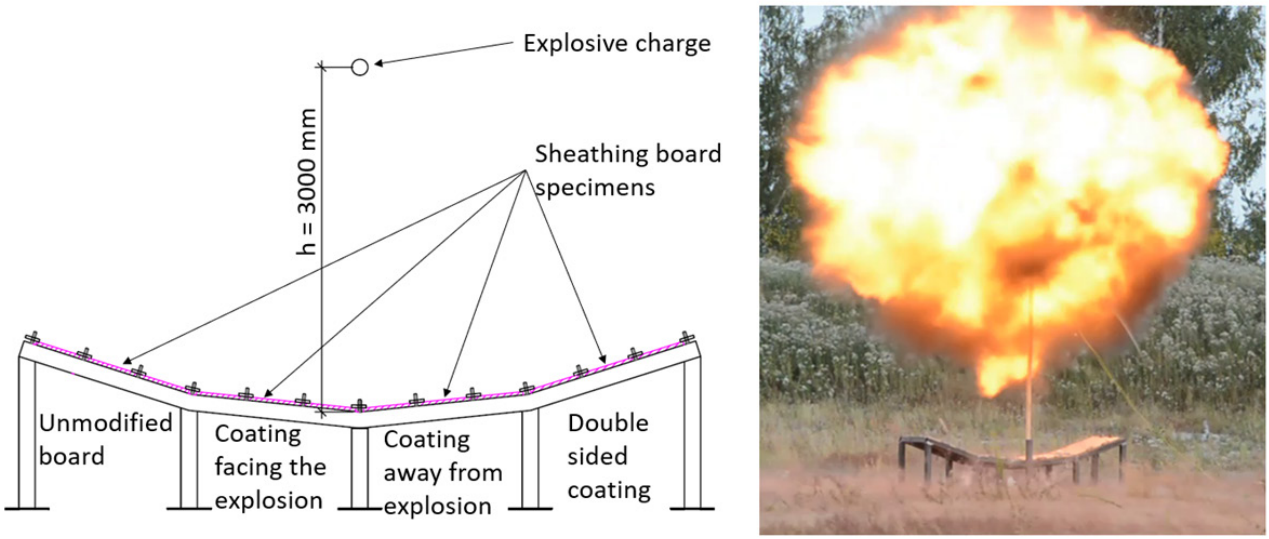

Figure 1. Test set-up for field testing.

RESULTS AND CONCLUSIONS

The novel testing principle using concentrically-positioned specimens worked well. Test results showed that all three reinforcement coatings had a strengthening effect over the unmodified sheathing board specimens. The residual flexural strength of retrofitted boards was on average higher than that of unmodified boards. As expected, double-sided coating provided the best protection. Gypsum boards broke very easily while the plywood tended to retain its structural integrity even without the coating, for the range of explosive masses used. Recommendations for the retrofitting practice for the sheathing boards against ATM focused criminal activities are provided based on obtained experimental results.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Estonian Explosive Ordinance Disposal Unit for the help with field testing.

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ID160

ASSESSMENT OF SMART YARN PROPERTIES TO PREDICT THEIR USE IN MANUFACTURING SMART CLOTHING SYSTEMS

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ABSTRACT

This research addressed the challenges of manufacturing knitted fabrics with integrated novel “smart” yarns, including the need to develop predictive and testing methodologies to predict suitability of these novel yarns for manufacturing and the resulting mechanical properties of the produced fabrics. This was achieved by using our advance Shima-Seiki knitting machines and controlling the manufacturing speeds and dimensions to obtain knitted fabrics with integrated smart yarns. Furthermore, yarns and fabrics were tested for their mechanical properties to help understand the best methods to integrate these yarns into knit fabrics and develop predictive models for mechanical performance of these fabrics. This study shows that there are substantial differences on the fabric mechanical properties when varying integrated smart yarn patterns. These properties are important to design smart garments while allowing optimal smart yarn performance, usability and comfort to the wearer..

INTRODUCTION

Recent developments in textile production technologies, such as knitting, weaving and braiding, provide a promising pathway to incorporate innovative technical fibers or yarns into textile structures, intending to produce high-performance fabrics that possess “smart” functionalities while maintaining excellent usability properties. For example, knitted fabrics have inherent high elasticity, realized by loop bending and deforming, and this may significantly be affected by the use of stiffer yarns. Incorporation of non-conventional specialty yarns into knitted structures is challenging due to their significantly different mechanical properties, in particular, most of the yarns are stiff and brittle and thus may cause problems during fabric formation. It is currently unclear, however, what the minimal requirements for these smart yarns are to allow manufacturing of knit fabrics and what their consequence for resulting fabric properties are.

In this research project we have evaluated mechanical properties of a set of novel “smart” yarns and compared basic yarn properties to the mechanical fabric properties, based on different knit structures with yarns integrated through the normal knitting as well as through tuck and inlay methods. This was achieved by using our advance Shima-Seiki knitting machines and controlling the manufacturing speeds and dimensions to obtain knitted fabrics with integrated smart yarns. The objective was to predict the knitability of novel smart yarns based on their basic properties as well as predict the resulting mechanical characteristics after manufacturing.

RESULTS AND CONCLUSIONS

The various production methods in knitting provide a variety of options to integrate smart yarns into the textile structure. Although the inlay method would be associated with the lowest requirements on yarn tensile modulus and bending rigidity, i.e. allow stiffer yarns, it also most strongly affects the resulting overall fabric mechanical properties. As knit fabrics are intended

to be worn on or close to the skin, this will negatively impact their usability. Due to the significant directionality, however, there may be options to integrate these integrated materials in knit fabrics, even more so if relative differences in skin stretching across the body are considered.

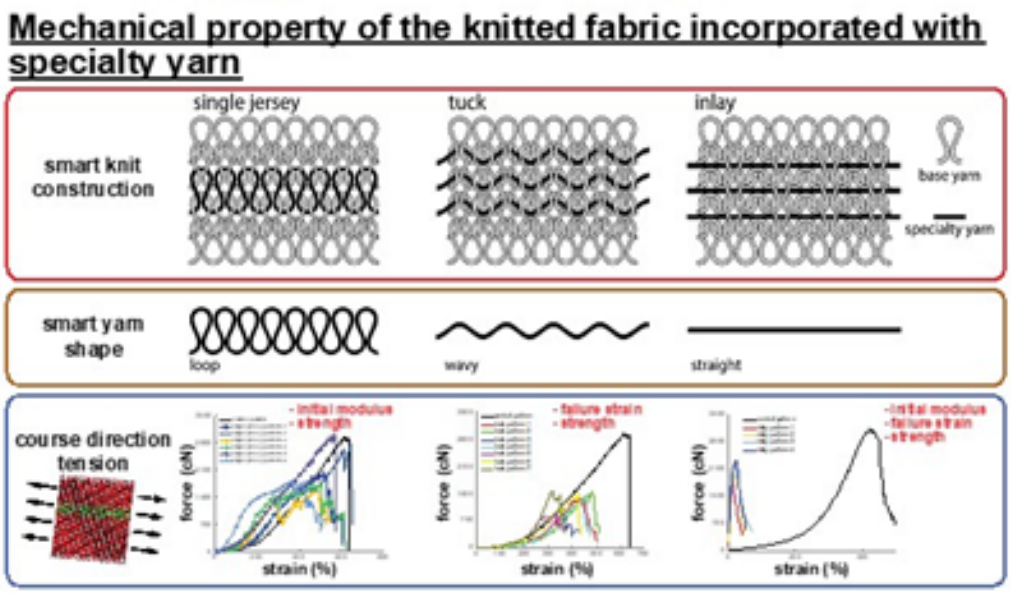

Figure 1. The influence of specialty yarn on the knitted fabric performances

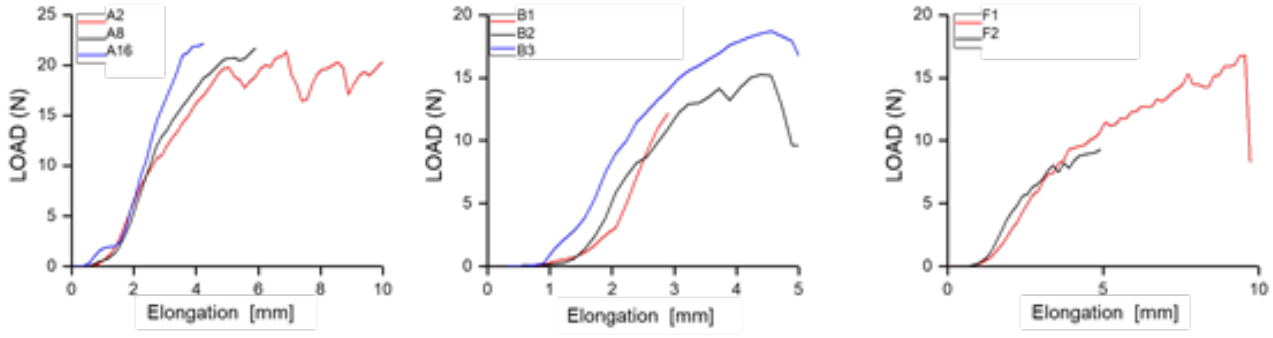

Figure 2. Smart Yarn mechanical tensile strength and modulus characteristics, Yarn types “A”, “B” and “F” denote a variety of commercially available conductive yarns with metal filaments, lowest numbers indicating finer yarns with lower numbers of filaments. Horizontal axis representing absolute displacement [mm] and vertical axis applied absolute load [N]. Gage length in these tests was 254 mm (10 inch).

The methodological approach developed in this project, linking basic yarn deformation measurements to the resulting mechanical properties of the knitted fabric can be expanded to different fabrics with a variety of performance requirements and basic characteristics. We have furthermore identified a need for new test methods on these specific innovative fibers, yarns and fabrics to enable prediction of the end product performance and optimize their integration into functional smart garments.
This study also showed that there were substantial differences on fabric mechanical properties with different integrated smart yarn patterns both between fabric types as well as directional within fabrics. These properties are important when considering to design smart garments while allowing optimal usability and comfort to the wearer.

ACKNOWLEDGMENTS

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ID161

DESIGN AND PRODUCTION OF A SMALL COMPOSITE OVERWRAPPED PRESSURE VESSEL FOR A FUEL CELL SYSTEM IN AN UAV

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ABSTRACT
The development of a small composite overwrapped pressure vessel (COPV), for hydrogen storage, to incorporate inboard of an UAV, for civil or defence application, is reported here.The developed COPV is a type III vessel, consisting of an aluminium liner and a carbon fibre/epoxy composite overwrap, which was produced by tape winding. The design of the COPV was supported by finite element analysis (FEA) and experimental burst testing has shown that the COPV is able to withstand an internal pressure that is three times that of the nominal working pressure of 350 bar.

INTRODUCTION
Burning of fossil fuels in combustion engines accounts for approximately 20% of the total produced CO2 emissions. Several research projects have been conducted to look for a replacement for fossil fuels in the transportation industry, aiming to contain global warming (Pollet, 2019). Hydrogen-powered fuel cells (FC), have been gaining traction for that purpose (Menon, 2016). It is expectable that FC will be largely used in automotive applications in a close future, as key automotive companies such as Toyota, Hyundai and Honda are already selling fuel cell electric vehicles (FCEV). FCEV present some attractive advantages over battery electric vehicles (BEV): shorter refuelling times (about 3 - 5 min) with an autonomy of around 600 km, decreasing anxiety associated with driving range, increased longevity (above 200 000 km), safety and improved driver experience (Pollet, 2019). Aviation industry is also paying attention to the potentialities of hydrogen-powered aircraft to achieve CO2 neutrality. Some examples of hydrogen based propulsion in aviation are the Boeing's airplane demonstrator (Lapeña-Rey, 2007) and the four-seat passenger air-craft HY4, developed by DLR in 2016 (Kallo, 2015). The implementation of FC systems requires the development of lightweight pressure vessels for hydrogen storage. In this application context, composite overwrapped pressure vessels (COPV) compromise the most weight efficient solution among the existent vessel construction types (Abdalla, 2018).
A small COPV, with approximately 1 litre volume and 80 mm internal diameter, consisting of an aluminium liner and carbon fibre/epoxy composite was developed for a nominal storage pressure of 350 bar. The composite overwrap was wound over the 6061-T6 aluminium liner, through prepreg tape winding. The composite layup was optimized via finite element analysis (FEA). The maximum working storage pressure has been validated by burst testing, where the COPV has proved to be able to bear an average internal pressure of approximately 1050 bar (safety coefficient of 3). Further testing, including pressure cycling testing, drop testing, flaw testing, etc., are currently being performed, according to the European standard EN12245, to ensure safety upon use of the COPV within the FC system.

RESULTS AND CONCLUSIONS

Several layup configurations of the composite overwrap have been studied by FEA and some of them were produced by tape winding and subjected to burst testing. The optimized laminate presents the following configuration [903/±152/903]. The damage onset, according to Hashin's criteria for fibre tension mechanism, was obtained from the FEA simulation with Abaqus software. Fig. 1 shows the damage onset on the helical layers at a pressure of 800 bar. However, the circumferential layers show damage onset between 1260 and 1540 bar, well above the required 1050 bar burst pressure.

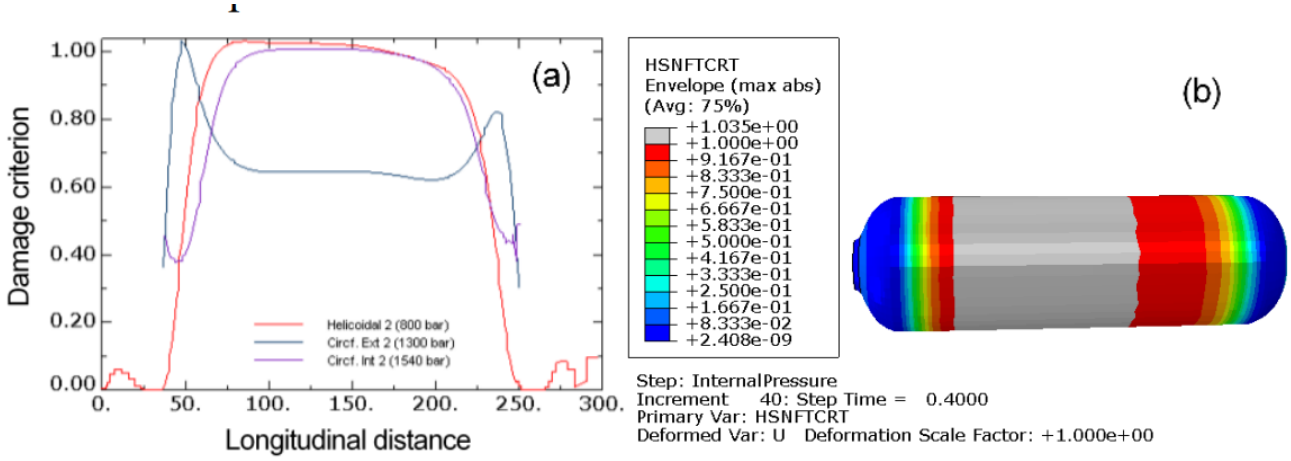

Fig. 1: Hashin's damage onset criterion for fibre tension mechanism as obtained from FEA simulation of the optimized COPV: (a) damage criterion along the longitudinal axis of the COPV, at the different lamina failure pressures; (b) illustration of the damage criterion on the composite geometry at a pressure of 800 bar.

Experimental burst testing performed on the optimized COPV revealed a burst pressure of 1050 ± 25 bar. An example of a COPV prior to and after burst testing can be seen in Fig. 2. Furthermore, a COPV with similar layup configuration [904/±152/904] was previously subjected to pressure cycling testing, being able to withstand 8566 ± 798 cycles, qualifying it for a service life of over 30 years.

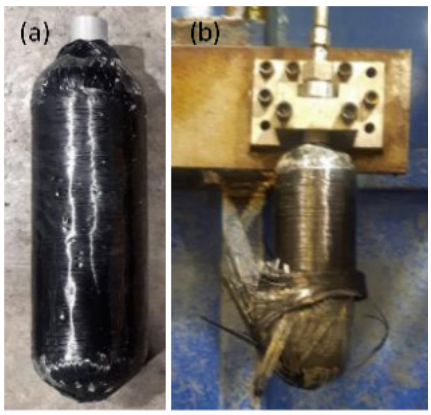

Fig. 2: COPV (a) prior to and (b) after burst testing.

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ID162

SMART TEXTILE IN MILITARY FIELD: CASE STUDY CAMOUFLAGE PROPERTIES OF TEXTILE STRUCTURES

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ABSTRACT

Camouflage properties for military textiles can come in the form of clothing, light flexible nets, garnishing and covers. Indeed smart textiles offer great potential for the next generation of camouflage products.
Status of art of smart textile in military field is presented in this survey, focus for camouflage textile applications.

INTRODUCTION

The diverse requirements of military fabrics have been a motivator for the rapid development of smart textiles
Smart technologies can be integrated into fabrics to protect against various threats including biological, mechanical, or chemical hazards, or to improve the functionality of fabrics such as changing appearance or through enhanced thermal regulation.

RESULTS AND CONCLUSIONS

This study shows that there are new potential of smart textile on the optical properties textile structure. Further biomimicry approach should be more applied in order to obtain better results.

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ID163
PROTECTION OF STRUCTURES AGAINST HIGH VELOCITY IMPACTS

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ABSTRACT

Nowadays, there is not an effective protective system for structures regarding high-velocity impacts (>1000m/s), using explosively formed penetrators (EFPs). This work seeks to fill this gap by developing a concrete panel, combining ductile and disruptive materials. This project is at an early stage and intends to present the state of the art, followed by many full-scale tests and numerical analysis, in order to find the most effective material configuration.

INTRODUCTION

Extreme loadings on structures, such as explosions or impacts, have increasingly attracted the attention of researchers to assess their effects and limit damages on structures. It is also known that local damage caused by extreme actions can lead to the progressive collapse of a structure. Within this context, improvised explosive devices (IEDs) present a significant challenge to conventional armour systems and civil engineering infrastructure. One type of IED that has been particularly difficult to defeat using conventional protective measures is known as explosively formed projectiles (or EFPs). An EFP is one of the most severe explosive and impact loading threats for civil infrastructure and military vehicles. This project will focus on developing a protection system against high-velocity impacts (>1000m/s), which will allow to dissipate energy, acting as a protective barrier to the structure, which is not designed to support this type of actions.

RESULTS AND CONCLUSIONS

Concrete became fundamental in the construction industry for more than one hundred years, which has led to an increased interest in its use to protect human lifes for civil and military purposes. The correct characterization of its behavior facing these extreme actions is critical to design bunkers, nuclear installations, dams, factories, embassies, or structures designed to withstand to accidental load scenarios such as collisions with vehicles, planes, ships, or fragments' projections resulting from explosions or tornadoes. Although there are several studies on the behavior of concrete against impacts and explosions, it is still an open area of knowledge due to the difficulty of characterizing the concrete's behavior facing these extreme actions, namely high-velocity impacts (Remennikov, 2019). An EFP uses the effect of the explosive charge to deform a metal plate into a slug or rod shape and accelerate it toward a target (Fig. 1). It can effectively penetrate targets with standoff distances up to several hundred charge diameters due to the high velocity reached (~1000 - 2000 m/s). EFP's also generates higher mass and larger diameter projectiles capable of delivering a large amount of energy to a reduced area, compromising the integrity of all or part of a concrete structure (Fig. 2) (Walters, 1989).

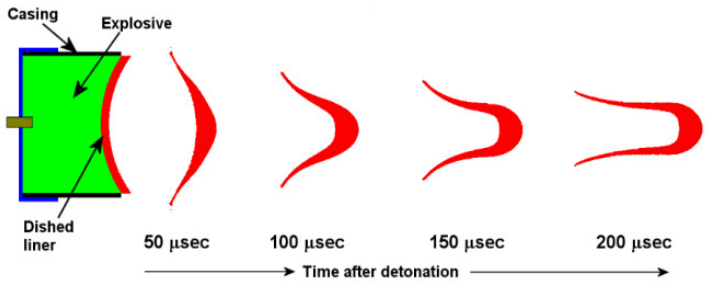

Fig. 1 Formation of an EFP (Remennikov, 2019)

Fig. 2 Reinforced concrete wall targets (Walters, 1989)

In summary, it is vital to develop protective systems for structures to solve the following problems: control failure mechanisms due to high-velocity impacts such as spalling, penetration, and perforation; increase energy dissipation of projectiles using disruptive and ductile materials and analyze their contribution to penetration resistance; ensure the ability of panels to withstand high-velocity impacts, allowing to protect the occupants. Materials adopted to solve these problems should have high bulk and shear moduli to prevent large deformations;
high yielding stress to avoid failure; and high dynamic tensile stress to avoid material rupture when tensile waves appear (Elhozayen, 2019). According to later remarks, a systematic study is proposed to evaluate different designs of concrete panels considering ductile materials such as steel, metallic meshes, and metallic fibers in order to mitigate the fragile behavior of concrete. Ductile materials will be combined with disruptive materials (high hardness materials (Tawadrous, 2016)) to dissipate energy from the projectile through its deflection and deformation. Thus, full-scale tests and numerical simulations will be performed to validate the protection system.
The aim is to collect relevant experimental data dealing with impacts of this type, allowing engineers to design retrofitting panels for buildings subjected to EFP or similar threats and develop the necessary specifications to protect personnel and equipment (Bookout, 2012).

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ID164

SUBJECTIVE ASSESSMENT OF MULTILAYERED TEXTILE SYSTEMS FOR MOISTURE-WICKING TEXTILES—FOCUSED ON SKIN TEMPERATURE AND HUMIDITY AND COMFORT SENSATION

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ABSTRACT
In this study, trilayered textile systems comprising hydrophobic, transfer, and hydrophilic layers were fabricated for functional moisture-wicking textiles, and subjective tests were conducted using two types of multilayered textile systems and control fabrics to investigate the effects of the trilayered textile systems on the skin temperature and humidity and the subjective comfort sensation of the human subjects while water supply was ensured to continuously simulate "sweating". After the water supply was stopped, the average skin humidity and temperature were restored close to the state before the water supply, indicating good moisture transport and fast-drying properties for the trilayered textile systems. In the evaluation of subjective comfort sensation, the subjects felt more comfortable with the multilayered textile systems than with control fabrics (cotton or polyester).

INTRODUCTION
Moisture transport properties of textiles remarkably affect thermophysiological comfort of the wearer; thus, they are crucial in protective and military clothing, especially when used under strenuous activities or extreme conditions. Textiles should quickly absorb sweat from the skin and release it into the outside environment to maximize human sensorial and thermophysiological comfort (Benltoufa et al., 2008). Various approaches have been adopted to improve moisture transport properties of textiles, and multilayered textile systems are one of them. Multilayered textile systems composed of a hydrophobic inner layer and a hydrophilic outer layer facilitate moisture transport through textiles. The hydrophobic layer pushes moisture, whereas the hydrophilic layer pulls it, creating what is known as the push–pull effect. The hydrophobic layer quickly transfers moisture generated by the human body away from the skin, whereas the hydrophilic layer absorbs and discharges it into the outside environment, maintaining the dryness of the skin surface (Supuren et al., 2011). In this study, multilayered textile systems consisting of hydrophobic, transfer, and hydrophilic layers were fabricated. Subsequently, subjective tests were performed using two types of multilayered textile systems and control fabrics to assess their effects on the temperature and humidity of the skin and the subjective comfort sensation of the human subjects while water supply was used to simulate a continuous supply of "sweat."
The following four samples were investigated in the patch test: (1) multilayered textile system, M1 (polyester (PET) tricot–polyurethane (PU)/poly(ethylene glycol diacrylate) (PEGDA) nanofibrous membrane–PEGDA coating), (2) multilayered textile system, M2 (PET tricot–PU/PEGDA nanofibrous membrane–modal/cotton jersey) (M2), (3) 100% cotton jersey (CO), and (4) 100% PET tricot (PE). M1 is a trilayered textile system developed by Song (2021), and M2 is a trilayered textile system newly developed in this study to reinforce the durability of M1.

Twelve healthy individuals (six males and six females) participated in this study. Each sample was placed onto each subject's forearm, where temperature and humidity sensors were attached, and then a fixed amount of water was supplied to the skin surface underneath the sample for 15 min. The skin temperature and humidity and subjective comfort sensation of the subjects were evaluated for 15 min during which water was supplied and then for 20 min after stopping the water supply.

RESULTS AND CONCLUSIONS

For a change in skin temperature, overall, the average skin temperature of M1 and M2 decreased steadily while water was supplied. The average skin temperature of M1 started rising 10 min after stopping the water supply. For M2, the average skin temperature began rising 6 min after stopping the water supply. Conversely, the average skin temperature of CO continued to drop even after the water supply was stopped. For PE, water flowed sideways, indicating that the sample did not absorb or wick water.
For a change in skin humidity, the average skin humidity of M1, M2, and CO gradually increased during 15 min of water supply, whereas PE exhibited slight difference in the average skin humidity during the water supply. After stopping the water supply, the average skin humidity of M1 decreased remarkably, and the average skin humidity of M2 also showed a gradual decrease. Conversely, CO maintained elevated skin humidity, and PE did not show a notable difference from the initial state. Considering the changes in skin temperature and humidity together, the multilayered textile systems induced the push–pull effect, driving moisture out from the skin efficiently, reducing the humidity of the skin surface, and drying it again.
The skin temperature and humidity measured using the sensors corresponded to the subjective comfort evaluations to which the subjects responded. The subjects felt most comfortable with M1, which exhibited fast drying, and most uncomfortable with CO, which exhibited little drying. This subjective assessment demonstrates that multilayered textile systems have better liquid moisture transport properties and drying properties than cotton or polyester single-layer fabrics, indicating that these multilayered systems have potential for moisture-wicking and fast-drying functional textiles, which would enhance wearer comfort.

ACKNOWLEDGMENTS

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ID165
FUNCTIONALIZATION OF THE BALLISTIC MATERIALS

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ABSTRACT
The research assumed the wide range of the functionalization of the ballistic textile materials made of the p-aramid woven textiles and UHMWPE fibres composites for the improvement of the performance, safety of the finally designed ballistic system (soft as well as in form of the hybrid composite) as well as processing behaviour. The application of the plasma assisted chemical vapour deposition (PACVD) technique with the precursors of the silicone- and fluor -containing polymers for the prolongation of the resistance of the ballistic systems against environmental factors as well as possibility to fabrication of the ballistic hybrid composites will be shown.

INTRODUCTION
Commercially available ballistic protections have a manufacturer's warranty for at least 5 years of use, i.e. Polish standards requirements impose a 10-year warranty period. In the majority of cases, there is no real possibility to control the storage/use conditions of ballistic protections. This generates a significant risk of losing the assumed ballistic resistance and a threat to the user's safety. The stability of the performance of textile ballistic materials during storage and use of ballistic protections is an important safety requirement of the above-mentioned products. A review of literature indicated a significant impact of storage/use environmental factors on reducing the ballistic effectiveness of fibrous ballistic products.
The aim of the interdisciplinary scientific research was to develop guidelines for the functionalization of textile ballistic materials (based on the p-aramid and UHMWPE fibres) for potential future use in the design of personal ballistic protections. These studies were carried out in the aspect of verifying the hypothesis assuming the possibility of increasing the usability and safety of textile ballistic materials, differing in content and the structure, by increasing the stability and resistance of the performance of these materials using the PACVD.
Phenomena related to the aimed modification of ballistic, textile materials have been defined and validated, which will enable in the future to search for ways to apply the effects of the project in the design of ballistic material systems for ballistic protections.
The surface properties of modified ballistic materials, both those made of p-aramid fibers and those made of UHMWPE, may be subject to aimed change in the PACVD process, which allows to expand the possibility of using modified ballistic materials to form hybrid composites assembling more than one type of ballistic and/or non-ballistic material. The usefulness of this solution at TRL IX level has been positively verified and validated.

RESULTS AND CONCLUSIONS
In the research, the synthesis of two types of plasma polymers on p-aramid woven fabrics and UHMWPE fibrous compositions were performed: based on the fluoroorganic monomer (tetradecafluorohexane; TDFH) and silicon--containing monomer (hexamethyldisiloxane; HMDSO).
The results of the research indicated that hydrophobic coatings, not reflected and containing structures in a composition similar to SiO2, can be obtained in the PACVD system, assuming the following process conditions:

(a) for p-aramid woven fabric: at a flow rate of 0.032 Pa m3 s-1, in an argon process gas stream with a flow of 0.24 Pa m3 s-1, with a power supplied to the electrodes of 100 W, in a time of up to 3 min.; (b) for UHMWPE fibrous composition: at a flow rate of 0.032 Pa m3 s-1, in an argon process gas stream at a flow of 0.24 ÷ 0.48 Pa m3 s-1, with a power supplied to the electrodes of 100 W, for up to 3 min.

The use of TDFH in the process of modification on both textile carriers resulted in the formation of polymer coatings with a strongly hydrophobic character (at a flow rate of 0.032 ÷ 0.064 Pa m3 s-1, with a power supplied to the electrodes of 100 ÷ 200 W, for 1 ÷ 3 min.).

The results of the conducted research indicate that the use of PACVD for the deposition of a polymer layer on the surfa es of textiles made of p-aramid yarns and UHMWPE fibers can significantly improve the material properties that are important for their future applications. The PACVD modification resulted in the increase of the resistance to surface wetting and significantly reduce of the water permeability through the p-aramid woven fabrics. The increase of the puncture resistance was also observed (Table 1.).

Table 1. Characterization of the initial and PACVD-modified p-aramid woven fabric

Parameter	initial p-aramid fabric	p-aramid fabric with nanolayer of fluoropolymer	p-aramid fabric with nanolayer of organosilicon polymer
Areal density [g/m^2]	212±2	210±3	210±2
Thickness [mm]	0.20±0.02	0.20±0.02	0.21±0.02
Puncture resistance [N]	79±10	65±24	117±8
Resistance to surface wetting on a 5-stage scale	1; 1; 1	4; 4; 3	3; 2; 2
Water absorption [%]	30.4±0.5	30.3±1.7	29.4±1.7
Average water permeability [cm^3]	23.0	1.0	2.25

Similar phenomena for PACVD-modified UHMWPE sheet was found (Table 2).

Table 2. Characterization of the initial and PACVD-modified UHMWPE sheet

Wyszczególnienie	UHMWPE sheet	UHMWPE sheet with nanolayer of fluoropolymer	UHMWPE sheet with nanolayer of organosilicon polymer
Areal density [g/m^2]	251±2	247±1	251±2
Thickness [mm]	0.29±0.02	0.29±0.02	0.25±0.02
Puncture resistance [N]	182±8	62±7	155±30
Resistance to surface wetting on a 5-stage scale	3 ; 3 ; 3	4 ; 4 ; 4	4 ; 4 ; 4
Water absorption [%]	9.18±1.71	13.2±2.4	10.8±1.1
Water resistant	654±43	815±169	911±65

Model ballistic packages. after the process of accelerated aging. were verified to estimate changes in physico-mechanical. structural and ballistic properties. There were no significant changes in the morphology and topography of the studied textile materials after the accelerated aging process. The PACVD process had a positive effect on the mechanical properties. especially those related to the multidirectional strength of the textile material. In the above case. the higher levels of mechanical parameters are due to the effect of consolidation of the structure of the p-aramid fabric or loosening of the spatial structure of the fibrous composition made of UHMWPE fibers. probably resulting from the action of the aging factor on the structure of these textile materials. Summing up the conducted research. it should be noted that the modification of PACVD in the presence of low-molecular substrates TDFH or HMDSO significantly changes the properties of p-aramid fabrics and UHMWPE fibrous compositions. positively affecting the stability of ballistic properties during accelerated aging. The PACVD process changes the effect of the generation and propagation of the shock wave of the projectile. The surface properties of modified ballistic materials. both those made of p-aramid and UHMWPE fibers. may be subject to

directional change in the PACVD process allowing to expand the possibility of using modified ballistic materials to form the hybrid composites assembling more than one type of ballistic or non-ballistic materials. Such a combination of textile and non-textile materials with different properties significantly improves the performance of the composites designed.

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ID166

THE DEVELOPMENT OF A SMALL-SCALE PPG-UAV FOR EMERGENCY RESPONSE ACTIONS

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ABSTRACT
The paper depicts the early phase of development for an integrated system tailored for emergency response actions and remote sensing. This paper focuses on a support system envisioned as an integrated Unmanned Aerial System (UAS) system that consists of one or more ultralight multifunctional aerial units with a configuration that can be adapted to the nature of the intervention: monitoring, mapping, observation and logistics etc.n.

INTRODUCTION
Starting from wing airfoil and material selection and ending with the experimental model manufacture, the paper will present the development of a single sail paraglider wing that can meet the operational demands for emergency response situations. The wing was designed mainly to have an easy handling and to have a predictable deployment at all times. The entire system and the aerial units were designed with increased modularity in order to be tailored for specific operational requirements of the intervention.

RESULTS AND CONCLUSIONS
This type of flexible wing UAV has major cost advantages over a fixed wing UAV. A UAV with flexible wing does not have the flight speed of a fixed wing and cannot fly in a fixed position as a rotor type UAV. If we are to enumerate the pros / cons of a flexible wing UAV, they would look like this:

Pros:
- Low cost;
- Low complexity;
- High reliability;
- High cargo capacity.

Cons:
- Low flight speed;
- Low flight dynamics
- Weaknesses facing adverse climatic factors.

The make of the experimental model starts with pre-dimensioning, everything is done with a software program developed within the institute, which includes a SQL database (Fig.1a, Fig.1b) that can easily be edited and stores the characteristics of the materials commonly used in making paragliders and parachutes. This database is populated with the existing stock of materials from which to select the parachute fabric. Material selection can be done manually or automatically by the program based on the physical parameters of the required material obtained from the calculation and / or on the basis of the existing stock.
The implementation methods in software for the initial pre-dimensioning phase derive from the empirical and interpolation graphical methods currently used for parachute design, then on the virtual model additional computational checks are iterated using the finite element methods, on the behavior of the parachute from deployment, flight attitude and landing

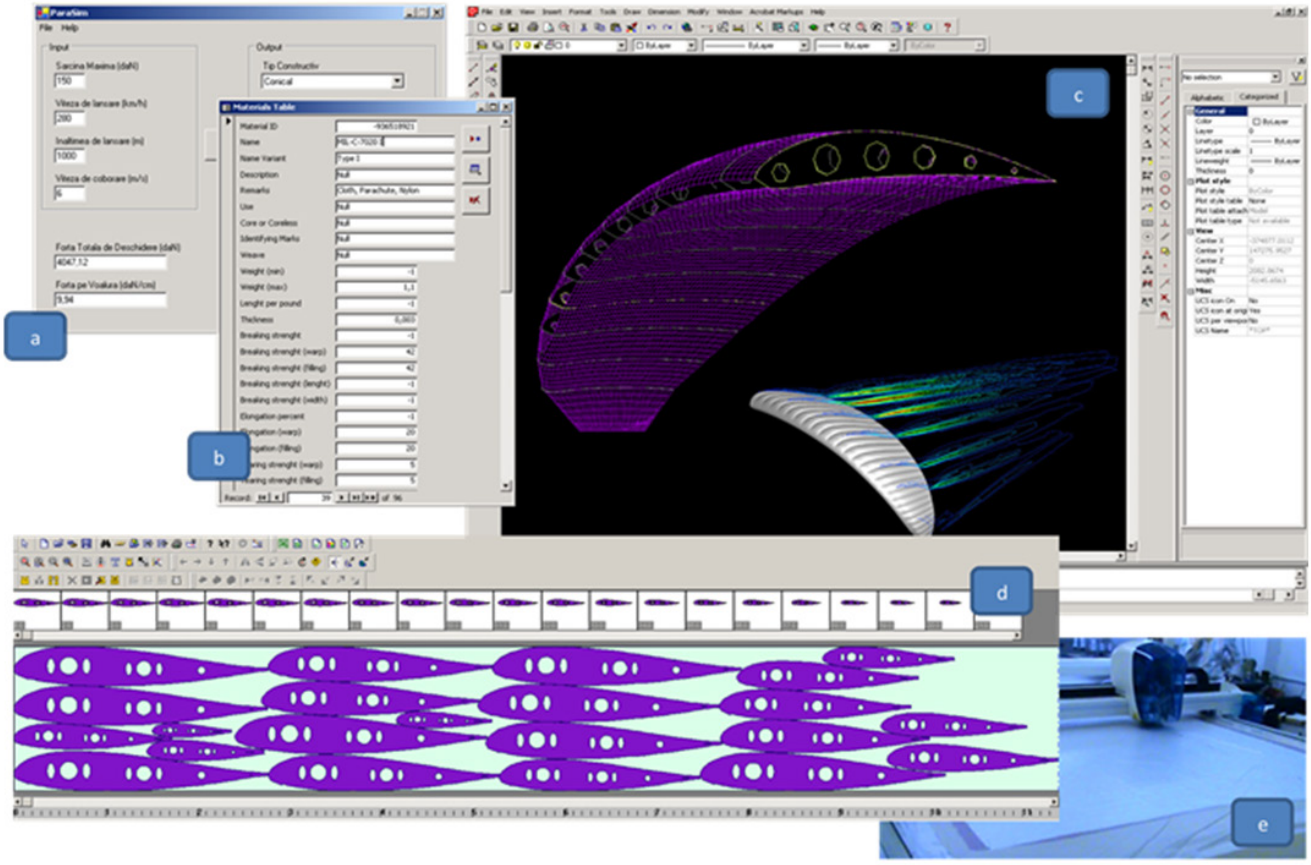

Fig.1. Textile wing design and manufacture workflow

The fabric used in the manufacture of the wing is a double rip-stop nylon 6.6 fabric with urethane amino modified poly siloxane coating for UV protection. The modular configuration of UAS support system and load variants of the UAS support system are:

- Video suite: permanently mounted (for observation, monitoring, cartography and GIS);
- Sensor detection and localization sensor set: if necessary (for locating missing persons, fire and wind direction detection) or Cargo unit: if necessary (or emergency transport, medicines and supplies in remote areas, small cargo, up to 10kg).

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A MULTIFUNCTIONAL THERMOACOUSTIC INSULATION FOR IMPROVED IMPACT PROTECTION IN AIRCRAFT FUSELAGE.

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ABSTRACT

Lightweight multifunctional structures are key aspects in the design of defense applications, especially in aircraft components. Fuselage cabin for passenger applications have the primary requirement to carry the aircraft structural loads, but also provide thermal and acoustic insulation. For defense applications, additional impact protection is desired from the fuselage, but this added functionality is accompanied with additional weight. In this work, a novel integrated solution is proposed by exploiting the multifunctionality aspects of the thermoacoustic insulation materials to improve the overall performance of the fuselage without increasing the solution weight. The proposed concept is capable to improve the overall thermoacoustic insulation and the impact protection.

INTRODUCTION

In commercial and military aircraft applications, the insulation system is usually intended for providing thermal, acoustic and fire protection (Mouritz, 2012). The insulation system corresponds to 10% of the fuselage weight, while fuselage structure corresponds to almost 30% of the take-off weight. Thermal insulation is required to achieve adequate cabin interior temperatures during flight due to low external temperature (depending on altitude it can reach -50ºC) and give flame shielding protection in case of fire. An additional functionality of this thermal insulation is to provide a noise barrier from external sources. (Norrefeldt & Riedl, 2021)

The fuselage assembly of a passenger cabin is composed by the fuselage skin and the frames which are part of the fuselage, and a set of insulating material components like the primary insulation and internal wall as shown in Figure1.

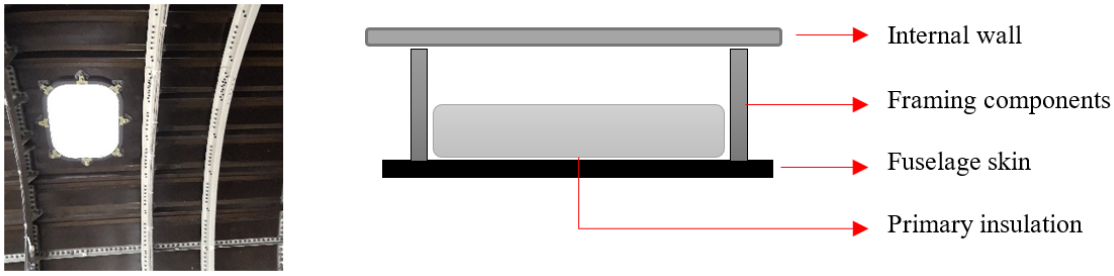

Figure 1. Components of the fuselage assembly.

The commonly used material for the thermoacoustic insulation is mineral wool wrapped by a covering film, and the internal wall is usually a flexible fabric, for military aircraft, or stiff panels, for commercial aircraft. In this work, a new design is proposed by introducing foam based thermoacoustic insulation, to replace the mineral wool, and a fiber reinforced sandwich panel as internal wall.

RESULTS AND CONCLUSIONS

The proposed design of the multifunctional thermoacoustic package have a melamine aeronautic grade foam (BASF, 2016) to replace the mineral wool as the primary insulation, and a sandwich composite panel with a Rohacell® core and Dyneema® reinforced epoxy at the faces. This sandwich panel has a perforation pattern to improve the acoustic performance (Liu et al., 2017).

The preliminary performance of the proposed solution is summarized in Figure 2, for a design concept with a similar mass that of the reference solution. The main improvements are for the impact energy absorption capacity (40%) and the acoustic absorption (50%).

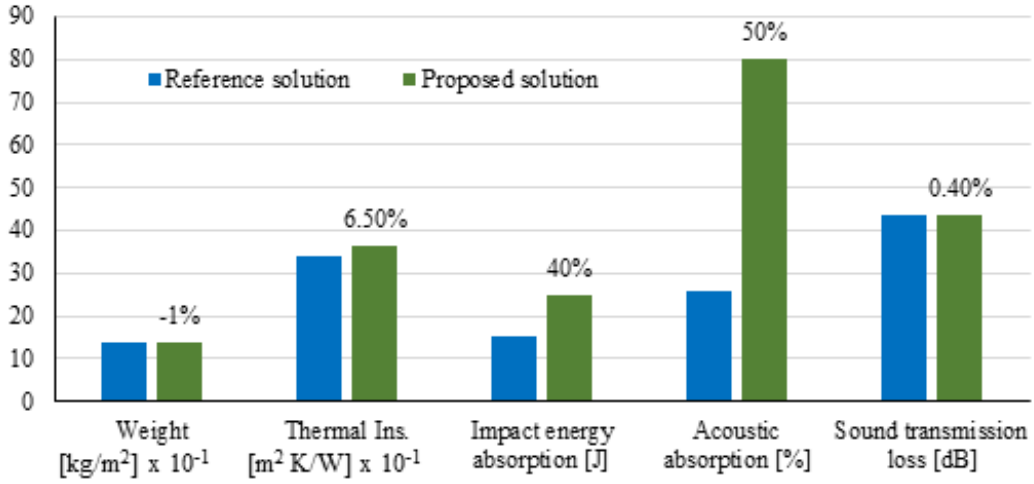

Figure 2. Performance summary.

According to these preliminary results, the proposed design has enhanced thermoacoustic performance, and improved the overall impact protection of the fuselage sidewall.

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STUDY ON THERMAL PERFORMANCE OF POLYOXADIAZOLE FABRICS FOR SPECIAL PROTECTIVE APPLICATIONS

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ABSTRACT

This work aims to investigate the special properties of fabric made from polyoxadiazole (POD) fiber materials that are currently used in high heat environments. Seven jersey knitted fabrics with different amount ranging from 0 to 100% of POD yarns along with polyester yarns were developed. The functional thermal performance such as CLO, thermal conductivity and resistance, thermal effusivity, thermal insulation, transmittance and reflection heat accumulation etc were studied and compared with the effect of different amount of polyoxadiazole in fabrics. Interesting dual functional effect of POD was discovered. POD fabric possess twice lower CLO compared with polyester one, highest thermal conductivity, very high effusivity and low heat accumulation which makes this material a good candidate for cooling. Whereas extremely high reflectivity, three times higher than polyester one, opens possibility for the usage of POD for warming.

INTRODUCTION

Clothing made from thermostable fiber materials are widely used for protective applications against high heat environment. Thermostable fibres are designed to use at temperature above 250oC. These fibres are mostly synthetic fibres and two most common types are the aramid family and the poly-benzazole family. Para-aramids are typically the basis for protective clothing due to their high strength, nonflammability, and high temperature resistance. Since aromatic and PBO materials are much more expensive. protective clothing industries are often trying to find new fiber materials to reduce cost without compromising required performance. As a result, the Belarussian manufacturer have developed new thermostable poly(paraphenylene-1,3,4-oxadiazole) synthetic fibres which are great interest among highly heat-resistant fibers due to low production cost combined with various advanced properties (Markarova et al).

The Polyoxadiazole (POD) fiber is widely used in various applications such as occupational safety and rescue equipment, aircraft and motor vehicle interiors, high temperature filter cloths, electrical insulation and brake composites. The selected features of this fibres are high glass transition temperature (330oC), working temperature in air is 250oC, high wear resistant, , high electrical insulation etc (Ryklin et al). A comprehensive investigation of fabric made from POD on special properties such as thermal effusivity, thermal conductivity and resistance, spectral behavior, thermal insulation and heat accumulation would allow POD fibers to be applied in special functional protective clothing.

RESULTS AND CONCLUSIONS

Thermal and physical characteristic of fabrics are presented in Table 1, fabric structure and analysis on different thermal performance are shown in Fig 1. From obtained results, it can be clearly seen that the thermal insulation (CLO), resistance and heat accumulation are decreases

with the increase of POD amount. Meanwhile reverse trend was observed for thermal conductivity and effusivity. The result suggested that the fabric with POD could provide cooling effect to human skin. Whereas reflectance is augmenting with the increase of the amount of POD which could be used for heat reflection for warming if placed in necessary layer in apparel.

Table 1 Fabrics characteristics with thermal insulation result

S. No	Samples	Yarn Linear Density (tex)	Amount of POD (%)	Areal Weight (g/m²)	Thickness (mm)	Thermal Insulation (CLO)
1	POD	29.4 tex	100	204.91	0.46	0.31
2			88	198.85	0.47	0.48
3			75	183.87	0.46	0.53
4	POD/Polyester	29.4 tex/19.7 tex	60	174.54	0.47	0.52
5			43	159.86	0.46	0.62
6			23	149.87	0.46	0.57
7	Polyester	19.7 tex	0	141.65	0.51	0.6

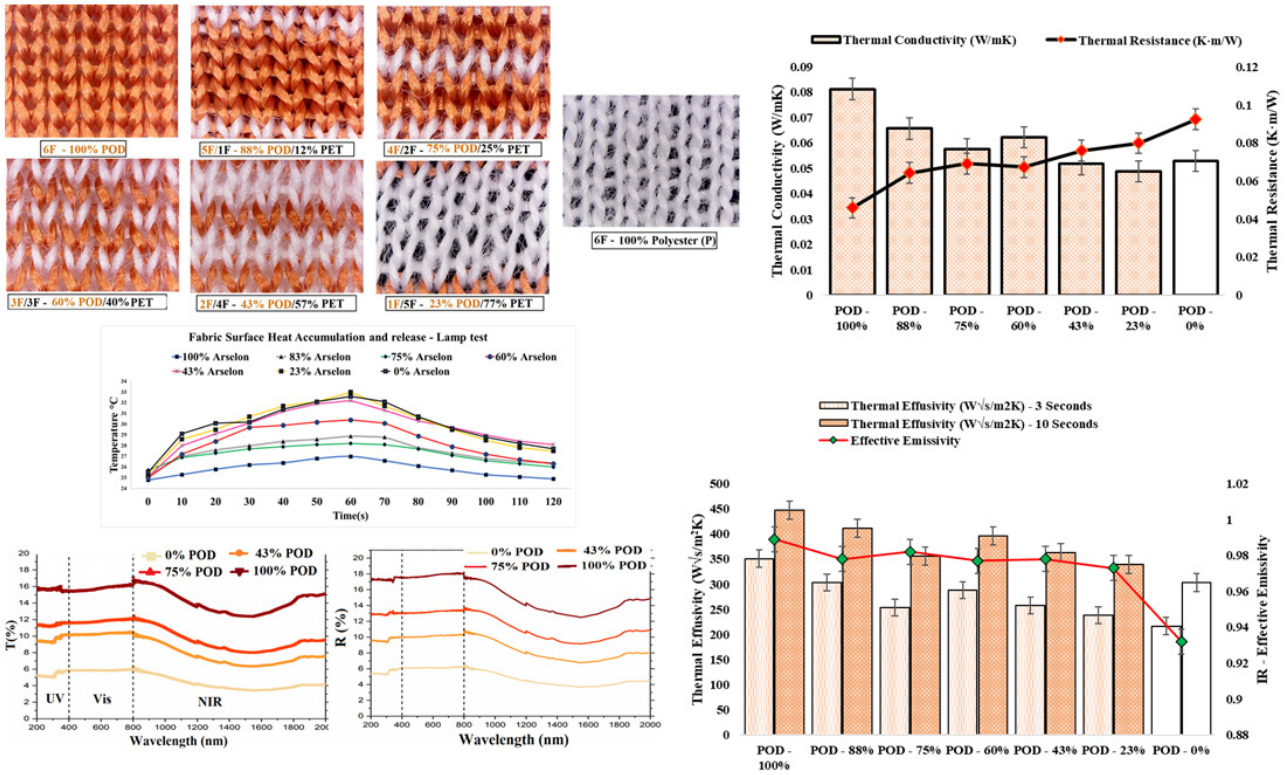

Fig.1 Thermal Performance of Fabric with different amount of Polyoxadiazole

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ID169

MANUFACTURING AND DETECTION OF MAGNETIC TEXTILES USED AS SECURITY FEATURES

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ABSTRACT

The aim of this project is to develop permanently magnetic textile fibers whose stability meets the requirements for textile surface formation. Magnetically encoded information can be written onto the fibers and read out again. For this purpose, magnetic particles are mixed into a thermoplastic polymer granulate in a suitable manner and size and spun into filaments. A magnetization system was developed to store magnetic information in the filaments and a magneto-optical system was used to read the information. The filaments can be written with magnetically encoded information individually or in complex in textile surface structures. The information can be modified as often as desired. Thus, a textile becomes a magnetic data carrier for a wide variety of applications for recording and reading information.

INTRODUCTION

The basic material chosen for thread formation is polyamide (PA). Furthermore, two main groups of magnetic materials are considered. These are neodymium-iron-boron magnets (NDFeB) with high high remanence and hard ferrites with simpler magnetization behavior of higher corriosion stability, After preliminary tests, NdFeB was selected as magnet material and fractionated into different grain sizes, fraction A (< 25 µm), fraction B (25 µm < x < 71 µm) and fraction C (> 71 µm) being the most important.
Fractions A and B were used for further filament processing. They were blended into the PA granules at 60 and 70 ma.%, respectively, and then spun. These filaments were processed into textile components (Fig.3).

Fig.1: Assembled

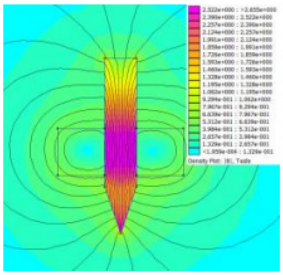

Fig.2: Simulation of the

Fig.3 Woven ribbon and knitted

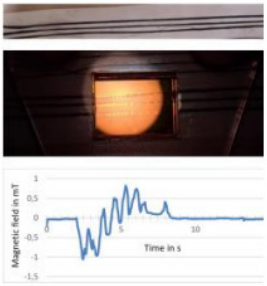

Fig.4 Visualization

A special magnetic tip and an associated power supply were developed for the targeted writing of magnetically encoded information. The following figure shows the magnetizing tool consisting of a coil with a soft magnetic core and the magnetizing tip made of VACOFLUX®: The shape of the magnetizing tip (Fig.1) was optimized by the simulations (Fig.2) in such a way that the highest possible stray field could be generated with the lowest possible lateral expansion. This enabled structures in the sub-mm range to be written into the magnetic textiles.Magneto-optical sensors and systems from Matesy GmbH were used to record the information from the magnetic textile fibers (Fig.4). The principle of magneto-optical visualization is based on the Faraday effect. Here, stray magnetic fields are converted into visible information in the form of a magnetic field image, depending on their strength and orientation. The following figure shows the sensor structure and the imaging principle of our magneto-optical systems: Linearly polarized light is irradiated and the plane of polarization of the irradiated light is rotated in the magneto-optical sensor by the magnetic field generated by the sample. The reflected light is then viewed through a linear polarizing filter, through which the local change in the plane of polarization can be made visible.

RESULTS AND CONCLUSIONS

During the project, various magnetically equipped filaments and textile were produced. Filaments exhibited diameters between 250 µm and 340 µm. The ones containing fraction A get the best results their higher content of magnetic particles. Compared to the filaments containing fraction B, they were not as brittle, possessed a lightly smoother surface and were easier to integrate into fabrics via various manufacturing processes like weaving, knitting and stitching.

During the project, magnetically equipped textiles were produced using the above-mentioned methods. This led to a variety of 2D fabrics and ribbons which could be written on and read out with the technologies developed by Matesy. It is easy to see how the alternating magnetization is visualized over a large area by the magneto-optical readout device. The code could thus also be introduced two-dimensionally into textiles. The readout process takes maximum 1 s. The image below shows a scan using a Hall sensor. The peak-to-valley value of the magnetic coding is approximately 0.7 mT. This shows the high magnetic sensitivity of the magneto-optical sensor technology. In addition, lateral resolution down to the µm-range can be achieved with this method, which means that the feature can also be very small geometrically. The results of the study presented here show that the process for integrating security features into textiles with magnetizable fibers is technically possible. Counterfeiting would be very difficult for counterfeiters because the production of the magnetic fibers, the appropriate magnetization and the detection process present extremely high hurdles. Furtherhin all kinde of digital Information can be stored and read out from the magnetic textile.

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ID170

DESIGN, MANUFACTURE AND TESTING OF 3D LATTICE STRUCTURES WITH POTENTIAL AUXETIC BEHAVIOR AND HIGH RESISTANCE TO DEFORMATION AND IMPACT, ACHIEVED BY POWDER BED FUSION ADDITIVE MANUFACTURING TECHNOLOGIES

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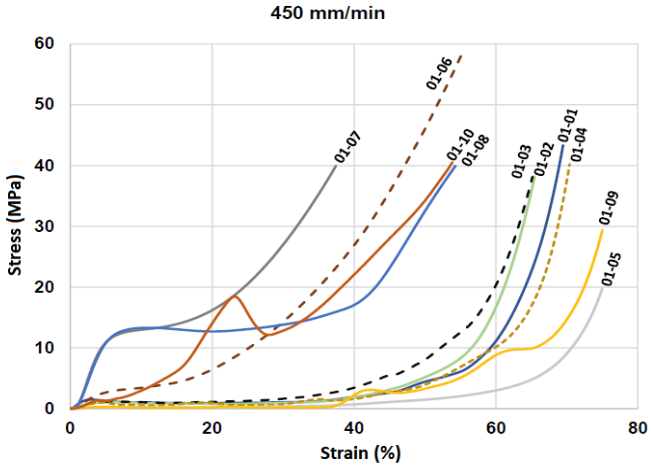
ABSTRACT
This article presents the developments on the design and manufacturing of 3D lattice structures with potential auxetic behaviour, produced in plastic (polyamide) and metallic materials (AlSi10Mg and Ti6Al4V matrixes, adhered to commercial silicon carbide plates), by using additive manufacturing (powder bed fusion technology). Main purpose is the production of lightweight structures that are able to resist compression and impact, and could be used for personal and equipment protection, as well as for industrial applications benefiting from a smart behaviour when structures are submitted to dynamic stress.

INTRODUCTION
Materials and structures presenting auxetic behaviour (characterized by having a negative Poisson's ratio) are currently of high interest in various sectors. This is justified due to some properties they present: greater resistance to penetration or fracture. In recent years, various applications have been explored in fields such as textiles, aerospace, automotive, high-performance equipment for sports activities, biomedicine, or sensors. Traditional technologies impose considerable limitations to the design and manufacturing of this kind of structures, as the required geometries are not manufacturable in practice by this means. In this sense, the proliferation of additive manufacturing technologies has provided new opportunities for the design, development and the empirical assess of these structures.
IDONIAL Technology Center is working in the design and manufacture of novel auxetic structures through a power bed fusion process. The objective is to develop and obtain plastic or metal structures that present the best possible compromise between weight and resistance, in structures subjected to static or dynamic stresses.

RESULTS AND CONCLUSIONS
Various lattice structures with potential auxetic behaviour have been produced. 3D printed polyamide (PA2200), aluminium (AlSi10Mg) and titanium (Ti6Al4V) specimens have been tested, obtaining the following results:



-Polyamide: 10 different lattice structures were designed and 3D printed. Specimens containing re-entrant and chiral structures were subjected to low speed (5 mm/min and 450 mm/min) compressive stresses (up to 145 KN), being able to evaluate the behaviour of the various alternatives. Lattice structures with "hourglass" geometry showed a more marked auxeticity (figure 1).

-Aluminium and titanium: A high-speed impact test was defined. It consists in a solid steel bearing with a diameter of 13 mm and a weight of 9 grams, impact speed ≈ 850 m/s. Specimens were 3D printed, composed of a metallic lattice matrix (115x115x16 mm), additionally provided with a silicon carbide plate (50x50x10 mm), which would act as an impact layer. The specimens with a titanium matrix showed that they withstood the impact in a solvent manner; not so those of aluminium, showing however a high energy absorption rate (>90% impact energy) for the tested design

Figure 2. Left: Composite test specimen (titanium reticular matrix + CSi tile) in the very moment of a high velocity impact (9g, 13 mm solid steel bearing, 864 m/s impact). Right: titanium matrix after impact.

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The authors want to thank the support provided by the General Subdirectorate of Planning, Technology and Innovation of the General Directorate of Armament and Material of the Spanish Ministry of Defense, that finances IMPACT project ("3D Printing of new Materials and Auxetics Structures for the Improvement of Passive Protection Systems". exp: 2020/SP03390102/00000053). In the same way, the authors want to show their gratitude to their collaborators in the IMPACT project, ArcelorMittal, Aciturri and CIDETEC, as well as to University Carlos III from Madrid, for their support in the impact tests carried out.

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ID171

INVESTIGATING THE BLAST RESPONSE OF AUXETIC HELMET INSERTS FOR BLAST PROTECTION

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ABSTRACT

Incorporation of blast protection into a constrained mass-volume envelope is extremely challenging as there is very little space for a material to absorb or dissipate the shockwave. This study looks at the blast mitigation capacity of contemporary and auxetic foam helmet inserts, which are fitted for comfort and standoff purposes to understand the mechanism of transmission of shock. While conventional foams are currently used within this application, auxetics have yet to be tried. It is suspected that auxetics will exhibit superior performance due to the behaviour observed in sandwich panels under similar loading conditions.

INTRODUCTION

Materials and structures presenting auxetic behaviour (characterized by having a negative Poisson's ratio) are The most common weapon seen in recent conflicts is the Improvised Explosive Device (IED) with injuries caused by fragmentation and blast as opposed to ballistic penetration or blunt impact [1], [2]. Improvements in ballistic and impact protection of body armour and helmets has led to increased rates of survival, but shifted the focus of the injuries up to the exposed head and neck [3]. IED blast can cause multiple injuries to vehicles, structures and personnel, with increasing prevalence of Traumatic Brain Injury (TBI) noticed amongst survivors [4]. Relatively low peak overpressures and short positive impulse time durations can result in Blast-Induced Mild TBI (bTBI), manifesting as anxiety, behavioural changes, even loss of fine motor control, symptoms which can often be confused with Post Traumatic Stress Disorder (PTSD) [5]. In contrast to ballistic injuries they are difficult to attribute to a particular event, often presenting much later and difficult to diagnose with confidence [5], [6]. Modern combat helmets have been through several iterations with different variants offering greater protection for impact or ballistic projectiles [7], but incorporating blast protection into the same mass-volume envelope is extremely challenging [8].

Open cell polyurethane foam specimens of varying pores per inch and thicknesses were subjected to blastwaves generated from an air-driven shocktube. Auxetic foams were manufactured via 3D printing using the Fused Deposition Modelling technique. Auxetic and contemporary foams were compared using multiple variables; porosity, thickness, volume, blast mitigation, and relative density of samples. Precursor work looked at unidirectional auxetic foams manufactured from conventional open cell foams using a thermomechanical process

RESULTS AND CONCLUSIONS

Results were mixed, with auxetic structures provisionally showing some reduction in peak overpressure. This has important implications for the reduction of mass in an already constrained mass-volume envelope which is one of the most important drivers for current research in helmet design. Figure 1 shows the movement the

helmeted head undergoes when impacted by a blastwave. The movement of the helmet itself is also thought to be a possible cause of bTBI, as energy is transmitted to the head; first through the chinstrap as the helmet lifts, then causing a whiplash effect as it rotates, and finally by landing back down on the head causing direct mass transfer.

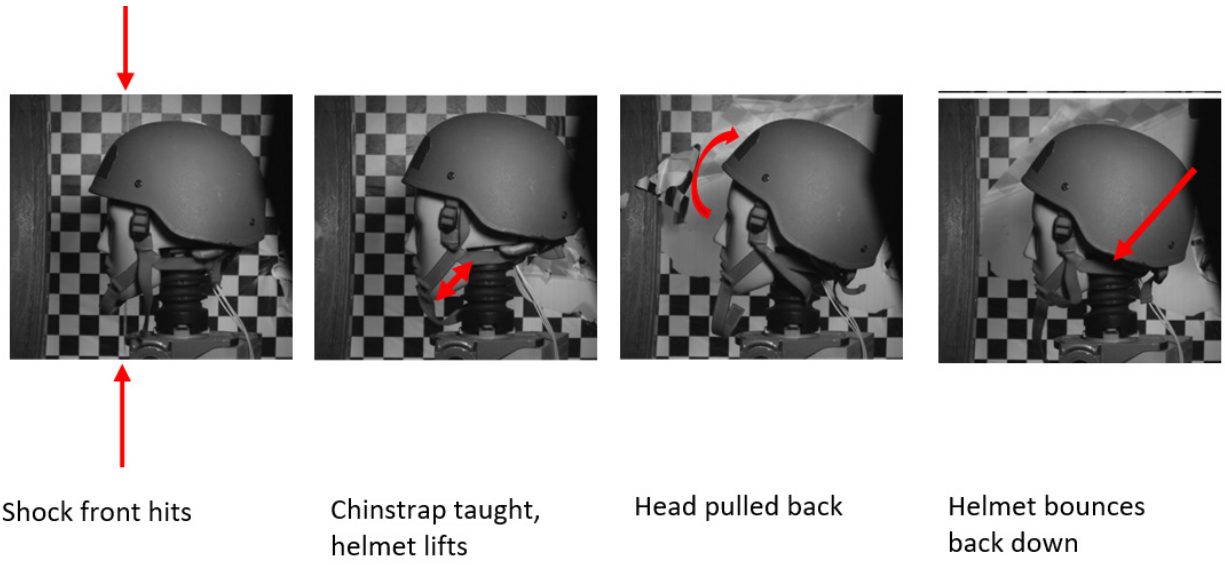

Figure 1 : Movement of the helmet under blastwave impact, captured using high speed video.

Retrofitting a blast mitigation layer to a system that was fundamentally designed for impact and ballistic protection may not be possible, in which case the industry may need to design for purpose in the first instance. If mitigating against all types of insult cannot be achieved, then using different helmet variants for different roles (where possible) may be the most effective solution based on the most likely threat or greatest element of risk in the given situation.

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ID172

ANALYSIS OF ELECTROMAGNETIC SHIELDING MATERIAL CONSISTING OF RECYCLED CARBON FIBRES IN CARDED NONWOVENS

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ABSTRACT

The topic of this work is the utilisation of the electrical conductivity of carbon fibres to influence electromagnetic (EM) fields. For this purpose, recycled carbon fibres were used as a material for the development of components for influencing EM fields (e.g. shielding). The recycled carbon fibres were processed as cost-effectively as possible into a textile semi-finished product, which was then thermally shaped into organic sheets or components. The semi-finished products produced were tested for their EM properties. The produced nonwovens with carbon fibre content were examined and tested for their mechanical and EM properties. For reasons of sustainability and price, recycled carbon fibres were used, as they are comparatively inexpensive and have a good ecological balance. The developed materials can be used for defense applications like shielding interference radiation or radio radiation (eavesdropping protection e.g.).

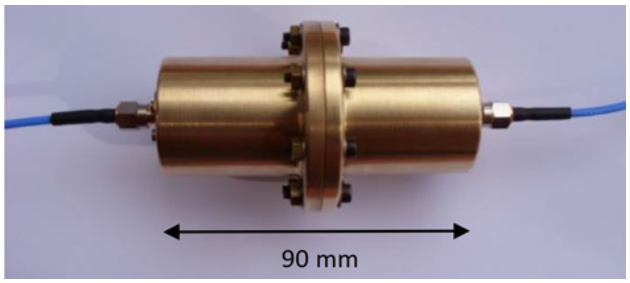
INTRODUCTION

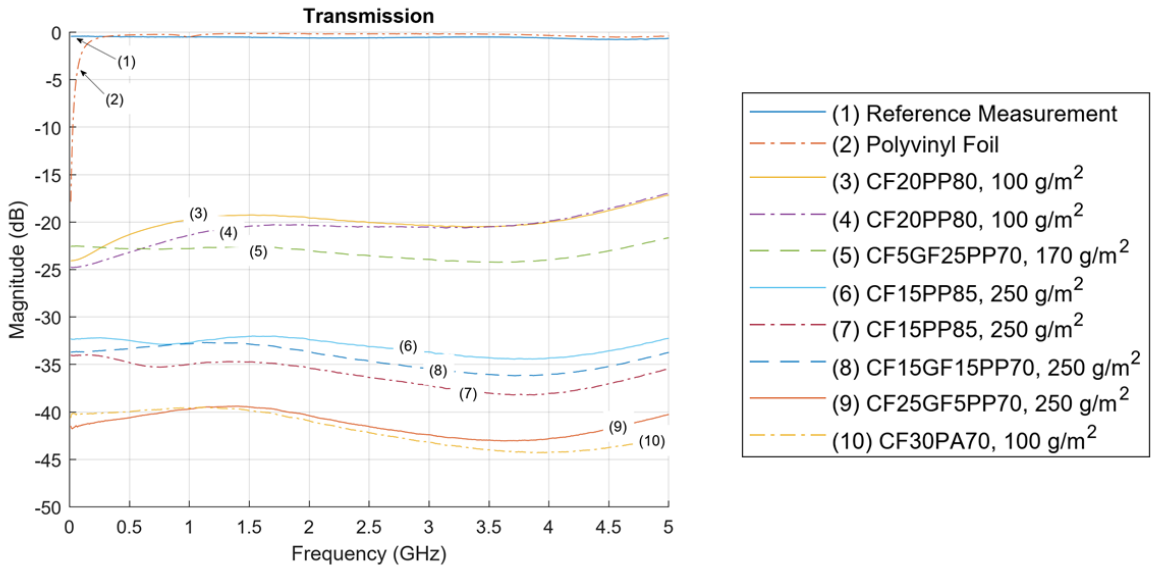
Since recycled carbon fibres (rCF) are no longer an endless filament, they can only be further processed with very few processing methods. A particularly efficient and inexpensive process for producing a textile from rCF is the production of a carded nonwovens. Therefore, rCF were mixed with polypropylene fibres and processed into hybrid nonwovens in a carding process. The hybrid nonwovens afterwards got thermoformed by hotpressing. During the process the polypropylene fibres melt and impregnate the rCF, creating a fibre-matrix composite as they cool down again. Various recycled carbon sheet materials were produced and tested for their EM properties (including the shielding effect) in a test rig that was developed and commissioned as part of the project. The measured values of the transmission and reflection values as well as the dielectric material properties were used for the development of a physical model. For this purpose, based on simple structures, i.e. limited in the number of layers and preferred direction of the fibres, extensive series of measurements were carried out and mathematical relationships are derived from them. The mechanical properties of the sheet materials were also investigated

RESULTS AND CONCLUSIONS

To measure the EM properties of the materials in a frequency range from 100 MHz up to 110 GHz, various measurement rigs were used. Since the application of EM shielding is mainly concentrated on wireless communication up to frequencies of about 5 GHz, this frequency range is emphasised below. A two-part coaxial line was designed and built to measure the shielding properties using transverse EM waves (see picture of the measuring cell). In this measurement setup, the material samples can be mounted in the middle of the coaxial line. The transmission as well as reflection parameters are determined by connecting the coaxial line to a network analyser. Due to the fixed installation of the sample, no angle variation is possible. The coaxial line is designed to ensure

single-mode operation up to a frequency of 5 GHz, i.e. only the transverse EM wave can propagate [Poz11]. The dynamic range of the measurement setup was determined by measuring a metal plate and is higher than 85 dB. Measurement results of the transmission parameters are depicted below for materials with different carbon fibre proportions and areal weights. A measurement without any sample and a measurement of a polyvinyl foil serve as reference.





The measurements show that the developed rCF materials are suitable for shielding even with a low rCF content. The measured attenuation values are in the range of up to 45 dB, which corresponds to a reduction in power of the shielded EM field by a factor of about 31623. Depending on the matrix used, good mechanical mechanical properties can also be achieved without significantly affecting the attenuation. As expected, the attenuation value can be adjusted by the concentration of the carbon fibres embedded in the matrix. A dependence on the polarisation and the frequency cannot be determined in the measurements. This can be explained on the one hand by the arbitrary orientation of the fibres and on the other hand by the fact that no specific fibre length is dominant in the samples. Rather, the fibre length is very mixed which is caused by the manufacturing process of the samples. During the carding process of the recycled carbon fibres, the very thin fibres get mechanically stressed and break off to different lengths.

ACKNOWLEDGMENTS

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ID173

AUXETIC TEXTILE REINFORCED COMPOSITES: CLASSIFICATION, MECHANICAL PROPERTIES AND APPLICATIONS

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ABSTRACT

Auxetic textile reinforced composites are increasingly used in various industries such as aerospace, construction, automotive, medicine, sport, etc. due to their distinctive advantages. This paper reports a review of the mechanical properties and applications of auxetic composites. This review puts an emphasis on auxetic fibres, yarns, and fabrics that can be used to fabricate auxetic composites.

INTRODUCTION

A composite is a material with two or more distinct constituents or phases that have different physical or chemical properties, which are constructed into a complex architecture at micro-, meso-or macro-scale levels [1]. Auxetic composites by virtue of having a negative Poisson's ratio are unique and exhibit high energy absorption, high shear modulus, and high bonding properties [2]. Fibres, yarns, and fabrics can be used to fabricate auxetic composites with intrinsic auxetic behaviour. In addition, the use of auxetic fibres, auxetic yarns or auxetic fabrics as reinforcement can further enhance other properties of composites, such as the fibre pull-out resistance, fracture toughness, and delamination resistance [3].

The benefits of using auxetic fibres and yarns as reinforcement have been demonstrated in references [4-7]. The results reflect that manufacturing composites by using auxetic textiles is a simple and effective way to enhance the mechanical properties of composite materials.

RESULTS AND CONCLUSIONS

Auxetic composites made of fibres and yarns as reinforcement: (i) Auxetic composites can be made of the conventional fibres by using the angle ply method to create laminated composites. The results showed that the auxetic performance depends on the structure of the laminates the auxetic effect still leads to enhanced mechanical properties such as static indentation, low-velocity impact and cyclic fatigue behaviour [8]; (ii) Auxetic fibres are also adopted as the preform for manufacturing auxetic composite laminates. They absorb more energy than conventional composites.

The auxetic composites made of fabric structures: (i) Exhibiting negative Poisson's ratio by using a woven auxetic fabric made of double helical yarn [5]; (ii) Exhibiting excellent impact strength and energy absorption characteristics and considered to be highly suitable for advanced technical applications [9-11].

Applications of auxetic textile reinforced composites: (i) Auxetic fibre reinforced composites, also have enhanced mechanical properties and can be used for potential application in bulletproof vest, cut resistance fabrics, helmets etc. [9, 12, 13]. (ii) Auxetic composites using braided structures have been widely developed for civil engineering applications [10, 11].

Auxetic composites made of fibres, yarns or fabrics are still in the development stage due to their potential applications. This report is the premise for our further studies in the design and production of auxetic composites.

ACKNOWLEDGMENTS

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DEVELOPMENT OF IMPACT RESISTANT COMPOSITE SOLUTION FOR AIRCRAFT FUSELAGE

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ABSTRACT

Advanced composite materials have been increasingly introduced in aircraft structures by replacement of traditional metallic ones. To promote a widespread use of composites, the developed solution must withstand high energy impacts that may arise from uncontained engine rotor failure and other metal debris, in addition to the typical mechanical loads that may be applicable for aircraft skins. This work compares the impact resistant behaviour of several composite solutions against the performance of a sandwich-structured solution applied as an add-on in the lateral fuselage of an aircraft close to the propellers. Five different solutions were evaluated. The best performance was achieved by a fiber metal laminate (FML) solution made of Dyneema® and aluminium face sheets. In fact, the performance of this solution surpasses the commonly applied add-on, since it was able to stop a 28 g metal sphere at 148 m/s (309 J). reducing the thickness by 54.4%, and the areal density by 14.5%.

INTRODUCTION

Composite materials are increasingly used to manufacture aircraft and aeronautic structures due to their excellent mechanical properties and their low density [1]. Actually, all industries in transportation sector are in constant pursuit of material solutions that promote weight savings and, consequently, lower fuel consumption, and reduction on their environmental impact. In addition, the study of medium and high energy impacts on composites used in the aerospace industry is a field of great concern and a very active research topic. Energy absorption is an important and necessary subject in aircraft engineering [2]. This work compares the impact resistant behaviour of few composite solutions against the performance of a Rohacell® foam and aluminium solution applied as an add-on in the lateral fuselage of an aircraft in the vicinity of the propellers. The cannon used for the experimental impact tests is a single action compressed air device with barrel with 108 mm diameter configurable to 3 or 4 meter length. A sabot seals the barrel, and allows the air pressure to be applied, shooting a 28 g steel sphere with 19 mm diameter (used as impactor) at velocities between 100 and 250 m/s.

The impact velocity was measured with a Caldwell G2 ballistic chronograph and a Photron SA5 camera. The residual speed is measured by a Photron AX200 high speed camera mounted behind the target and perpendicular to the projectile trajectory. Non-destructive inspections were performed using a phased array ultrasound scan or radiography depending on the material to be tested. Five solutions were tested, namely (1) a sandwich with aluminium and Rohacell® foam, (2) a fiber metal laminate (FML) of Dyneema® with aluminium, (3) a FML of Kevlar and aluminium, (4) a sandwich made of aluminium and T700 CFRP as face sheets and a core with a foam impregnated with shear thickening fluid, and (5) ceramic tiles bonded to T700 CFRP laminate.

RESULTS AND CONCLUSIONS

The results from the impact tests are shown in Fig. 1. The impact velocity was set for 150 m/s and a good repeatability was found, with a maximum deviation of 2.23%. In addition, for a 320 J impact energy only the FML Dyneema+Aluminium solution resists perforation. Moreover, the FML Kevlar+Alumimium was capable to absorb 87.9% of the impact energy while the Rohacell+Aluminium 63.1%. The sandwich solution with Aluminium + T700 CFRP + a foam impregnated with shear thickening fluid absorbed 59.8 %, whereas the ceramic with T700 presented the worst performance, absorbing 36.5%.

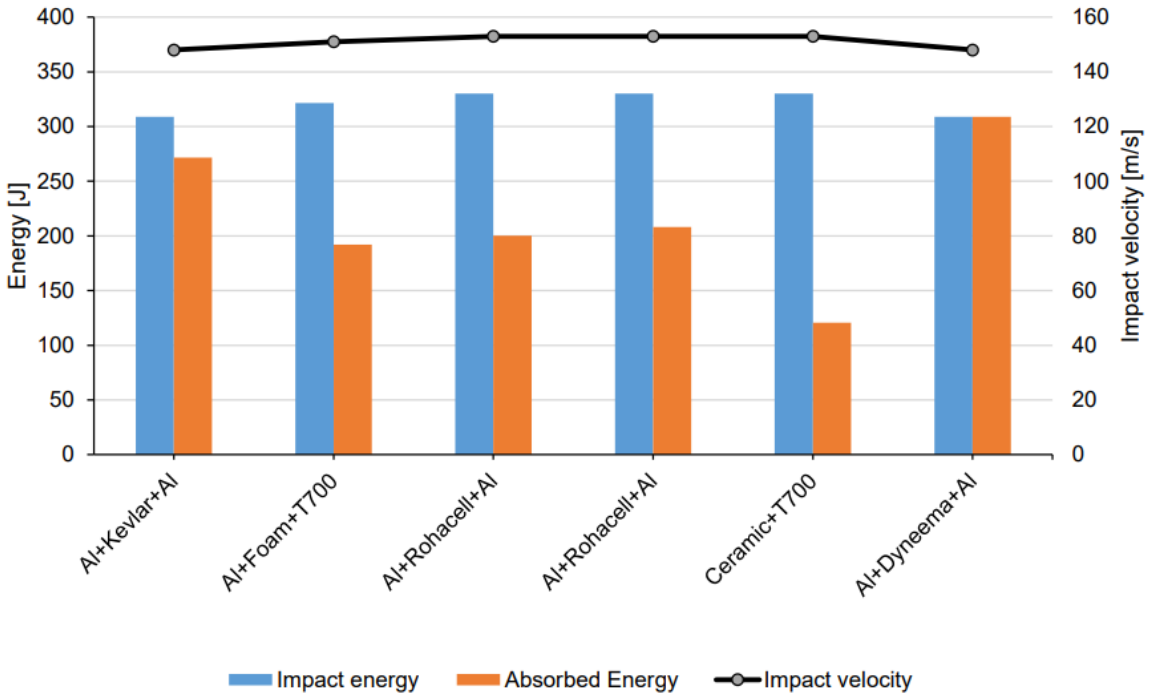

Fig. 1 - Impact tests results.

From all evaluated solutions, the FML made of Dyneema® and aluminium face sheets showed the best performance, exceeding the commonly applied add-on, since it was able to stop a 28 g metal sphere at 148 m/s (309 J). Comparing with the Rohacell® and aluminium solution, the thickness was reduced by 54.4%, and the areal density by 14.5%.

ACKNOWLEDGMENTS

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ID175

INFLUENCE OF TRANSPARENT COMPOSITES MATERIALS PARAMETERS ON THEIR OPTICAL PROPERTIES

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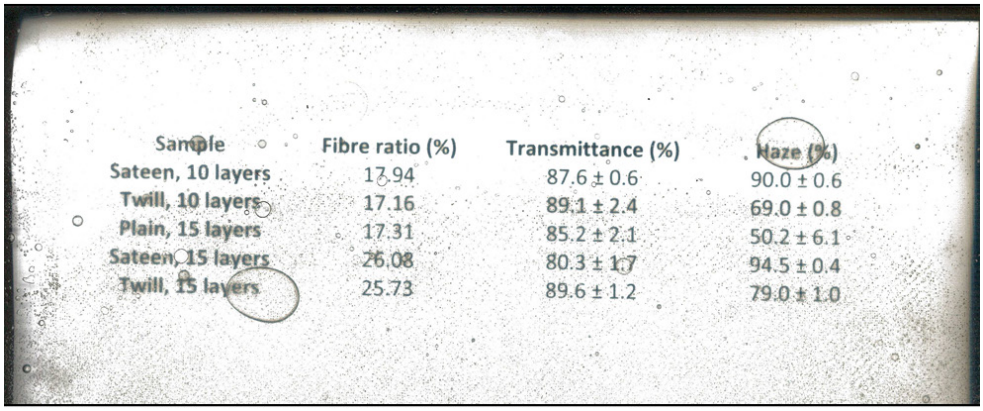
ABSTRACT
Making a transparent composite material opens up new possibilities for use, whether in the field of protection or safety. The notion of transparency is closely linked to the refractive indexes of the components used and to the homogeneity of the obtained structures.

INTRODUCTION
Composite materials are heterogeneous materials obtained by assembling different immiscible components. The design of transparent composite materials in the visible range is a challenge in the field of protection, since it is both to obtain a structure with adequate mechanical properties, while ensuring optimal light transmittance with a low haze. A material is considered as transparent if its transmittance is higher than 70% for a thickness of 1mm (Boulesteix, 2018). Obrien and Wetzel (O'Brien, 2015) elaborate transparent composites from different raw materials such as nylon, polypropylene, acrylic or epoxy. Velez et al. (Velez, 2011) made a glass ribbon/epoxy composite materials and measured a transmittance higher than 80% for 55 % wt. of fibre. Menta et al. (Menta, 2014) elaborate a composite material with 40% wt. of E-glass fibre and epoxy resin. Iba et al. (Iba, 2002) also elaborate a composite with glass fibre and epoxy resin. Iba et al. also highlight the decreasing of the transmittance with the increasing of the fibre ratio.
This study aims to design a transparent composite material and analyse the influence of textile reinforcement structures based on glass fibre integrated into an epoxy resin by impregnation. The performance of these materials has been analysed in terms of optical performance (transmittance, haze) and compared to the rates of fibre. Different composites have been realized, with three reinforcement woven structure (plain, twill and sateen) and different number of layers (5, 10, 15 and 20 layers). Glass fabric and epoxy resin are provided by Hexcel and Sicomin, respectively. Fibre ratio are calculated to allow to compare sample each other. Transmittance and haze are measured on a spectrophotomer Konika Minolta CM 3610a.

RESULTS AND CONCLUSIONS
Figure 1 allow appreciating the transmittance and the haze of our 10 layers twill glass fibre/ epoxy composite. Whatever the number of layers, and the type of woven structure used, the transmittance values are higher than 80%, for fibre ratios between 17 and 26%. Moreover, the increase of the number of layers (and a fortiori the fibre ratio) leads to a decrease of the transmittance for satin, whereas it is not the case for twill. The haze values are heavily influenced by the presence of bubble on some sample. Samples with the least amount of bubble lead to the fewest value of haze.



Sample	Fibre ratio (%)	Transmittance (%)	Haze (%)
Sateen, 10 layers	17.94	87.6 ± 0.6	90.0 ± 0.6
Twill, 10 layers	17.16	89.1 ± 2.4	69.0 ± 0.8
Plain, 15 layers	17.31	85.2 ± 2.1	50.2 ± 6.1
Sateen, 15 layers	26.08	80.3 ± 1.7	94.5 ± 0.4
Twill, 15 layers	25.73	89.6 ± 1.2	79.0 ± 1.0

Fig 1. Digitalization of the 10 layers twill glass fibre/ epoxy composite. Spectrophotometric results (on the table behind the sample) display the good value of transmittance (higher than 80%) for all samples and the dependence of haze to the fibre ratio, due to the bubbles.

If the results obtained (with the samples made to date) do not allow concluding on the influence of weaving pattern (due to the difference of areal density, and the presence of bubbles that disperse the light), transparent composites appear as complex materials that require perfect process control. Current works try to improve the mastery of process by removing bubble and using specific mould to produce the sample to produce sample soon for ballistic testing.

ACKNOWLEDGMENTS

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ID176

THIN FILMS OF OXYGEN-RICH MG BASED ALLOYS WITH TAILORED MICROMORPHOLOGY CHARACTERISTICS BY USING LAYERED DOUBLE HYDROXIDES AS PRECURSORS

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ABSTRACT

The continued advances in Mg alloys development have resulted in increasing their potential insertion into Army systems. However, the applications of Mg alloys are limited by the poor mechanical properties, low corrosion performances and high processing cost. Hence, the fabrication of oxygen-rich Mg-based alloys with controlled textural features is of high interests for structural applications. In this context our work presents the thin films of oxygen-rich Mg-based alloys obtained by controlling the thermal treatment of MgAlLDH and MgFeLDH layered double hydroxides (LDH) matrices. Results indicate that the structural and micromorphology characteristics of Mg alloyed with Al or Fe thin films could be tailored by manipulating the texture and the composition of MgAlLDH and MgFeLDH precursors.

INTRODUCTION

Mg alloys have considerable application potential in aerospace, aircraft or defense applications and are regarded as "the green engineering materials of the 21st century". However, compared to aluminum alloys or steels, inferior mechanical properties and high processing cost limit their applications. It was demonstrated that the mechanical properties of Mg-based alloys are greatly impacted by their micromorphology features while their corrosion is lowered by an oxygen-rich content. In this context, this work presents the synthesis of oxygen-rich Mg alloyed with Al and Fe using the controlled thermal treatment of layered double hydroxides (LDH) precursors. LDH are an important class of layered anionic clays with a structure that is similar to that of the brucite (Mg(OH)2); their controlled calcination gives rise to mixed oxides-based alloys. Furthermore, we obtained the thin films of oxygen-rich Mg-based alloys using MgAlLDH and MgFeLDH as precursors and the structural and micromorphology properties were optimized as a function of the texture and composition of the LDH 2-D matrix. MgAlLDH and MgFeLDH were prepared by using the co-precipitation method, as we previously reported. The controlled thermal treatment of the LDH was used to obtain the derived MgAl and MgFe alloys and their structure were verified by XRD analysis. Further, the thin films of the oxygen-rich Mg-based alloys were obtained by using a laboratory bench spin coater and their micromorphology was studied by FESEM microscopy.

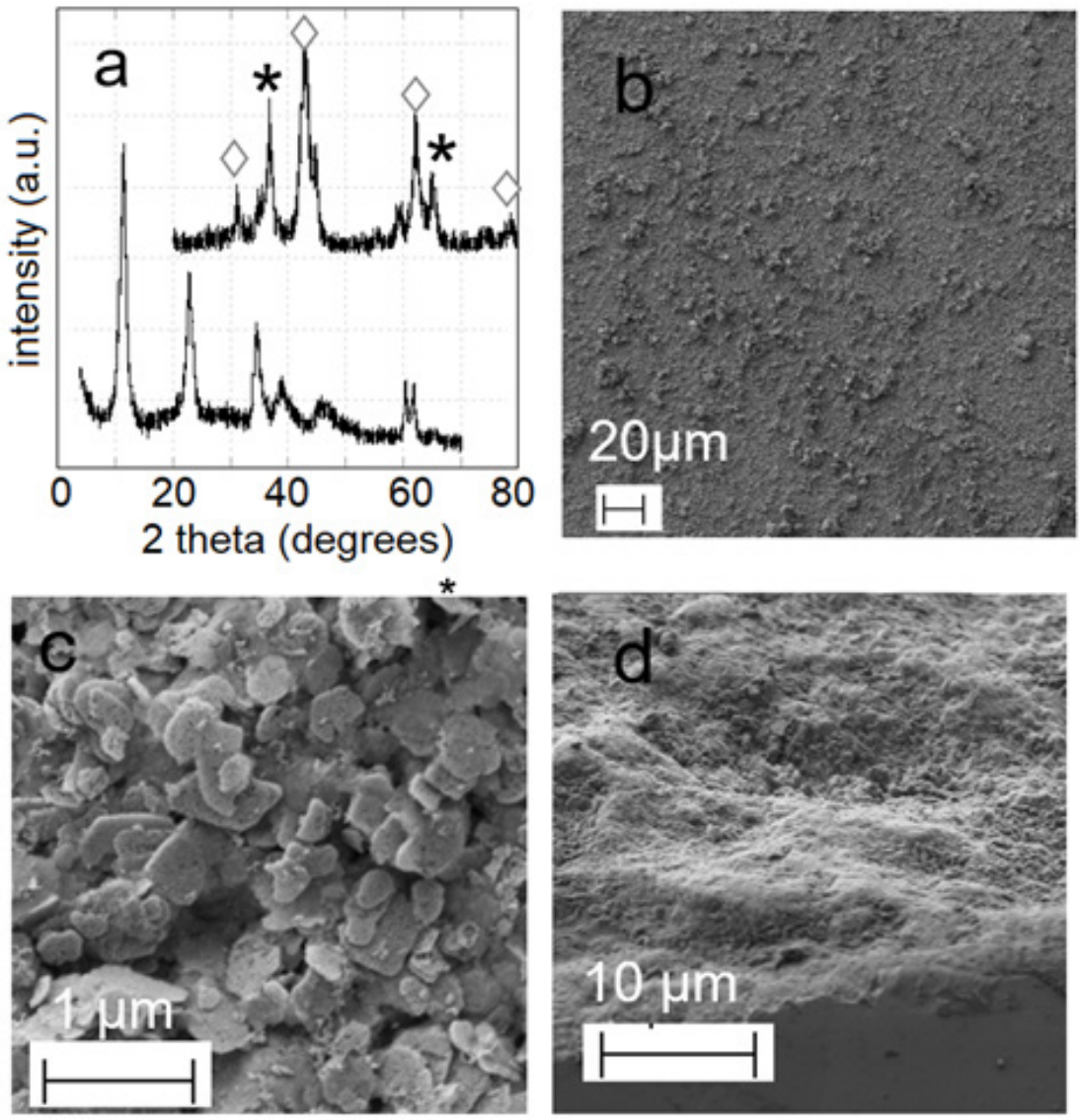

Figure 1 (a) XRD patterns of MgAlLDH and MgAl; (b) SEM image of the thin films of MgAlO (c) higher magnification of SEM image of MgAlO;(c) the SEM image of the thin film of MgFeO.

The results of the XRD analysis (see Fig. 1a) point out the successful synthesis of the LDH precursors. The calcination at 850°C of MgAlLDH destroyed the 2-D layered structure of the LDH giving rise to the well crystalized MgAl alloys identified as MgO (◊) and MgAl2O4 (*). Next, the calcination at 850°C of MgFeLDH produced oxygen- rich MgFe alloys, described by the structural characteristics of MgO/ MgFe2O4. Importantly, we found that the magnesium content in the alloy can be optimized as a function of the Mg/Al and Mg/Fe molar ratio in the LDH precursors. Micromorphology features of the obtained thin films were studied by FESEM analysis. The smoothness of the surfaces of MgAl and MgFe films is confirmed in Fig. 1b and Fig.1d, respectively. Further, Fig.1c demonstrates that the average particles sizes of MgAl film is around 300 nm. It is worthy to note that the average particle sizes are important for establishing the mechanical properties of derived thin films and might be optimized by altering the texture of the LDH precursors.
In this study the thin films of oxygen-rich MgAl and MgFe alloys were successfully fabricated by using the controlled thermal treatment of MgAlLDH and MgFeLDH. Mg content in the alloy and the its oxygen content was optimized by altering Mg/Al and Mg/Fe molar ratio in the LDH layers. Results show that the size and the organization pattern of the LDH's particles established the micromorphology properties of the studied thin films. These point to important differences in the thin films texture although, future experimental work is needed to analyse how the specific micromorphology of the LDH might influence Mg-based alloy thin films mechanical characteristics.

ACKNOWLEDGMENTS

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ID177

A NEW GENERATION TAILORED THERMAL PROTECTION MATERIAL FOR HYPERSONIC BOUNDARY LAYER CONTROL

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ABSTRACT

The current study aims for a new class of porous thermal protection material (TPS) able to withstand the extremely demanding hypersonic flight environment and being applicable for active and passive hypersonic boundary layer control through tailored porosity. The study addresses two of the many challenges to master hypersonic sustained flight; high surface heat fluxes and viscous drag in combination with the need to develop advanced high temperature materials. The study explores different manufacturing techniques to develop a new temperature stable, C/C-SiC material with controllable porosity. The technique will reuse selected components of an existing process to manufacture C/C-SiC, which is a temperature stable and oxidation resistant material used as TPS on hypersonic test vehicles. To generate the porosity a novel approach is chosen by using 3D-reinforcement techniques such as Zpinning, tufting and stitching. The design of the porous TPS will be guided by a methodology leading to optimal porosity parameters to control surface heat flux and vehicle drag by means of active and passive boundary layer control techniques such as mass injection into the boundary layer and boundary layer transition delay by means of ultrasonic absorption of instabilities. Ultimately, the study aims for verification tests at hypersonic flight conditions in the High Enthalpy Shock Tunnel (HEG) at DLR Göttingen.

INTRODUCTION

To master sustained hypersonic flight new high temperature materials need to be developed to cope with the unavoidable high surface heat loads. The extreme heat loads and the aerodynamic loads require the advancement of existing TPS materials. In general, three TPS approaches are used – passive, semi-passive and active. While passive methods are limited in the application time and maximum acceptable temperature, semi-passive techniques are based on surface regression and thus do not provide a constant, high quality outer contour. The latter is especially problematic for applications depending on a high aerodynamic quality such as hypersonic sustained flight (Schneider, 2010). Active methods include convective cooling, film cooling and transpiration cooling. Transpiration cooling has recently been considered the most viable active cooling method for TPS (Uyanna, 2020). It is based on forcing a coolant through a porous wall and into the thermal boundary layer. The latter is thickened leading to a reduction of the temperature gradient in the wall-normal direction and thus to decreasing heat transfer. On its way through the porous structure the coolant absorbs heat providing additional cooling. Another challenge is controlling the hypersonic boundary layer. The enormous heat flux and drag caused by high total temperatures and high skin frictions are largely dominated by the boundary layer. It starts in its laminar state and transitions at some point to a turbulent boundary layer. The state directly affects the viscous drag, the vehicle controllability, the engine inlet performance, the combustor mixing efficiency and the aerodynamic heating. In hypersonic flows, the latter can increase up to 8 times when a boundary layer transitions from laminar to turbulent and thus drastically changes the design requirements of a vehicle (van Driest,

1956). A passive boundary layer control strategy is boundary layer transition delay by means of ultrasonically absorptive surfaces. The concept is applicable at high Mach numbers in conditions at which the so called second-mode instability is found to be the dominant instability leading to transition (Malik, 1989). The instability is of acoustic nature which allows using an ultrasonically absorptive surface to attenuate the instability and thus delay laminar-turbulent transition. The concept was proven theoretically (Malmuth, 1998; Fedorov, 2006) and confirmed experimentally (Fedorov, 2001; Rasheed, 2002; Maslov, 2008). After experimentally proving C/C to be capable of delaying transition, (Wagner, 2013; Wagner, 2014; Wartemann, 2013), a research project was set up to overcome its shortcomings (Wagner, 2019; Dittert, 2018; Wagner, 2018). The main purpose was to develop a C/C-SiC with comparable porosity properties but a greatly improved temperature stability and oxidation resistance, thus, having the potential for use at hypersonic flight conditions (Wagner, 2015). Wind tunnel tests on a conical model in the High Enthalpy Shock Tunnel Göttingen (HEG) proved the effectiveness of the developed porous C/C-SiC and its improved performance (Wagner, 2019). Beyond the success, the study revealed the limited scope of influence on the porosity properties. Furthermore, the low contouring flexibility of the investigated C/C-SiC material turned out to dramatically increase the complexity of large wind tunnel model components, driving the manufacturing costs. The two drawbacks cannot be overcome by further optimizing the C/C-SiC manufacturing process. A complete reconsideration of the manufacturing process is required which is a focus of the proposed project.

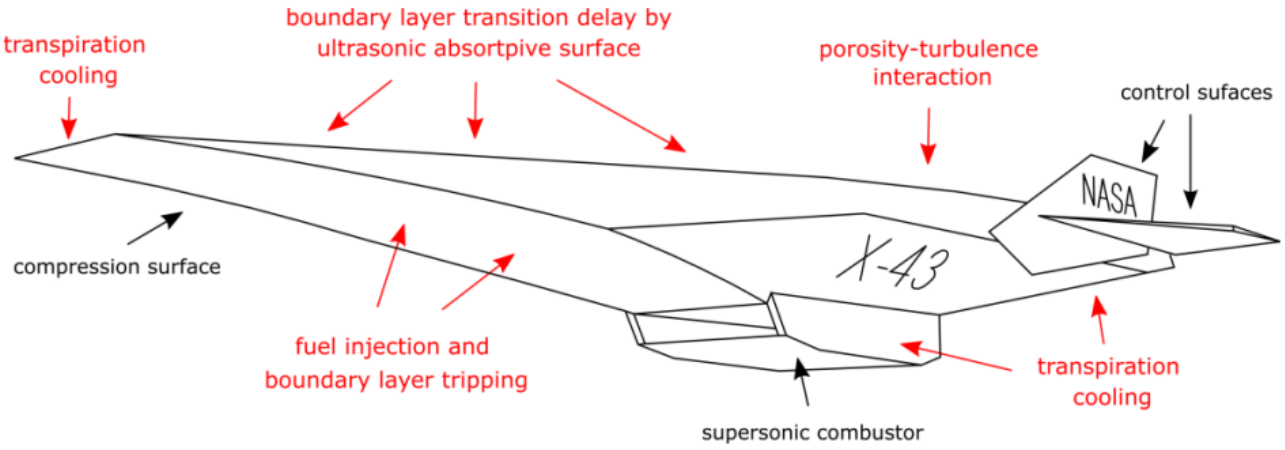

Figure 1: Sketch of the NASA X-43 scramjet vehicle, flight tested in 2004. Multiple conceivable positions along the vehicle are indicated where a porous TPS structure could be beneficially used to control the boundary layer and/or mitigate surface heat loads.

Figure 1 depicts the hypersonic flight test vehicle X-43 which was successfully flight tested in 2004. Around the schematic of the model multiple application scenarios of the proposed porous TPS material are indicated ranging for instance from transpiration cooled leading edges to boundary layer transition delay by ultrasonic absorption or surface fuel injection and boundary layer tripping upstream of a supersonic combustor. The successful development of the proposed TPS material will provide the potential for: 1) lighter hypersonic vehicles due to decreased surface heat loads, 2) decreased combustion chamber/vehicle length due to increased supersonic combustion efficiencies and 3) increased efficiency of control surfaces and increased robustness of intakes by locally changing the properties of the hypersonic boundary layer.

RESULTS AND CONCLUSIONS

The study explores different manufacturing techniques to develop a new temperature stable, C/C-SiC based material with controllable porosity. The technique will reuse selected components of an existing process to manufacture C/C-SiC, which is a temperature stable and oxidation resistant material already used as TPS on hyper-

sonic test vehicles (Turner, 2006; Weihs, 2008). To generate the porosity a novel approach is chosen by using 3D-reinforcement techniques such as Z-pinning, tufting and stitching (Dell'Anno, 2016; Mouritz, 1997).

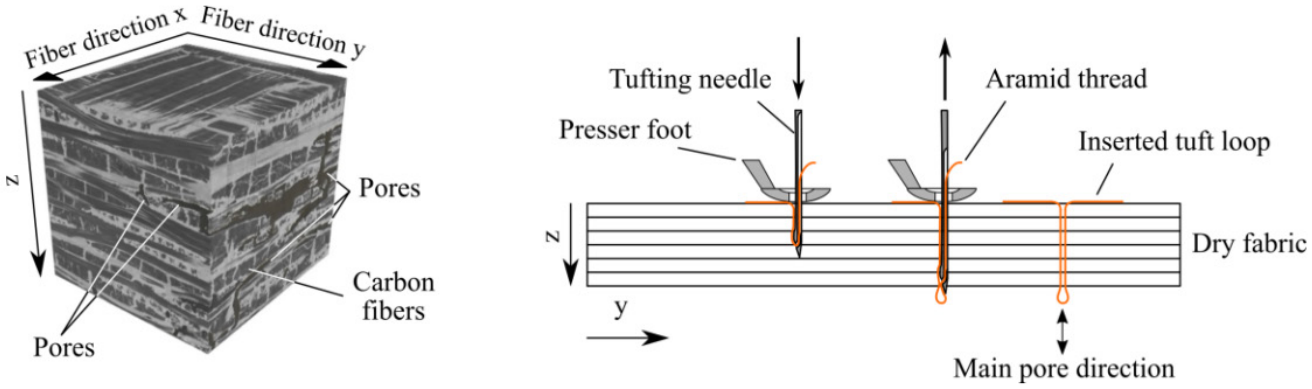

Figure 2: Computer tomography image of existing C/C-SiC with the main pore orientation in the x,y fiber plane (left) and the proposed process realizing a pore orientation perpendicular to the fiber plane (right), adapted from (Dell'Anno, 2016).

As depicted in Figure 2 on the right, these techniques insert an organic thread, perpendicular or at an angle through the fibre plane into the dry fabric preform. In the course of the subsequent manufacturing process the thread will be decomposed thereby defining a cylindrical channel of approximately the former thread size, forming the material porosity. Compared to the existing C/C-SiC this is a major change leading to a number of advantages. As shown in Figure 2 on the left, the randomly formed pores predominantly expand between the fiber layer generating the surface porosity on the side of the depicted cube (x,z and y,z plane). In contrast, the proposed techniques generates the porosity in the (x,y) fiber plane. This allows a greatly improved contouring flexibility of curved components and, at the same time, ensures the pore alignment to be perpendicular (or at a predefined angle) with respect to the surface. The porosity properties are mainly controlled by using appropriate organic thread diameters and techniques with adjustable stitching distances. Figure 3 shows a first computer tomographic image of a C/C-SiC sample in the (z,y) fiber plane. The sample has been manufactured applying a tufting technique in the scope of a first feasibility study. First results
are very promising as can be seen in the figure.

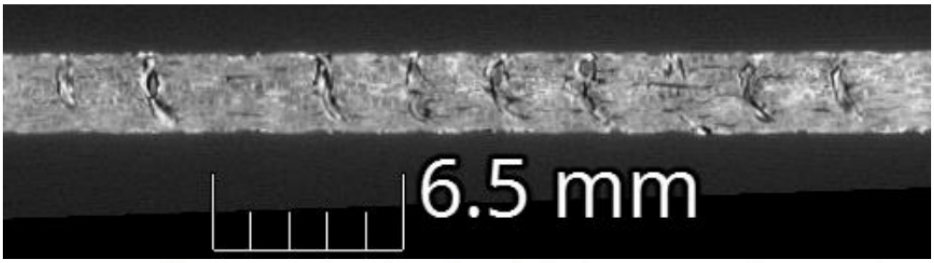

Figure 3: Computer tomographic cross-section view of a tufted micropore tunnel structure in a C/C-SiC sample plate. White colors indicate SiC.

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ID178

A REVIEW ON AUXETIC KNITTED FABRICS: GEOMETRICAL STRUCTURES, AUXETIC PERFORMANCE AND INFLUENCING FACTORS

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ABSTRACT

Knitting technology is one of the most important textile processes. It has advantages of high structural variability, high materials adaptability, high productivity and huge potential for applications in both apparel and industries. The studies have shown that both weft- and warp knitting have been adopted for producing auxetic knitted fabrics based on different auxetic geometrical structures. This paper summarizes research work related to auxetic knitted fabrics. This review puts an emphasis on auxetic knitted structures and mechanisms including weft-knitted auxetic structures and warp-knitted auxetic structures, factors affecting the auxetic performance of these structures and the applications of auxetic knitted structures.

INTRODUCTION

Most materials exhibit a positive Poisson's ratio, they laterally shrink when stretched or expand when compressed. Unlike the conventional, natural auxetic materials and man-made auxetic materials can exhibit a negative Poisson's ratio (NPR) [1-3] such as re-entrant structures, rotating rigid structures, chiral structures and folded structures and other structures. Each auxetic structure exhibit different deformation mechanisms and auxetic performance. Research works on textile materials with NPR including auxetic fibres, auxetic yarns, auxetic fabrics, and auxetic textile reinforced composites [4]. Auxetic fabrics have been produced based on woven and knitted structures [5-15], nonwoven structures [16,17] and braided structures [18,19]. This report comprehensively demonstrates an organizational integration of auxetic knitted structures, mechanisms, performance and influencing factors regarding to their applications.

RESULTS AND CONCLUSIONS

Auxetic materials can be used as medical textiles. A typical example for carrying some wound-healing agent is the smart bandage being made from auxetic filaments. Auxetic fabrics can be used in protective clothing and equipment because of their good energy absorption properties and shape fitting. Protective clothing and equipment are indispensable for some dangerous sports, such as riding, racing and skating, to protect wearers from injuries by impact forces.

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ID179

MECHANICAL BEHAVIOUR OF ADDITIVELY MANUFACTURED MARAGING M300 - 316L STEEL LAMINATED COMPOSITE MATERIAL

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ABSTRACT

This work presents the preliminary results of experimental investigations related to a laminated composite material made from Maraging M300 and 316L SS metal powders with the use of Direct Energy Deposition (DED) Additive Manufacturing technique, namely LENS (Laser Engineered Net Shaped) system. Quasi-static and dynamic shear tests allowed identifying the strain rate sensitivity of proposed material samples as well as the influence of the laminated structure of the material sample on the deformation process.

INTRODUCTION

One of the specific technological possibilities that is available in the case of DED techniques is the possibility to manufacture objects with gradually varying material composition, namely FGM (Functional Gradient Materials) [1]. By using metallic or metallic-ceramic powders as input materials, it is possible to manufacture composites with specific physical and mechanical properties that are impossible to be manufactured with the use of any other technology. With the use of such manufacturing techniques, it is possible to fulfill the complex set of design requirements for modern structural and functional materials.

The main goal of this research is related to technological, microstructural, and mechanical studies of laminated Maraging M300 and 316L SS composite material samples. The authors assumed that a combination of the high strength Maraging M300 steel with the ductility of 316L should combine into a high strength, yet ductile, composite (Fig.1) with very specific deformation behavior. The proposed combination of materials results in specific mechanical properties that can be useful in the fabrication process of elements of new ballistic systems (dedicated to vehicle and critical infrastructure protection).

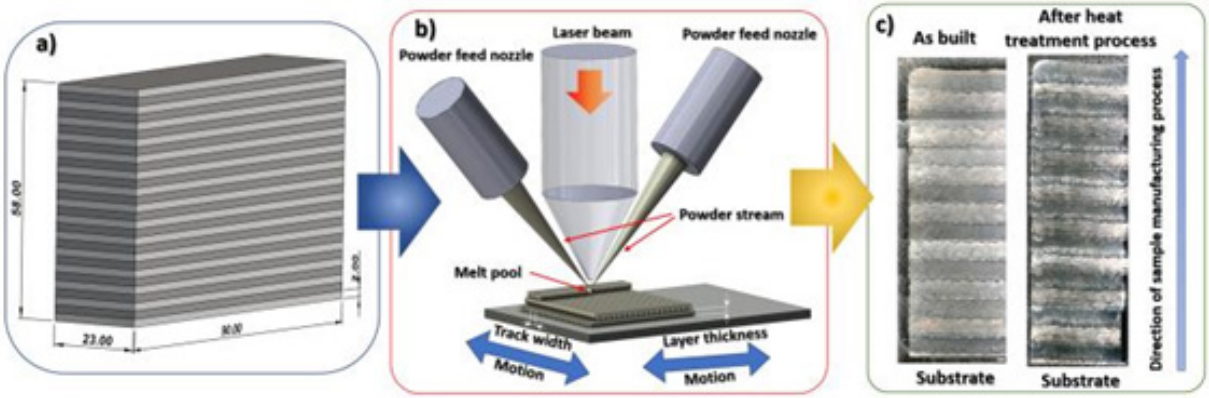

Fig.1. The main scheme of technological process related to the fabrication of M300/316L laminated composite a) 3D CAD model, b) scheme of applied LENS system, c) view of laminated composite

However, apart from the possible application, the combination of materials possessing martensitic and austenitic structures is very interesting just from the cognitive point of view, especially considering the formation of interlayers and compositional and structural gradients.

Laminated material samples composite subjected in these studies were manufactured with the use of LENS® 850R system and later on subjected to two types of heat treatments (ST+AT - solution treatment followed by age treatment and AT –age treatment only).

RESULTS AND CONCLUSIONS

Optical and Scanning Electron Microscopy was used to identify the morphology and presence of material imperfections (cracks, porosity, voids). Microhardness tests were performed to estimate the influence of the proposed heat treatment process on the mechanical properties of the material. The final stage of studies was related to shear tests under quasi-static and dynamic loading conditions with the use of Split Hopkinson pressure bar stand. The shear sample geometry used in the tests was defined based on the shape and geometry proposed by Dorogoy and Rittel [2]. Characteristic results of shear tests are presented in Fig.2.

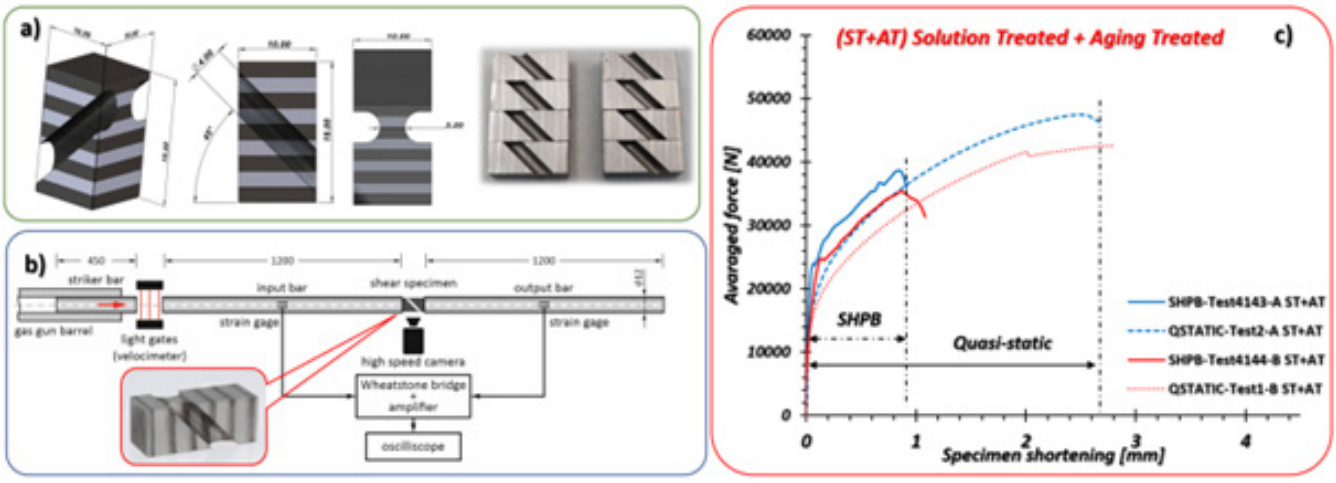

Fig.2 Exemplary results of dynamic shear tests carried out with the use of laminated composite material samples a) – the geometry of the sample, b) – scheme of applied SHPB stand, c) – results of shear tests

Based on the results of shear loading tests, it was found that the selected heat treatment has an effect on the material microstructure and mechanical behavior, which was reflected in the deformation process. Samples subjected to (ST+AT) process were characterized by higher values of strain rate sensitivity. Adopted (AT) heat treatment resulted in a higher deformation range and lower strain rate sensitivity.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Polish Ministry of Science and Higher Education, Centre for Research and Development under research grant No. TECHMATSTRATEG2 /410049/12/NCBR/2019

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ID180
AUXETIC METAMATERIALS FOR IMPACT PROTECTION

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ABSTRACT

This work investigates the impact protection properties of auxetic metamaterial lattices for impact velocities between 40 and 100 m/s, in a 1D impact scenario. After successful previous experiments and simulations with lower impact velocities and nylon samples, we now investigate whether or not the auxetic properties of such metamaterial are retained under higher impact velocities using metal samples. The aim is to use auxetic metamaterials in the design of impact protection concepts. In order to qualitatively illustrate the effect of the auxetic lattice, numerical simulations of the auxetic lattice are compared to a non-auxetic lattice of similar density. The numerical simulations in this extended abstract are performed in Abaqus, and are used to design the test set up that will be used to validate the model.

INTRODUCTION

Auxetic metamaterials---microstructured materials with a negative Poisson ratio---are shown to have superior mechanical properties such as energy absorption due to the fact that the material contracts underneath the impact location (Kolken and Zadpoor, 2017). However, most literature on auxetics for impact protection focusses on low-velocity impact. The goal of this work is to investigate, measure, and model the auxetic behavior under increasingly higher impact velocities. The overall aim of these efforts is to develop a model for auxetic metamaterials that may be used to design impact protection concepts.

RESULTS AND CONCLUSIONS

A numerical experiment was performed in Abaqus/Explicit, where a stainless steel auxetic lattice, and a similar non-auxetic lattice of the material and similar mass (Fig. 1) were subjected to impact of a plunger with the same width as the sample, a weight of ~1.5 kg and an initial velocity of 70 m/s. The stainless steel has a Youngs modulus of 190 GPa, Poisson ratio of 0.265, yield strength of 290 MPa, and density of 8000 kg/m3 , and is modeled as a linear-elastic, ideally plastic material. Both lattices are close in weight, although the nonauxetic lattice is slightly heavier at 264g, compared to the 258g auxetic lattice. Both samples are clamped along the lower two edges as indicated in the figure to mimic the force sensors in the experimental setup. Figure 2 illustrates the numerical prediction of the behavior of both lattices during such an impact scenario. The graph on the left shows the total reaction forces on the bottom two clamped areas. From this graph it is clear that both lattices initially behave like a crumple zone, where the total reaction force on the back remains constant while the lattice is collapsing. After this initial collapsing phase both lattices start to behave differently.

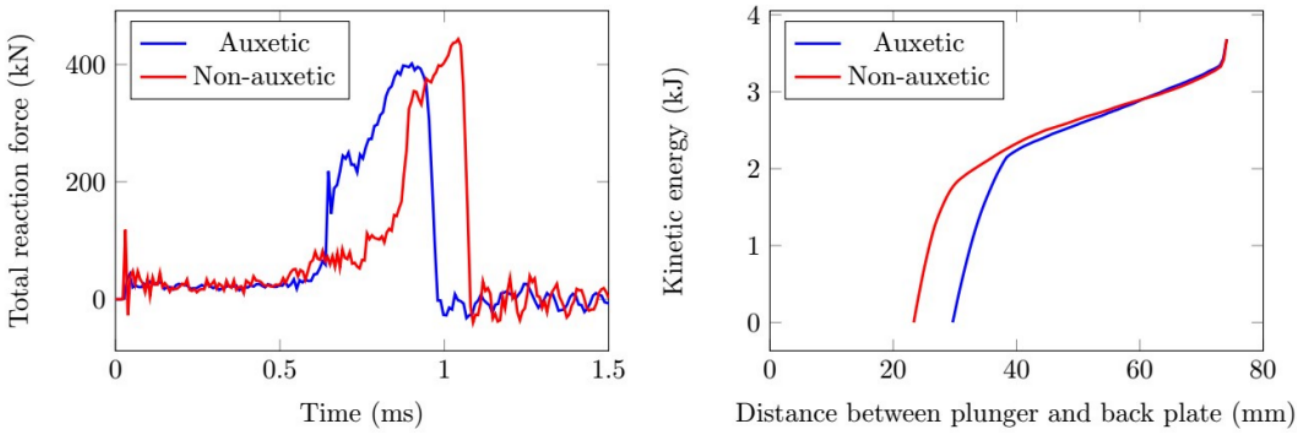

Figure 1: Numerical results of the auxetic and non-auxetic

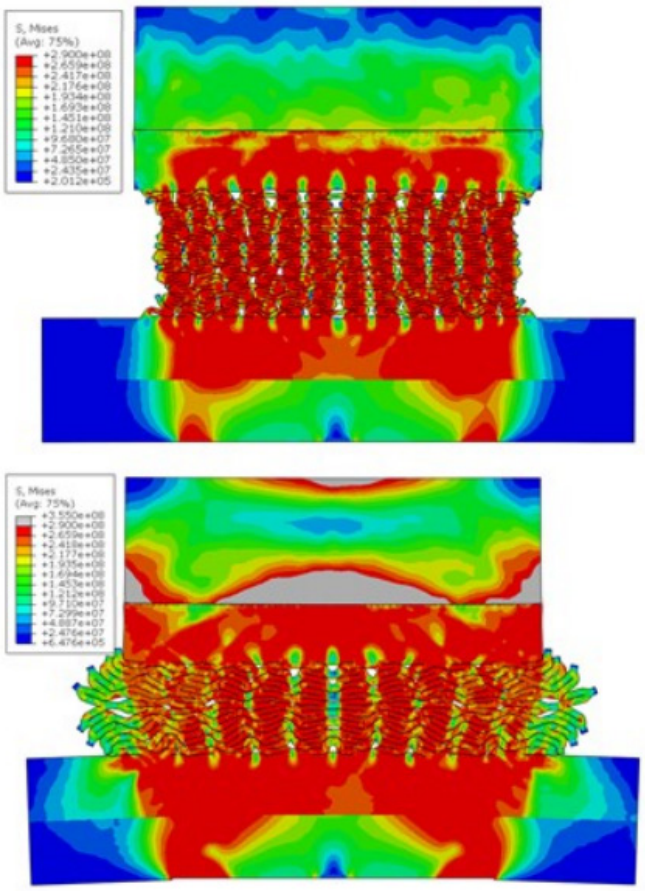

Figure 3: Deformations and stresses of the auxetic (top) and non-auxetic (bottom) samples at the time the peak reaction force for each sample is reached.

Whereas in the auxetic lattice the reaction forces quickly rise as the lattice is collapsed, this rise is initially more gradual for the non-auxetic lattice. However, the peak force is eventually larger for the non-auxetic lattice. This can be attributed to the fact that for the auxetics, all lattice material is folded underneath the impact location, causing it to behave almost like a solid (Fig 3.). This behavior is clearly different from that of the non-auxetic lattice, where the lattice folds outwards. The graphs in Figure 2 on the right show the kinetic energy as a function of the distance between the plunger and the backplate. It is clear that the plunger
is stopped at a larger distance from the back plate in the auxetic lattice compared to the non-auxetic lattice.
In a protection concept, the reduced forces on the backing plate increase the survivability of the subsequent protection layers. As such, an auxetic lattice may provide light-weight protection against impact. Furthermore, as the plunger was stopped at a greater distance from the back plate compared to the non-auxetic lattice, auxetic metamaterials provide a volume reduction compared to other lattices. In conclusion, these
numerical experiments show promising results for the use of auxetics for impact protection against higher velocity impacts. Based on these results, a test set-up is being designed for experimental verification of the model.

ACKNOWLEDGMENTS

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ID181

STUDY OF THE ABSORTION ENERGY OF AUXETIC STRUCTURES WITH NON-NEWTONIAN FLUIDS (STF)

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ABSTRACT

The main aim of the work consisted in comparing the energy absorption capacity of different composites that use auxetic structures impregnated a polyurethane matrice, mixed with an additive named non-Newtonian fluid. The composites structures were developed using high tenacity polyester 3D auxetic structures. The study analysed the energy absorption capacity of each combination produced when compared with standard foams used in vehicle seats subjected to high impacts. To evaluate the performance of the various combinations selected, Dynamic Mechanical Analysis (DMA) and impact absorption tests were carried out.

INTRODUCTION

Several studies have shown the influence that constant impacts and vibrations generated by irregular roads and engines, can lead to chronic problems in back and neck of the driver/passenger. This occurs because the seats do not absorb or dissipate the majority of the impacts and vibrations provoked by the vehicle. To overcome this issue will be necessary to develop a new seat produced based in innovative materials and advance designs capable to absorb and dissipate impacts and vibrations. Recently solutions as, auxetic materials, have being studied to be used in the production of solutions with higher performance [1].

Auxetic materials are defined as solids with a negative Poisson coefficient, which making them, materials with very interesting behaviour for applications that require high energy absorption. Nowadays there are many materials which present auxetic behaviour example of it are materials as foams, metals, ceramics and composites. These types of materials, due to their properties, can be applied on several use areas as military and aerospace industry, among other industries that need impact absorption [2].

In the research area of impact absorption materials, a new generation of it have also gain in the recent year interest of researchers, there are named shear thickness fluid (STF). These materials or composites (suspensions) present high impact absorption capability. This occurs because these materials tend to instantly increase its viscosity when it is subjected to an impact, returning to initial viscosity after the impact. Due to its properties, the STFs were tested in several engineering applications that goes from protective structures to shock/vibration absorbers [3].

RESULTS AND CONCLUSIONS

The results from DMA and energy absorption are shown in Fig. 1 and 2. The absorption tests were performed to a standard sponge used in seats, an auxetic structures, and to different auxetic composites produced using a polyurethane matrice, with STF, and with a mixture of them The DMA results shows that to this type of materials

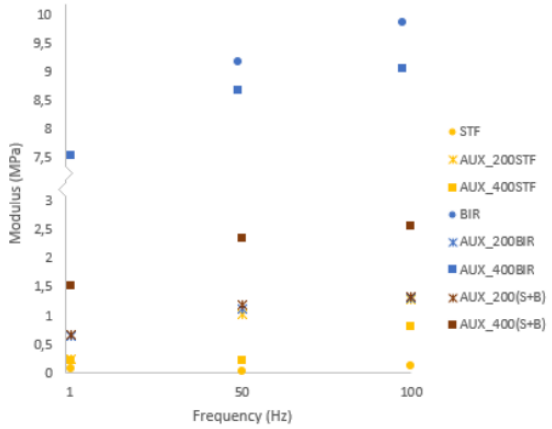

Fig.1 - DMA results.

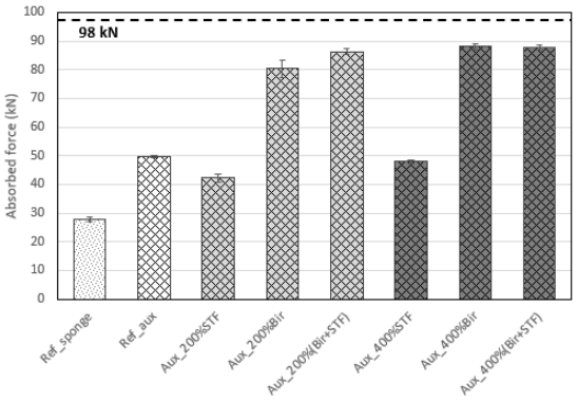

Fig. 2 - Energy absorption test results.

with good absorption capacity, higher the frequency higher the modulus. STF samples presented the lower modulus, but when added to an auxetic structure, modulus increased from 0,12 up to 0,82 MPa (increasing 683%). With the addition of Biresin to the STF in 75:25 ratio, the combination auxetic/Biresin/STF present a modulus up to 2,57 MPa. The combination that presents higher modulus was the Biresin and the Auxetic impregnated with 400 wt% of Biresin.

According to the energy absorption tests, the study shows that an auxetic structure presents better absorption capacity comparing to a reference sponge. The impregnation of the auxetic structure with resin (Biresin) and mixture of resin with STF in 200 and 400 wt%, increases the impact energy absorption capacity of the auxetic structure. Adding STF mixed with resin in a 25:75 relation, increased the energy absorption of the auxetic composite. It is possible to conclude the auxetic structure impregnated with a mixture of Biresin with STF, have the ability to store energy, showing good capability to absorb and dissipate the impact energy.

ACKNOWLEDGMENTS

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ID182

INVESTIGATING THE INFLUENCING FACTORS OF ADDITIVE 3D PRINTED FIBER REINFORCED PROTECTIVE SURFACES FOR PERSONAL SAFETY CLOTHING

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ABSTRACT

This work presents a new development of stab protection equipment with the use of a special 3D printing process. Investigations were carried out with regard to material selection, geometry design and the influence of the textile layer. Different material combinations of filament and imprinted continuous fiber reinforcements and their influencing parameters are investigated, with the target to achieve a K1 class according to VPAM standard (Association of Testing Institutes for Attack Resistant Materials and Structures). The study shows that class K1 can be achieved by the use of the right selection of parameters.

INTRODUCTION

Attacks on police officers, civil employees and security staff are becoming more and more frequent and violent in intensity. Therefore, the personal protective equipment is increasingly important in today's times. In order to minimize the risks seriousness of the injuries for the employees, a stab protection vest is absolutely essential. 3D printing technology has advanced greatly in recent years, offering new possibilities in terms of the wide range of material combinations and the individual design of parts. Initial efforts are being made in the additive manufacture of stab protection surfaces (Johnson 2013; Maidin 2018 & 2019). High-strength printed components manufactured using the Fused Filament Fabrication (FFF) technique from special thermoplastics and incorporated fiber reinforcements (aramid, carbon) are becoming increasingly important in the industry (Sitotaw 2021, Ahrendt 2019). Therefore, this study focuses more deeply on whether and how 3D printing (FFF) fibre reinforcement can be used for the application of textile stitch protection. For this purpose, test objects were developed using 3D CAD software and printed using a special FFF technique. The figure 1 shows a curved sample designed of matrix and incorporated fiber reinforcements. The printed fiber composites were tested in accordance with the VPAM K1 standard (Association of Testing Institutes for Attack Resistant Materials and Structures) - KDIW 2004.

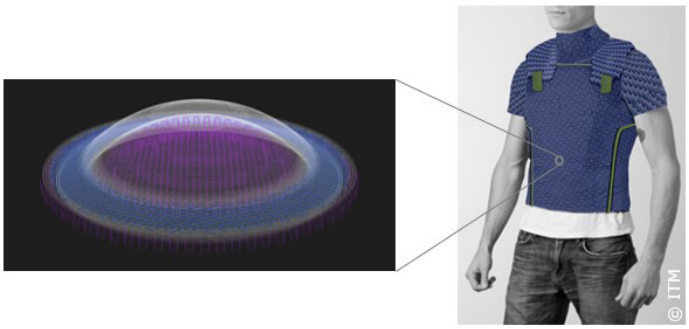

Fig. 1 Round test sample showing incorporated carbon fiber reinforcements (blue) for 3D printing

RESULTS AND CONCLUSIONS

The used material selection of the thermoplastic and the integrated fibre reinforcement (type, quantity and orientation) have a high influence on the penetration depth. Various material combinations (nylon with and without aramid and carbon) were tested, whereby the material combination of nylon with additional carbon (short fibres) and endless fibre reinforcement of carbon proved to have the best resistance to penetration by a knife. In addition, the penetration depth depends on the fibre reinforcement angle (0°,45°,90°,135°) at which the continuous filament is printed. By adjusting the wall thickness and therefore the amount of fibre volume, the maximum penetration depth of 20 mm (according to K1 standard) could be undercut.

The figure 2 shows the knife penetration depth of the standardized knife. Firstly, it can be shown that the standard can be achieved by additive pressure elements and that the type of geometry (round or flat) has no influence on the penetration depth.

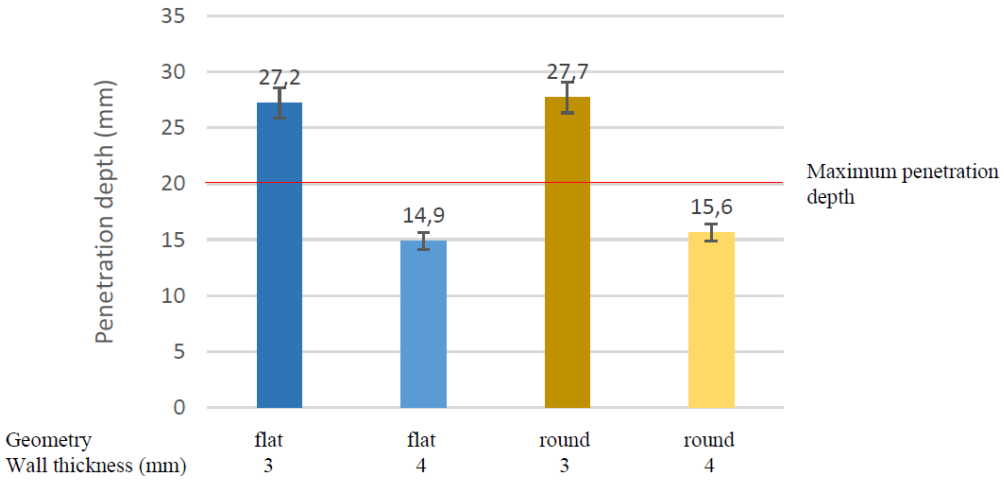

Fig. 2 Effect of the geometry (rund/flat) and wall thickness on the penetration depth of the knife

In summary, the combination of parameters (material combination, wall thickness, fibre volume and orientation) are significant factors. In the future, the advantages of additive manufacturing can also be used for personally made protective clothing. In the future, custom-made protective clothing will increase the wearer's comfort and safety.

ACKNOWLEDGMENTS

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ID183

INVESTIGATION ON THERMAL PROPERTIES OF 3D WEFT KNITTED FABRICS

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ABSTRACT

The main objective of this work was to develop new 3D knitted structures combined from three layers, knitted by flat weft knitting machines, for thermal insulation and investigate dynamic of the heat transfer through these fabrics. Wool, cotton, and multifilament polyester (PES) yarns were used to knit the projected samples in separate layers of the 3D fabrics. All 9 knitted 3D samples had the same structure but different raw materials combinations in layers. All the newly developed 3D weft knitted fabrics show thermal insulation. After one hour of observation, the temperature on the outer layer of all tested fabrics does not reached the temperature of the heated plate. The best result showed the fabric whose outer layers are knitted from woolen yarns and the inner layer – from polyester filament yarns.

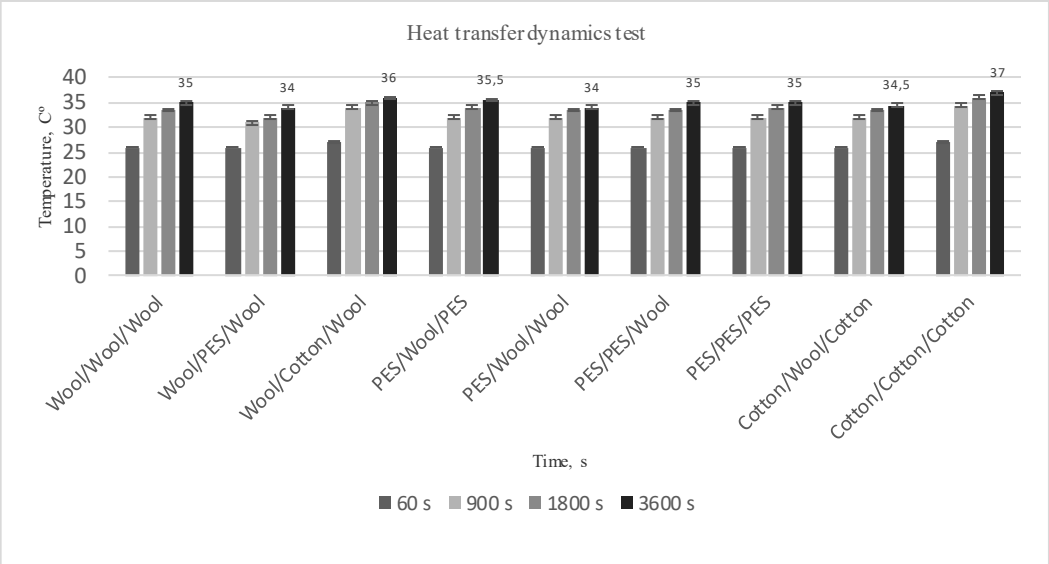
INTRODUCTION

The proper comfort characteristics of the fabrics increase the significance of attire and are gaining more interest in the global market (Yang, 2019). Physiological comfort is the effect of many coefficients related to the human body, climatic conditions, environment, and clothing (Puszkarz, 2018). Good thermal insulation is a primary property of winter clothing and can be achieved by using double- or multi-layered knitted fabrics (Bivainyte, 2012). Many researchers have been carried out in order to analyse and evaluate the effect of the fiber type and fabric structure on the thermal comfort of woven and knitted fabrics. Studies of thermal wearing tests showed that fabric properties influence the subjective wearing sensations and the microclimate inside the clothing. It was found that the thermal comfort of the textile fabric was influenced by the raw material, properties of yarns, thickness, water absorption properties, and thermal conductivity of the fabric (Bivainyte, 2012).

Based on the results of previous research, designed and knitted on the E12 gauge flat double needle-bed knitting machine SES 122-S, 3D samples of three layers – two outer layers and inner layer made of long floats between two outer layers and infixed into these layers by using tucks. The main goal was to find the best variant of the raw material composition in different layers of fabrics used for thermal insulation. The heat exchange dependence on the structure and raw material of knitted fabrics was investigated using the IG/ISOC (Giuliani Technologies, Italy) attachment designed for investigation of the heat insulation. The plate was heated up to 40℃, and this temperature was maintained during the experiment. The changes of temperature were observed during 3600 s (1 h) period. Also, the thickness of all samples and the angle of the inner layer tucks with the outer layer were measured

RESULTS AND CONCLUSIONS

The results from the heat exchange dynamic tests are shown in Fig. 1. As it can be seen from the results presented in Figure 1, after 1-h observation, the best result was seen in the fabrics Wool/Wool/Wool, Wool/PES/Wool, PES/Wool/Wool and Cotton/Wool/Cotton. During 1 h, the temperature of the upper layer (outward side) of these fabrics was increased from initial 26℃ up to 34℃. The best thermal insulation property has the fabric outer layers which were knitted from woolen yarns, and the inner layer was knitted from polyester filament yarn.



Whereas the correlation between sample thickness and heat exchange dynamics is insignificant, such a result can be explained by the fact that good thermal insulation is a characteristic of woolen fabrics and multifilament polyester tucks gives the fabric additional rigidity and maintain the dimensional form of the multi-layered structure, thus ensuring more air gaps between the yarns. The relation between the tuck angle of the inner layer with the outer layer and the dynamics of heat exchange is also not significant. Therefore, it can be concluded that the dynamics of heat exchange in this study was influenced mostly by raw materials properties and the combinations of raw materials used for the individual layers.

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ID184

EFFECT OF RADIATION-ASSISTED CURE ON FUNCTIONAL PROPERTIES OF CARBON RESIN COMPOSITES

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ABSTRACT

It is long documented that it is possible to enhance polymers' thermal and mechanical properties by exposing them to radiation. This study aims to assess if this is possible on carbon-based composites, with potential application in aeronautics, through controlled exposition to gamma radiation. The material was systematically subjected to gamma radiation doses in different stages of the resin's cure to evaluate how the radiation-assisted cured composite material properties compare to post-cure irradiation treatment

INTRODUCTION

The advent of composite materials that combine stiff fibers, such as carbon fiber, with highperformance polymer resins has been helping to overcome major difficulties posed by the complex design of modern aircraft. As a result, fiber-reinforced polymer composite materials are becoming the primary material for aircraft construction (Mangalgiri, 1999). Modern military aircraft have over 30% of their structural weight built-in advanced composites (wings, propellers, control surfaces and radome) while modern civil aircraft already have more than 50% (Alemour et al., 2019). The scientific community has recognized that ionizing radiation can modify polymers' physical and chemical properties. For example, it has been shown that radiation has the power to change a polymer's molecular structure by promoting polymer crosslinking (Drobny, 2012). When ionizing radiation interacts with a polymer, its energy is absorbed, and radicals are produced, initiating various chemical reactions, such as:

• Crosslinking, where polymer chains are connected, formatting a network;

• Chain scission, where the molecular weight of the polymer is reduced.

Crosslinking between polymer chains improves some of the material's mechanical and thermal properties; unfortunately, gamma rays also promote chain scission. These reactions always coexist under radiation; nevertheless, depending on the radiation dose, one tends to be predominant. Radiation-assisted cure can accelerate the curing process and promote crosslinking in an earlier stage when the polymer chains are still developing (Makuuchi & Cheng, 2011).

RESULTS AND CONCLUSIONS

The laminates used for mechanical test specimens were fabricated according to ISO 527- 4/2020 - Plastics – Determination of tensile properties. The laminates were fabricated with a 3K carbon mat with 160 g.m-2 and a two-component resin SR8200 with an SD7206 hardener from Sicomin©. The tab reinforcements added before curing were made from a 1K carbon mat with 90 g.m-2.

A preliminary study was conducted to assess the optimal doses of gamma radiation regarding its effect on the temperature of degradation of the prepared composite. This study was performed through thermogravimetric analysis (TGA) of composite samples fully cured, irradiated with different doses of gamma radiation (1.5kGy to 10kGy). Irradiations were done in an experimental cobalt-60 gamma irradiator (PRECISA 22 at C2TN/IST), under an inert atmosphere, at an average dose rate of 0,4 kGy.h-1.

TGA curves show that the effect of gamma irradiation on the increment of the degradation temperature of the composite is more pronounced in the range between 4 and 7 kGy, with its maximum effect at 6 kGy. So, this optimal range was selected to test the composite specimens under 3 irradiation methodologies: i) Post-cure irradiation, where the specimens were irradiated after the resin is fully cured (>10 days); ii) Irradiation after 2 days of curing; iii) Irradiation after 10 days of curing. The specimens were evaluated through tensile and flexural testing, TGA, and Differential Scanning Calorimetry (DSC). Young's modulus and flexural modulus evolutions are represented in Figure 1 and the degradation and glass transition temperatures in Figure 2.

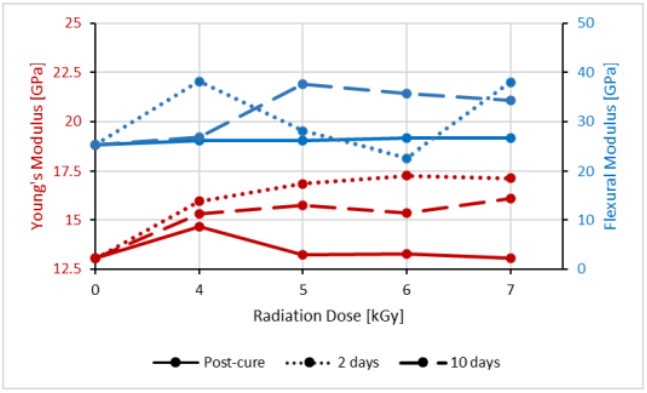

Figure 1 - Evolution of the flexural and Young's moduli at different doses through 3 irradiation methodologies.

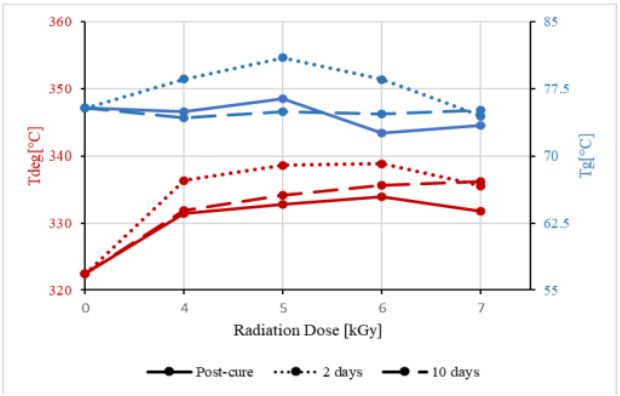

Figure 2 - Evolution of the glass transition and degradation temperatures at different doses through 3 irradiation methodologies.

This study shows that the glass transition and degradation temperatures improve compared to non-irradiated specimens, e.g., the Tdeg at 6kGy after 2 days is 338.9°C (improvement of 16.5 °C). It is also observed an increase in Young's modulus for all doses and methodologies compared to non-irradiated specimens (the maximum improvement registered is 32.36%).Flexural modulus has a similar improvement at all doses but 5 and 6 kGy when irradiated after 2 days (the maximum improvement registered is 51.23%). Both the irradiation after 2 days and after 10 days show higher values in the mechanical and thermal properties, which indicates that the radiation-assisted cure can provide better characteristics to the composite material when compared to the post-cure irradiation.

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ID185

AUXETIC PERFORMANCE OF WOVEN FABRICS AND IMPACT PROPERTIES OF ITS COMPOSITES WITH VARIED FABRIC CONSTRUCTION PARAMETERS

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ABSTRACT

Auxetic fabric and its composites are of great importance due to its improved impact and auxetic performance. In this research, 3D Auxetic fabric samples were produced on semi-automatic sample loom. Five 3D woven samples were developed by varying the construction parameters of fabric. The picks per inch (PPI) and ends per inch (EPI) of the 3D fabric was varied. Cotton yarn was used as warp and weft while the Jute yarn was used as a binding yarn. The tensile load was applied using a locally developed setup and poisson's ratio was calculated. The result showed that by changing the construction parameters the result shows a significant change in auxetic property. Similarly, these fabric reinforcements were converted to composites using compression molding technique by applying epoxy resin as matrix. These composites were tested for impact performance using drop weight test. In this way the optimized samples were identified for improved low velocity impact performance.

INTRODUCTION

In the last few years, various geometrical structures have been built and tested to realize their mechanical properties showing auxetic behavior. Such structures include re-entrant, rotation, nodule and fibril, chiral model etc. These auxetic structures can be used for the development of various auxetic fabric (Hu and Zulifqar, 2020). In a study, alternative arrangement of 4-ply auxetic yarns with S- and Z-twist in a woven fabric were developed showing high negative Poisson ratio (NPR). The higher single-stiff auxetic yarn modulus results in an increased NPR behavior, where as a finer soft auxetic yarn does not produce such an auxetic effect (Ng and Hu, 2018).
In this research, a proven 3D multilayer woven fabric design with improved auxetic effect was produced as shown in Fig. 1 by using semi-automatic loom and effect of change in ends/inch and picks/inch on auxeticity has been investigated using thickness tester and drop weight test.

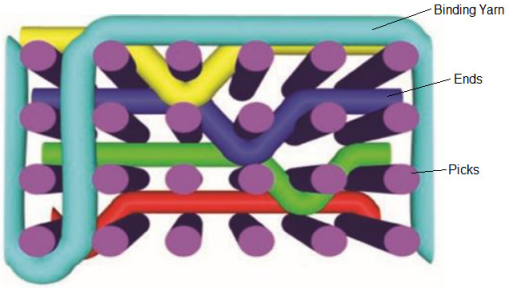

Fig. 1 Design adopted and developed to study the effect

RESULTS AND CONCLUSIONS

All the structures studied in this paper, showed auxetic nature as shown in the Table 1. The study shows as the ends/inch increase the Poisson's ratio increases as there are more ends to push the picks to produce Poisson effect. Similarly, as the picks/inch increase the Poisson's ratio increase as there are more threads pushed by the binding yarn during an axial load. The drop weight test of composites show that more the Poisson's ratio the higher the energy absorption and impact strength as shown in Fig. 2.

Table 1 Poisson's ratio results of developed samples

Samples	Transverse Strain (mm)	Axial Strain (mm)	Poisson's ratio
S1 (30EPI, 30PPI)	0.35	0.33	-1.06
S2 (30EPI, 40PPI)	0.63	0.43	-1.46
S3 (30EPI, 50PPI)	0.72	0.45	-1.60
S4 (24EPI, 30PPI)	0.23	0.23	-0.97
S5 (30PPI, 30PPI)	0.35	0.33	-1.06
S6 (36PPI, 30PPI)	0.20	0.50	-0.40

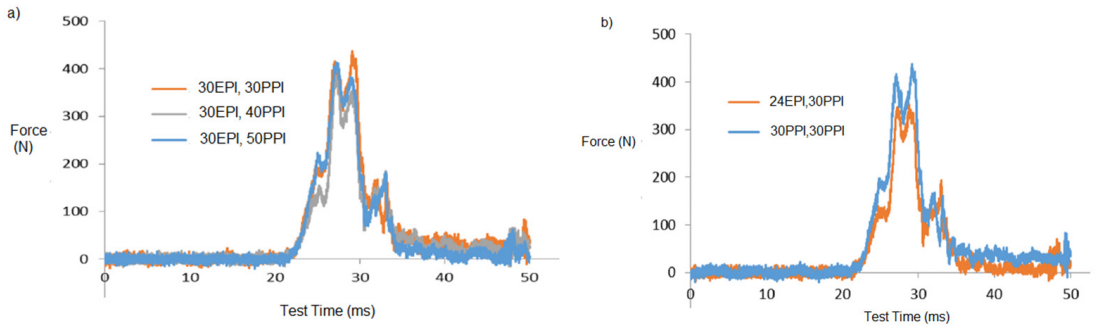

Fig. 2 Drop weight impact test results

This study shows that there are substantial differences on the low velocity drop weight impact and auxetic properties studied. Further tests should be performed in order to analyze other detailed mechanical properties.

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ID186

NUMERICAL ANALYSIS OF THE COMPOSITE PENETRATION BY 9X19 MM BULLETIN WITH THE USE OF THE MCT METHOD

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ABSTRACT

The paper presents modifications of the Multicontinuum Theory (MCT) theory based on the limit deformation. The ultimate deformation parameter was introduced as a description of the structure discontinuity for the considered composite. The layered composite based on aramid filament (Twaron) and a polymer matrix as epoxy resin was considered. The quick-changing phenomenon loaded with the 9 x 19 mm FMJ Parabellum projectile was considered.

INTRODUCTION

Numerical modeling of the fabric arrangement in the form of rigid panels is a challenge that must be precisely defined to obtain the correct results assumed in the numerical model. Due to the specific structure, aramid fabrics are characterized by a favorable combination of very good mechanical properties (high strength, flexibility, ability to absorb energy, impact resistance) and low weight. In ballistic fabrics, it should be emphasized that it must be resistant to impact load [1,2], namely it must have appropriate fiber properties, fabric properties such as weave, number of layers, etc. Considering the number and complexity of mechanisms influencing the behavior of fabrics in the conditions of shelling a projectile, a thorough analysis and understanding of the phenomenon of a projectile hitting woven layers with the use of experimental methods is burdensome [3]. Accurate numerical mapping of the impact of a projectile on a ballistic packet containing woven layers is a major challenge. In this case, it is necessary to consider the mechanisms of absorption and dissipation of projectile energy resulting from the interaction of fabric components at the lowest level of the structure [4,5]. For this reason, it is necessary to search for new simplified methods of modeling the phenomenon of a projectile hitting ballistic packets containing fabric layers, which would ensure an appropriate balance between the level of adopted simplifications and the accuracy of the obtained results. The aim of the article is to present such a numerical modeling method using MCT and experimentally validated using 9 mm Full Metal Jacket Parabellum ammunition at a speed of 356 m/s.

RESULTS AND CONCLUSIONS

The numerical analysis was performed in the ABAQUS software using the Explicit type calculations. In the first part, a two-step homogenization of parameters was carried out to determine the material constants of the analyzed system. For the second system, the fibers themselves were homogenized, while the parameters for the fabric-warp system were considered as separate systems using the modified MCT method. The modification consisted in replacing the stresses of the centers with deformations and introducing the limit deformation as a parameter determining the discontinuity of the structure.

Rys. 1. Przykładowy wynik symulacji numerycznej

A comparative analysis of volumetric modeling with the use of two-stage homogenization and simulation based on the limit deformation showed differences in the obtained results. In the first case, despite the anisotropy of the system, the test sample showed high stiffness compared to the second system.

ACKNOWLEDGMENTS

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ID187

CARBON DIOXIDE REMOVAL FROM CONFINED SPACES BY MEMBRANE CONTACTOR ABSORPTION

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ABSTRACT
Gas-liquid membrane contactor absorption (GLMCA) combined with alkaline saline water as liquid absorbent seems to be a reasonable choice for CO2 removal in confined space, eliminating the regeneration step and saving energy and space. GLCMA presented low specific energy (0.18 kJ/m3) when applied to guarantee safety CO2 levels in confined space.

INTRODUCTION
Confined spaces are characterized by not having natural atmosphere regeneration. Crew respiration consumes oxygen and produces carbon dioxide, which is the most important pollutant abord. Column absorption uses monoethanolamine (MEA) to absorb CO2 from gas stream and is the most applied process throughout the world (Row 2017). This process has many problems, such as ammonia release and highly toxicity, though. Pressure Swing Adsorption (PSA) uses high pressure and low temperature to fix CO2 on mesoporous support, such as zeolites. This process has low efficiencies. Alternative processes, such as solid amines, cryogenic distillation, and membrane processes, are being developed in order to replace conventional ones (Zhan et al. 2020, 2021).
CO2 removal using gas-liquid membrane contactor absorption (GLMCA) with alkaline saline water as liquid absorbent, exploring the benefits of seawater pH levels. GLMCA emerge as an alternative process since it combines advantages of absorption processes such as solvent selectivity, with the large contact area per unit volume provided by a typical porous hollow fiber membrane permeator. The membrane is a phase contactor, with pore size small enough so that capillary forces predominate and therefore phase mixing and dispersion is totally avoided

RESULTS AND CONCLUSIONS
As depicted at Figure 10, the CO2 flux decreased when temperature increased, for same liquid flow rate. This effect can be attributed to the decrease of gas solubility in liquid due to temperature increase. CO2 solubility is 45.6, 33.5 and 25.8 mol/m3.bar at 10, 20 and 30ºC, respectively, and 2 bar. the increase of the liquid flow rate promotes an increase of CO2 flux. It is important to notice that the increase in flow rate outweighs the decrease of CO2 solubility in liquid due to temperature increase.

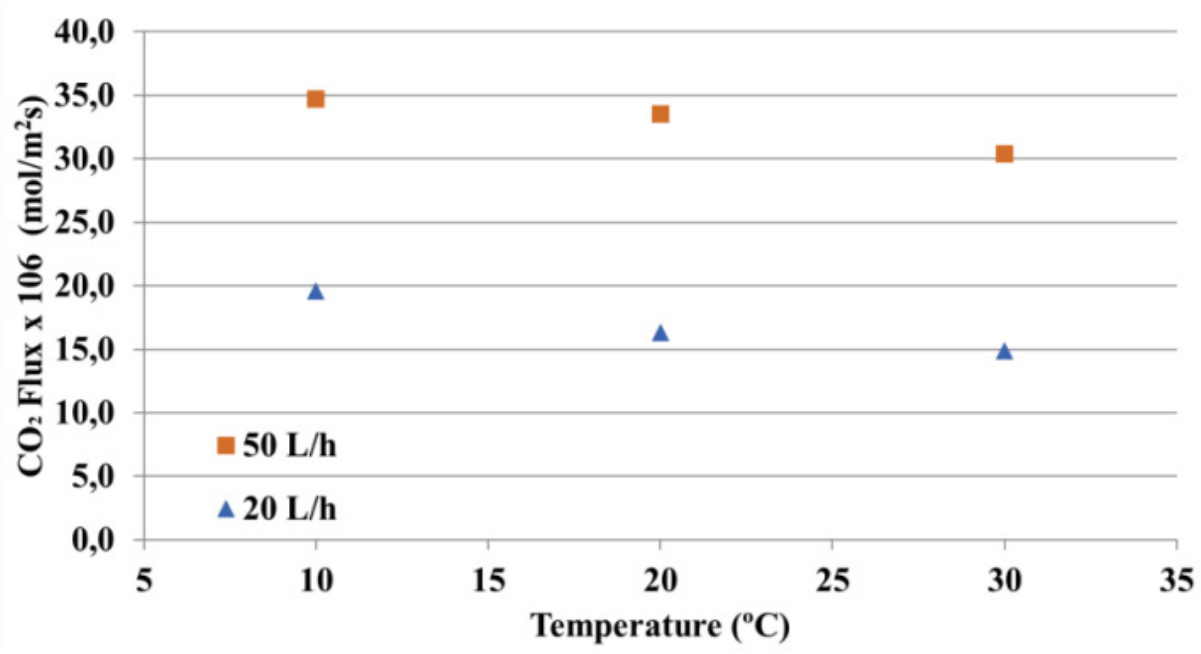

Fig.1 Effect of liquid flow rate and temperature on CO2 flux: model predictions and experimental data (Feed 10% CO2 / N2; Qg = 100 mL/min; Pg = 2 bar, Pl =Pg + 0.2 bar).

As showed at Table 1, GLMCA presents much lower specific energy than PTSA for the same CO2 removal rate and equipment volume, for almost the same N2 recovery, so that it could be an alternative as CO2 removal process in confined space.

Table 1 Uniaxial tension test results

Process	Volume (m^3)	N_2 Recovery (%)	Specific Energy(kJ/m^3)
GLMCA	0.20	96.3	0.18
PTSA*	0.20	97.3	55.03

*(Zhan et al. 2021)

This study shows that there is substantial chance of GLCMA being applied inside confinedspaces to remove CO2 from atmosphere in order to replace conventional technologies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge all support held by the Brazilian Navy.

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ID188

DESIGN AND SIMULATION OF LINEAR GRADIENT 3D AUXECTIC STRUCTURES FOR DEFENSE PROTECTION

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ABSTRACT

This work presents a new approach to accurately model and simulate customized linear gradient 3D auxetic structures, namely the gyroid structure. A set of simulation and experimental results concerning different linear gradients produced by fused filament deposition method were analyzed as well as the correspondent background theory. The results show that, even for large deformations (>10%), the simulations agree to the experimental results. The proposed methodology was validated and can be used further for various auxetic structures.

INTRODUCTION

Auxetic materials are known to have application in the endeavor of energy absorption. Such materials, which exhibit a Negative Poisson's ratio (NPR), have shown increased shear modulus and fracture toughness, and improved impact and indentation resistance, all properties beneficial for armor systems (Underhill, 2018). Due to their unique performance in sandwich panel systems, auxetic core structures are good applicants to protect critical infrastructures and military vehicles (Remennikov, 2019). As several types of sandwich panels with different cores, such as the honeycomb (Imbalzano, 2018) and chiral structures (Novak, 2019), have been applied as protection plates in military vehicles for the protection of threats such as the explosion shock wave, it is essential to balance their protection performance in addition to the lightweight of the military vehicle. Studies are also being conducted for personal protection, showing that the mechanical requirements can be adapted for specific impact and protective applications for personal protection (Photiou, 2021). Moreover, the synclastic feature facilitates the creation of curved surfaces. When impacted, the material flows into the area to provide reinforcement allowing for less deflection within the equipment and consequently fewer injuries to the user (Underhill, 2014). A foreseeable prospect is also the use of anepectic materials presenting, simultaneously, negative thermal expansion (NTE) behavior (Raminhos, 2019).

A unit cell of the gyroid surface was defined by Eq.1 (x, y and z varying in [π, π], a = 1 and b = 0). To generate the linear gradient, the coefficient b was replaced with the sum of the space defining variables x, y and z. The finite element method (FEM) was used to simulate the mechanical behavior of the modelled structures and the validation specimens were 3D printed using FilaFlex UltraSoft 70A TPE filament.

RESULTS AND CONCLUSIONS

Table 1 presents the values of the average error for each geometry. The data in Table 1 shows that the method is, on average, below the 10% mark, which is a reference value for simulation error in engineering applications.

Table 1 Average error between simulation and experimental results

Geometry	Average error (%)
No gradient	8.3
Linear gradient (0.05)	4.2
Linear gradient (0.075)	8.3

Figure 1 shows an example of comparison between experimental and simulation images.

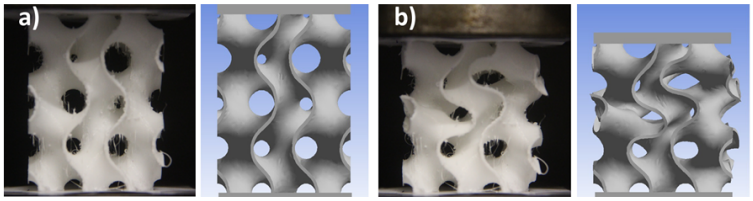

Fig.1 Geometry with a linear gradient coefficient of 0.075: a) before and b) after compression

Based on the good agreement between computational and experimental results, the results show that the developed methodology can realistically perform and can be used further for other auxetic structures.

ACKNOWLEDGMENTS

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ID189

THERMAL MANAGEMENT OF CBRN EQUIPMENT USING PDMS MICROCHANNELS BASED HEAT SINKS WITH NANOFLUIDS

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ABSTRACT

The present study is part of a wider project addressing the development of a thermal management system for chemical, biological, radiological and nuclear – CBRN equipment. At this stage of the work, preliminary tests were performed with Polydimethylsiloxane microchannel based heat sinks using different working fluids. The tests also explored potential benefits vs disadvantages of using liquid phase change. The results show some advantages in terms of cooling potential of using two phase flows with nanofluids, as long as pressure drop and flow instabilities during phase change are controlled. The Polydimethylsiloxane heat sinks, fabricated based on additive manufacturing, offer a cost-effective solution, which can be further improved by enhancing the properties of the Polydimethylsiloxane, based on nanoparticles addition.

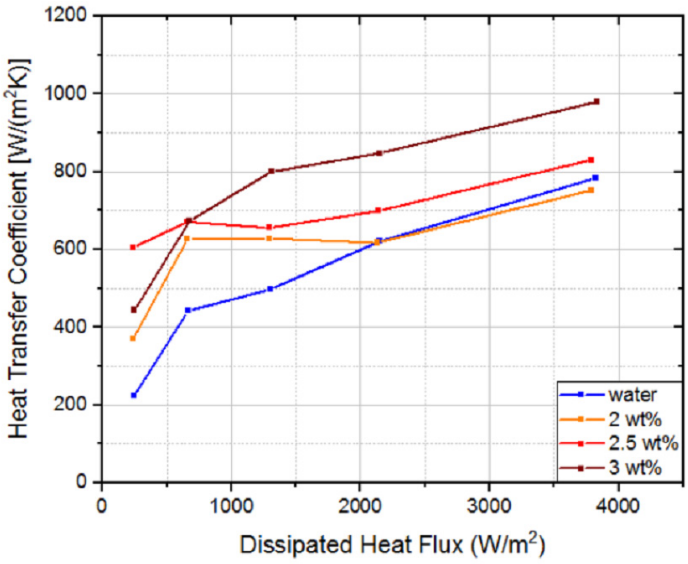
INTRODUCTION

Given the particularly harsh environmental conditions in which chemical, biological, radiological and nuclear (CBRN) equipment is intended to be used, it must work as an isolated system in terms of heat and mass transfer. Consequently, humidity regulation and thermal management are very difficult to achieve in this kind of equipment (Tokizawa et al., 2020) ultimately leading to thermal stress, hyperthermia and metabolic modifications. Despite of the research performed so far in this field, there is still no effective solution allowing for the use of a comfortable, light, and safe equipment. Recent solutions, introduced for instance by Tokizawa et al. (2020) address a complex tubes system for a liquid cooling system. However, the tubes have large dimensions, thus requiring a significant pumping power, which requires a pump that may increase the weight of the equipment up to 10kg. In this context, the work introduced here addresses a multidisciplinary approach in which a detailed analysis to the skin and internal temperatures during equipment operation are monitored (together with several other biometric parameters) to identify the relevant working temperature range and target body regions to be cooled. Then, the cooling system to use is modular to tackle these target points, making use of small heat sinks, based on microchannels. At this stage of the work, preliminary tests were conducted using microchannel based heat sinks made from PDMS – Polydimethylsiloxane, a cost effective and easy to use polymer. The heat sinks, fabricated from molding and additive manufacturing are composed by straight microchannels. The tests performed consider the use of various fluids and nanofluids to explore the best working conditions which balance the maximization of the heat transfer against the minimization of pressure losses and consequent pumping power.

RESULTS AND CONCLUSIONS

The heating source is currently simulated with a stainless-steel foil (AISI 304) 20 m thick, heated by Joule effect, by applying direct current supplied by an HP 6274B DC power supply. Flow dynamics is captured by visualization and image post-processing, using a high-speed camera (Phantom v4.2 high-speed camera). Temperature

distribution is taken based on the post processing of thermal images acquired with a high-speed infrared thermographic camera (Onca MWIR-InSb-320, from Xenics). Tests were performed firstly at pool boiling conditions (quiescent fluid) and then on forced convection in the microchannel based heat sinks. The results obtained with quiescent liquids under phase change conditions show advantage of using nanoparticles (in this case alumina, Al2O3) to increase the heat transfer, as the obtained heat transfer coefficients are clearly higher (Fig 1), and consequently the cooling potential is enhanced. However, when using liquids under phase change conditions in the heat sinks, the results are not so straight forward as, despite of the increased heat fluxes achieved (of the order of 7000W/m2), there is a penalty (which increases about 4 times when compared to single phase flows) on the pressure drop which consequently will increase the required pumping power. However, numerical studies currently under development suggest that controlling the flow instabilities by surface micro/nanostructuring may solve this issue allowing to take advantage of the use of this cooling solution. Nanofluids were observed to be stable enough to be used in the entire experimental campaign.



ACKNOWLEDGMENTS

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ID190

HEMP FABRICS COATED WITH CHITOSAN-TIO_2 ELECTROSPUN NANOFIBERS AS PERSONAL PROTECTIVE FIBROUS SYSTEMS

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ABSTRACT

This work aims to develop a fibrous based material able to adsorb and degrade chemical and biological hazardous agents. Thus, hemp fabrics were functionalized with chitosan (CS) electrospun nanofibers doped with titanium dioxide (TiO2) nanoparticles (NPs). The NPs were synthesized using a very simple precipitation method. All the samples were characterized by Field Emission Scanning Electron Microscopy (FESEM), Attenuated Total Reflectance-Fourier-Transform Infrared Spectroscopy (ATR-FTIR) and Ground-State Diffuse Reflectance (GSDR). The antibacterial activity as well as the degradation of dimethyl methylphosphonate (DMMP) were also evaluated.

INTRODUCTION

The development of technologies to protect the human being is getting more and more crucial due to the increasing exposure to harmful threats. Fibrous based materials that can actively protect its user, without compromising the weight of the material are of extreme importance. The introduction of NPs on textiles can provide several functionalities like easy/self-cleaning, decomposition of chemical agents, antimicrobial activity, UV protection and monitoring/sensing behavior. Metal oxides, especially TiO2 NPs, present excellent properties and exceptional photocatalytical activity, being able to degrade hazardous chemical agents (Araújo et al., 2021).

The functionalization of textiles with NPs presents one major drawback, the poor adhesion of the nanomaterials onto the fibers' surface. Electrospinning can be a great strategy for the improvement of the anchorage of the NPs onto the fabrics. Electrospun fibers, that can be obtained at nanoscale can be deposited directly onto a textile substrate, which will not only improve the bonding of the NPs onto the substrate, but also will increase the specific surface area and the filtration capacity, which results in a higher adsorption of contaminants (Costa et al., 2022).

A wide range of polymers can be used for the production of electrospun nanofibers, but biopolymers are always a more sustainable option. Chitosan is a natural biopolymer that has great properties, being widely used due to its biodegradability, biocompatibility, non-toxicity and antimicrobial activity, which is of great importance for the protection against biological agents (Ribeiro et al., 2021). For the development of military personal protective equipment, synthetic fibers emerge as the most valuable options, such as: HT polyamide, UHMWPE and aramid. Although the use of natural fibers (like hemp) in this application is not as common, they could be very promising materials to replace synthetic ones due to their low cost, lightness, durability, abundance, biocompatibility and biodegradability (Araújo et al., 2021).. The combination of chitosan nanofibers with hemp, is a great alternative for the development of more sustainable fibrous structures that can replace or complement the already existent personal protective equipment.

This work aims to develop a fibrous system based on hemp and chitosan nanofibers doped with TiO2 NPs, able to degrade microorganisms and chemical agents (DMMP).

RESULTS AND CONCLUSIONS

The TiO2 NPs were synthesized by a simple precipitation method, using titanium (IV) butoxide as the precursor and water as solvent. Poly(ethylene oxide) (PEO) was added to the CS polymeric solution in order to improve its spinnability. The synthesised TiO2 NPs were incorporated onto the CS/PEO solution and nanofibers were obtained. The successful incorporation of the NPs, as well as the coating of the hemp fabrics with the electrospun nanofibers was confirmed by FESEM (Figure 1). This information was corroborated by ATR-FTIR (data not showed in this abstract).

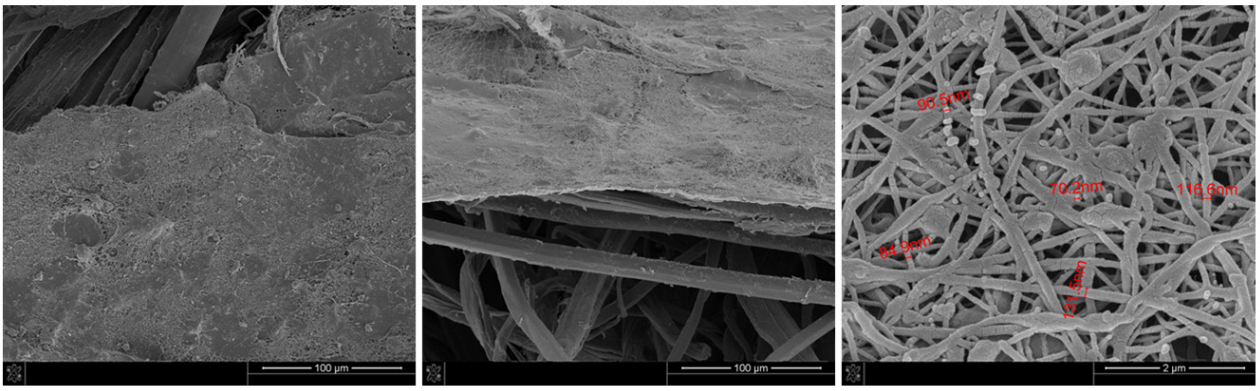

Fig.1 FESEM images of the hemp fabrics coated with electrospun chitosan nanofibers functionalized with TiO_2 NPs.

Functional properties, like the degradation of harmful chemicals (DMMP) and bacteria, Staphylococcus aureus and Escherichia coli, are being evaluated, being that some promising preliminary results were already obtained.

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ID191

EFFECT OF NATURAL PIGMENTS ON COTTON FABRICS FOR SKIN CANCER PREVENTION

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ABSTRACT

Excessive exposure to the sun can affect soldier's performance in the field, besides other consequences, such as burns and skin cancer, one of the most common types of cancer nowadays. One of the biggest technological challenges is finding alternatives to reduce sun exposure and, consequently, the chances of developing skin cancer. This work aimed to develop functional UV protection fabrics for soldiers protection and skin cancer prevention, with the goal of developing functionalized fabrics with a high ultraviolet protection factor, derived from dyeing with pigments extracted from the Brazilian flora, with great sustainable potential. The cotton fabrics were functionalized by the exhaustion method, using 5 different natural pigmentations: Brazil nut, baru, grape, sweet potato, and blueberry. The dyed fabrics were evaluated by determining the ultraviolet protection factor (UPF), and the results showed an increase in the UPF of fabrics dyed with natural pigments in relation to non-functionalized cotton fabric, mainly for baru (90 UPF) and grape (50 UPF), showing the effectiveness of the method and sustainable potential from dyeing using natural pigments.

INTRODUCTION

The National Cancer Institute (INCA) registers 135,000 new cases of cancer each year, and skin cancer accounts for about 30% of all cancer diagnoses in Brazil (Napoles, 2018). Thus, it is necessary to start prevention in early childhood. Photoprotectors integrated into textile structures are an excellent tool for the prevention of skin cancer, as garments are easy to use, practical and safe. In this study cosmetic attributes of hydration and photoprotection were transferred to the fabrics and consequently through the fabrics to the skin. Five different pigmentations were used, Brazil nut (Bertholletia excelsa), baru (Dipteryx alata Vogel), grape (Vitis vinífera), sweet potato (Ipomoea batatas) and blueberry (Vaccinium myrtillus).

Cotton fabrics were functionalized by the exhaustion method. Each sample had a mass of approximately 5 g, and the bath ratio was 1:20, using 100 ml of water at 70 °C. It was used NaCl (30% of the fabric weight) and citric acid (2% of the fabric weight), as well as the photoprotective actives (3% of the fabric weight for grape, and 6% for the other actives). The UPFs of the fabrics treated with natural pigments were determined using a UV-VIS spectrophotometer (Lambda 800, Perkin Elmer), with a 150 mm integrating sphere from the Colorimetry Laboratory of SENAI CETIQT, according to the AS/NZS 4399:1996 Standard

RESULTS AND CONCLUSIONS

The samples obtained after dyeing and drying are illustrated in Fig. 1. The dyeing with Brazil nut did not present a uniform dyeing, due to an inefficient dispersion of the dye in the medium. Among the sweet potato, grape, blueberry and baru dyes, it was noticed that the more acidic media had a more efficient adhesion and dispersion in the meshes. Most likely due to a greater solubility of these dyes in acidic media. The UPF values were obtained statistically and then normalized. The data are presented in Table 1.

Fig.1 Functionalized fabrics with application of baru (a), grape (b), Brazil nut (c), sweet potato (d) and blueberry (e) pigments

Table 1 Results of UPF Analysis

Fabric	Concentration (%)	UPF value (average)	Normalized UPF value (rated)
Cotton (Control)	-	0	0
Cotton/Baru	3	90	50+
Cotton/Grape	6	50	50
Cotton/Brazil nut	6	30	30
Cotton/Sweet Potato	6	25	15
Cotton/Blueberry	6	40	30

Table 1 shows that the addition of natural pigments significantly improved the UV radiation blocking properties of cotton, as the functionalized fabrics showed a drastic attenuation of UV protection (Crews, 2005; Dubrovski, 2009; Silva, 2018). Fabrics functionalized with baru and grape were the ones that resulted in fabrics with higher sun protection factors.

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INFLUENCE OF THE CHEMICAL BONDS IN THE BLAST MITIGATION ABILITY OF POLYUREAS

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ABSTRACT

This work compares the influence of the chemical bonds in the blast mitigation ability of two distinct polyureas. The FTIR test conducted on the polyureas allowed the identification of the chemical bonds that make the unique microphase separation structure of polyureas, composed of a soft segment and a hard segment. The mechanical tests performed showed that polyurea B has excellent flexibility and maximum elongation, characteristics that make this polyurea suitable to be used as a blast mitigating coating in buildings.

INTRODUCTION

The ever-increasing safety requirements demanded in the engineering and construction of structures to protect people from terrorist threats or industrial accidents are fostering the study and development of new materials and processes. The polyurea is one of these versatile engineering materials, which has been commercially available since the early 1990s (Choi, 2012), (Miao, 2019). The polyureas subjected to blast and impact loads tend to exhibit high strain to failure, thereby absorbing, dissipating, and mitigating the energy arising from dynamic loads, such as explosions (Mott, 2016). The polyurea has a unique microphase separation structure composed of a soft segment and a hard segment. The extent of this blastmitigation effect is proportional to the hard domain volume fraction contained in the polyurea (Iqbal, 2016).

The two polyureas analyzed were part of the R&D Project “Protection of Infrastructures and Systems Against Explosives – Advanced Protective Coatings (PRINSE - APC)” managed and led by the NATO Counter Improvised Explosive Devices Centre of Excellence (C-IED COE). The Fourier Transform Infrared Spectroscopy (FTIR) tests performed on the polyureas were carried out according to the standard ASTM E1252, performing 60 scans with a resolution of 16 cm-1to obtain an IR spectrum in the range of 4000-550 cm-1. The tensile tests were conducted on a universal testing machine, according to the ASTM D412 standard, in which five specimens of the each polyurea sample were tested with a crosshead speed of 15 mm/min and a gauge length of 10 mm. A 100 kN load cell was used to stretch the specimens until failure - yield or fracture.

RESULTS AND CONCLUSIONS

In the FTIR spectrum of polyureas A and B, presented in Fig. 1, two peaks are present in the range of 1600–1700 cm-1 attributed to the C=O stretching vibrations, with two nearby N-H in the urea group, which is conventionally called “ordered” bonding, that forms the hard phase (–NH–CO–NH–) of the polyurea. The hard realms - dispersed throughout the polyurea matrix- are responsible for the high elongation capability of this type of material. Table 1 shows the results for the tensile tests. The most significant difference is the excellent flexibility and

elongation characteristics shown by the polyurea B. 1.

Table 1 Tensile tests results

Sample	Tensile strength (MPa)	Maximum Elongation (%)	Young Modulus (GPa)
Polyurea A	16,80 ± 1,84	113,61 ± 15,82	0,17 ± 0,03
Polyurea B	31,23 ± 2,04	2920,86 ± 43,98	0,03 ± 0,00

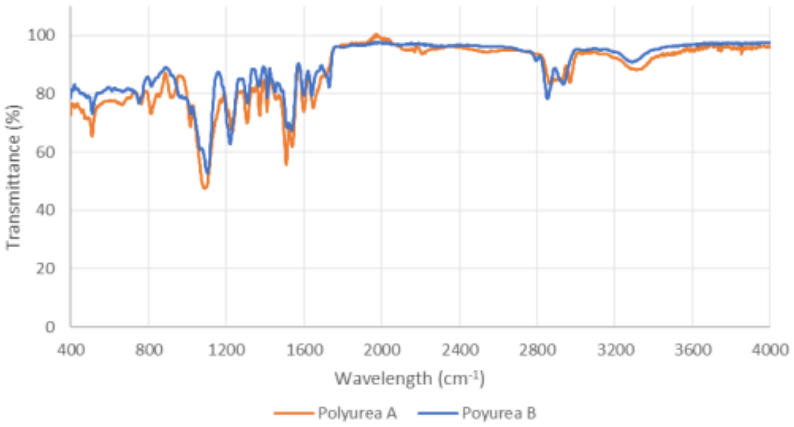

Fig.1 FTIR test results.

In addition to the chemical bonds present in both polyureas that contribute to the blast mitigation ability, the appearance of titanium in the polyurea B could eventually have helped in the substantial increase of the tensile elongation of this material compared to the polyurea A since titanium nanoparticles are commonly used in composites to improve the mechanical properties of materials.

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Not applicable.

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AIRFLOW METHOD FOR SIMULTANEOUS DETERMINATION OF THE STRUCTURAL PARAMETERS OF NANOFIBROUS MATERIALS

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ABSTRACT

This work proposes an airflow method to simultaneously determine the structural parameters (i.e., porosity, thickness and fiber diameter) of nanofibrous materials with the help of inverse characterization. The airflow velocity and pressure drop of three types of nanofibrous materials are measured. The Kozeny-type and Ergun-type equations are selected to fit the measured airflow velocity and pressure drop. The optimization method is conducted to solve the inverse problem. The results from the airflow method are compared with directly measured values. It is found that the airflow method is feasible for the characterization of nanofibrous materials.

INTRODUCTION

Nanofibrous materials have been widely used for various applications in medicine, engineering, the environment, and many other fields (Tan et al., 2021; Xiong et al., 2020). It is essential and meaningful to characterize the nanofibrous materials' structural parameters. Some direct methods can be used to simply characterize the conventional fibrous materials (Yang et al., 2022). For example, the gas sorption and liquid intrusion methods for porosity determination (Espinal, 2012), the micro-CT (Micro Computed Tomography) and SEM (Scanning Electron Microscope) methods for fiber diameter measurement (Andrews et al., 1987), and the standard of ASTM D1777-96 for thickness determination (European Committee for Standardization, 1996). However, it is complicated to determine their thickness and porosity. For instance, researchers used liquid nitrogen to treat nanomembranes to remain stable state during the preparation phase, and the thickness from SEM images was subsequently measured (Ulrich & Arenas, 2020). And the porosity obtained by SEM images is usually higher than the actual value. Exclusive to the existing direct methods, indirect methods are alternatives to determine the structural parameters. The indirect acoustical method is able to estimate the fiber diameter, porosity, bulk density, tortuosity, viscous and thermal characteristic lengths (Yang et al., 2021). One of the main shortcomings of the acoustical method is that a specific device is required, i.e., an impedance tube. The measurements in the impedance tube are relatively complicated. The airflow method was developed to rapidly measure the fineness of cotton wool fibers in the mid of the last century (Brown & Graham, 1950). In 1966, Uno et al. devised an apparatus based on the airflow method to measure the fiber diameter of Nylon, acetate and polypropylene fibers (Uno et al., 1966a, 1966b). Hence, it is possible to use the airflow method to characterize the structural parameters of nanofibrous materials. So far, however, there has been little discussion about using the airflow method to simultaneously determine the structural parameters of nanofibrous materials. In this work, the structural parameters of three nanofibrous samples are concurrently characterized based on their airflow penetration behavior and the inverse characterization method. The inversely determining porosity, fiber diameter and thickness were compared with the directly measured values.

RESULTS AND CONCLUSIONS

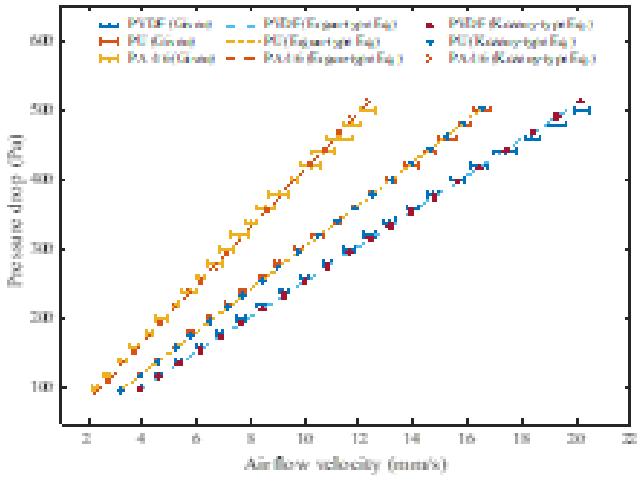
Three nanofibrous materials with different fiber diameters, porosity and thickness were selected in this work. The samples are made by PVDF (polyvinylidene fluoride), PU (polyurethane) and PA 4/6 (polyamide 46). The specifications of the samples are demonstrated in Table 1.

Table 1 The specifications of the nanofibrous samples

Materials	Areal density [g/m^2]	Thickness [mm]	Bulk density [kg/m^3]	Porosity [%]	Average fiber diameter [μm]
PVDF Nanomembrane	5.93	0.022 ± 0.005	272.09	84.45	0.250 ± 0.068
PU Nanomembrane	30.91	0.134 ± 0.009	231.03	80.75	0.255 ± 0.072
PA 4/6 Nanomembrane	8.04	0.050 ± 0.013	159.32	86.50	0.374 ± 0.079

A square size specimen of each sample was cut into the size of 10 by 10 cm. Then the weight was measured on a digital balance. The areal density was subsequently obtained. A thickness gauge (SOMET CZ sro, Bílina, Czech Republic) was used to measure the thickness of nanofibrous samples. A flat plastic film was placed between the test head and samples to avoid compression on the samples. The ImageJ software was subsequently used to read the dial for a result. Each sample has been measured ten times. Sample porosities were determined according to $\phi=1-\rho/\rho_f$, where ρ_f is the fiber density and ρ is the materials bulk density. A Matlab-based image analysis tool, called SIMPoly, was used to semi-automatically get the average fiber diameter and its standard deviation (Murphy et al., 2020).

By means of the optimization algorithm along with the measured airflow velocity, the coefficients of the Ergun-type equation and modified Blake–Kozeny–Carman constant of the Kozeny-type equation are obtained. The comparisons between the given pressure drops and the values from the Ergun-type and Kozeny-type equations, referred to as predicted values, are demonstrated in Fig. 1.



It is found that both Ergun-type and Kozeny-type equations showed excellent predictions for nanomembrane samples. This is due to the high flexibility of the Ergun-type equation and the relatively low airflow velocity (i.e., 2 – 22 mm/s under 100 - 500 Pa pressure drop). The findings indicate that when the airflow velocity is relatively low (e.g., < ~400 mm/s), Ergun-type and Kozeny-type equations are suitable for pressure drop prediction for fibrous materials. In comparison, the Ergun-type equation is more applicable when the airflow velocity is higher than approximately 400 mm/s.

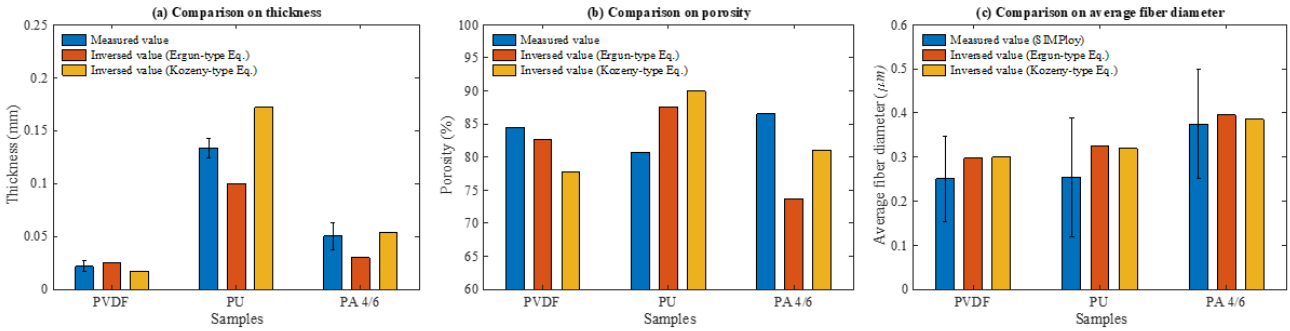


Fig.2 Comparison of the inversely determined thickness, porosity, average fiber diameter and the measured values

The inversely determined thickness, porosity and average fiber diameter are compared with the measured values in Fig.2. The difference between the Ergun-type equation and the Kozeny-type equation on thickness is more significant compared with porosity and average fiber diameter. From Fig.1, it was found that the Kozeny-type equation is suitable for pressure drop prediction for the nanofibrous samples since the pressure drop and airflow velocity of these samples are nearly linear related. That's the reason why the Kozeny-type equation has better thickness determination on thickness compared to the Ergun-type equation. Since the samples are very thin, a small change caused by compression may result in a big deviation. And the air penetration behavior of the samples was measured at an uncompressed state. Therefore, the inversely determining porosity and thickness among the samples are not stable. In Fig.2(c) 5 (c), it can be seen that the inversed average fiber diameter from the Kozeny-type equation is more close to the measured values.

This study shows that the Ergun-type equation exhibited reasonable results for the samples with good permeability, while it is not suitable for nanofibrous materials. The Kozeny-type equation is able to precisely characterize the nanofibrous materials with the help of the optimization method. Considering the uncertainties during the direct measurements, it can be stated that the inverse characterization method on fibrous materials based on their air penetration behavior is feasible. Accurate and rapid characterization of nanofibrous material can help the application of nanomaterials into various fields, such as medical, engineering, defense and so on.

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ID194

ANTIBACTERIAL AND BIODEGRADABLE ELECTROSPUN FILTERING MEMBRANES FOR FACEMASKS: AN ATTEMPT TO REDUCE DISPOSABLE MASKS USE

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ABSTRACT

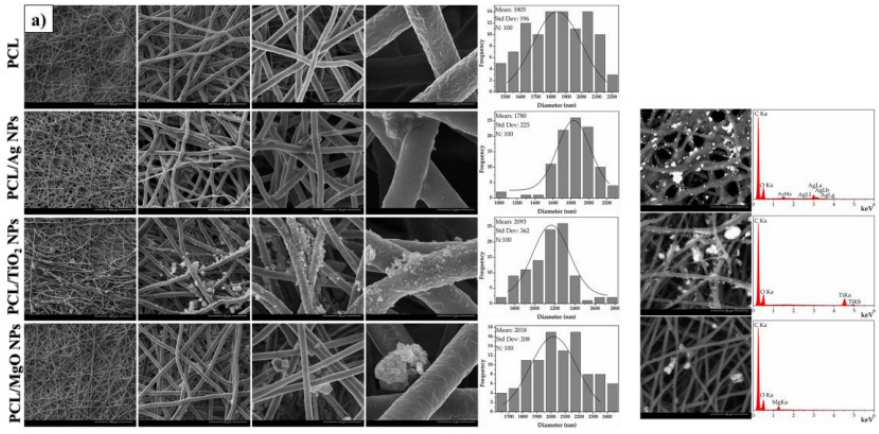
This work aims the development of an active and biodegradable facemask, not only able to exhibit high filtration efficiency but also to degrade the microorganisms, taking advantage of the great properties of electrospun membranes, nanoparticles (NPs) and natural fibers(cotton). The filter layer was produced by electrospinning using poly(ε-caprolactone) (PCL) biodegradable polymer. After their production, electrospun membranes were functionalized with different NPs, such as silver (Ag), titanium dioxide (TiO2) and magnesium oxide (MgO), in order to include new properties, namely antibacterial effect. The developed membranes were characterized by FESEM, EDS, ATR-FTIR, GSDR and TGA. The antibacterial effect and filtration efficiency were also assessed. Different facemask prototypes were developed, and their filtration efficiency, air permeability and thermal comfort were evaluated.

INTRODUCTION

The COVID-19 pandemic has contributed to the extensive production and consumption of facemasks worldwide. Facemasks are generally composed of nonbiodegradable polymers, being their disposal responsible for generating a large amount of waste, causing severe environmental problems. One option to minimize this negative impact is the replacement of conventional materials by eco-friendly ones, such as natural fibers and biodegradable polymers, like PCL (Das, 2020; Fadare, 2020). Recently, membranes produced by electrospinning have acquired tremendous interest to act as high-performance filters, due to their outstanding properties, such as a high specific surface area, which results in the higher adsorption capacity of contaminants, highly porous structure with small pore sizes and internal interconnectivity, flexibility, etc. Due to their low weight and high permeability, these fibrous membranes provide high filtration efficiency, without adding extra weight and maintaining the wearer's comfort and breathability (Das, 2020). Electrospun membranes can also be functionalized with different materials in order to achieve new functions, such as antimicrobial activity. Several metal and metal oxide NPs, such as Ag, TiO2 and MgO, have been explored as effective antimicrobial agents against various microorganisms (Araújo, 2021). Thus, the combination of antimicrobial NPs with electrospun membranes is a very promising strategy to improve the overall performance of the facemasks, namely the filtration efficiency as well as elimination of microorganisms (Costa, 2020).

RESULTS AND CONCLUSIONS

PCL membranes were firstly produced by electrospinning, and then, functionalized with different NPs: commercial (TiO2 and MgO) and synthetized (Ag) NPs. Fig. 1 shows the FESEM and EDS analyses of the PCL/NPs membranes as well as their antibacterial effect and filtration efficiency.



b)

Samples	Mean diameter of the halos (mm)	
	S. aureus	*E. coli*
PCL	0.0 ± 0	0.0 ± 0
PCL/Ag NPs	18.3 ± 0.6	16.5 ± 0.7
PCL/TiO_2 NPs	18.7 ± 1.2	0.0 ± 0
PCL/MgO NPs	25.3 ± 0.6	13.5 ± 0.7

c)

Samples	Thickness (mm)	Basis weight (g/cm^2)	Filtration efficiency (%)
PCL	0.376	0.005	84.9
PCL/Ag NPs	0.600	0.010	70.8
PCL/TiO_2 NPs	0.506	0.008	86.0
PCL/MgO NPs	0.147	0.003	99.4

Fig. 1 (a) FESEM and EDS analysis, (b) inhibition zone diameters, (c) thickness, basis weight and filtration efficiency (%) of the different electrospun membranes (PCL, PCL/Ag NPs, PCL/TiO_2 NPs and PCL/MgO NPs).

FESEM images and EDS analysis revealed the successful synthesis of Ag NPs and their attachment to the PCL electrospun membranes as well as the presence of TiO2 and MgO NPs onto PCL membranes. Moreover, all membranes functionalized with NPs exhibited antibacterial effect against Gram-negative and Gram-positive bacteria, expect PCL/TiO2 against E. coli. The highest filtration efficiency was obtained with PCL/MgO NPs membrane, achieving 99.4 %. This sample was used to develop the facemask's prototypes.

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FINITE ELEMENT ANALYSIS OF BIOINSPIRED AUXETICS

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ABSTRACT

Finite Element models inspired by nacre (a naturally occurring auxetic) were created to allow future development of biomimetic composites with enhanced impact protection capabilities. In addition, the relationships between the structure and mechanical properties are explored.

INTRODUCTION

With current developments in materials engineering, some of the key structures of naturally occurring materials can be replicated to enhance mechanical properties for specific applications (Li, Chen, & Choi, 2021).

In the case of auxetics, Negative Poisson's Ratio (NPR) leads to beneficial properties like higher material stiffness, indentation resistance, plane strain fracture toughness, shock and sound absorption, and higher energy absorption (Evans, 1991). These properties are considered highly desirable when considering materials for impact protection applications.

Finite Element Analysis is used to obtain numerical solutions for complex problems within solid mechanics. A huge benefit of using computational simulation is that it can be carried out to evaluate the model without creating the physical samples whilst obtaining representative data. This allows for multiple iterations of the model to be made and optimise its structure/geometry in a more time-efficient manner.

METHODOLOGY

Ansys DesignModeler was used to create a series of models inspired by the work of Wang & Boyce on the nacre-inspired microframe mechanism, figure 3. The 2D models were analysed using ANSYS Static Structural, 3D models were analysed using ANSYS Static Structural and ANSYS Explicit Dynamic.

During the 2D analysis, displacement and/or force is applied in the longitudinal direction, and lateral deformation is measured to find the global value of the Poisson's ratio. The model was investigated with variable volume ratios (volume of platelets to the polymer microframe), variable displacements/forces were applied, and a mesh convergence study was performed. Finally, the results were compared to the FE model by Wang & Boyce, and experimental results for the nacre itself were found in the literature published by Song et al.

Fig.3 Section of the Microframe used for FEA (Wang & Boyce, 2010)

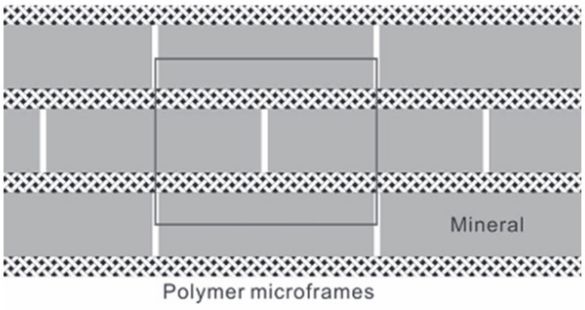
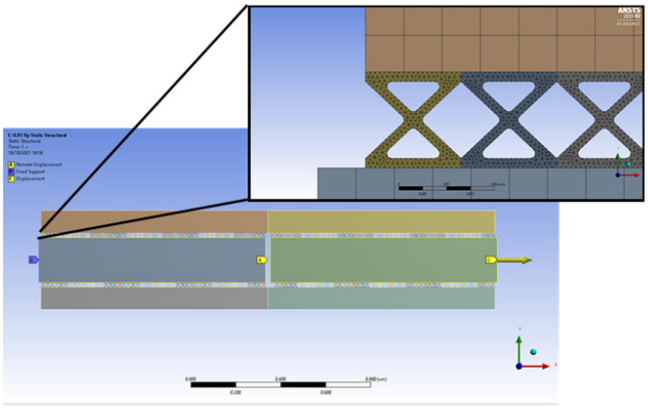


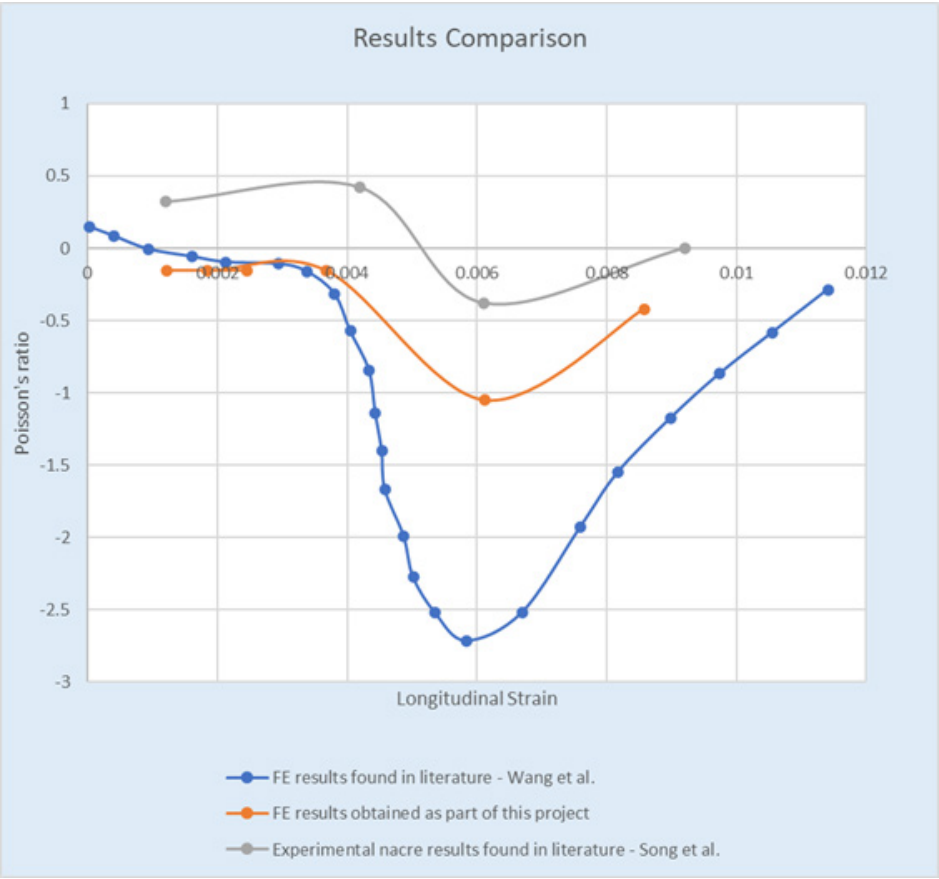
Fig.4 2D model created for the analysis



Later, a 3D model was developed and subjected to various blunt impacts to investigate the structure's protection capabilities. Future work will involve optimising the nacre-inspired 3D structure for blast and ballistic loading conditions.

RESULTS AND CONCLUSIONS

Figure 5 shows similar trends, with a significant similarity between experimental data (Song et al., 2008) and FEA data obtained in this project, and hence the model was considered validated. It was further used for the foundation of an optimised biomimetic design, developed into a 3D structure, with current work looking into the optimisation of its impact resistance properties.



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ID196

FE3O4/GRAPHENE OXIDE/FE4[FE(CN)6]3 NANOCOMPOSITE FOR HIGH PERFORMANCE ELECTROMAGNETIC INTERFERENCE SHIELDING.

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ABSTRACT

Carbon based materials have attracted much attention due to their high conductivity and shielding properties. In the present investigation, Fe4[Fe(CN)6]3 (Prussian blue), graphene oxide (GO) and magnetite (Fe3O4) nanocomposite was prepared and their electromagnetic (EM) shielding efficiency was evaluated. The GO was prepared via Hummer's method and composite was prepared with Fe3O4 and Fe4[Fe(CN)6]3. The prepared composite was characterized by X-ray diffraction (XRD), photoluminescence (PL), Fourier transform infrared (FTIR), ultraviolet visible (UV–Vis) and Raman spectroscopy techniques. The average particle size of Fe4[Fe(CN)6]3/GO/Fe3O4 (PBGF) composite was 13.19 nm with density of 0.943 g/cm3, Using dielectric parameters, the shielding effectiveness of the sample was evaluated. A −51.66 dB of reflection losses was observed at 2 MHz and results revealed that the PBGF has manifesting properties of shielding absorbance which are useful for EMI shielding application.

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ID197

MECHANICAL PERFORMANCE CHARACTERIZATION OF ANTHERAEA PERNYI COCOON COMPOSITES

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ABSTRACT

Cocoon is a natural composites for defense environmental, biological and physical hazards. This work analyzes the mechanical properties of two Antheraea pernyi (A. pernyi) cocoons composites from different source regions. Tensile property tests were carried out by using rectangular specimens cutting from four directions 0°, ±45°, and 90°, seperately. The properties of a cocoon show distinct differences in the longitudinal and transverse directions. The relation between the mechanical properties and microstructures is also discussed.

INTRODUCTION

Cocoon is a type of unique and important biopolymer composite in nature with excellent microstructure and ecological functions, which plays important roles in the transformation from silkworm and pupa to adult moth. In comparison with domesticated silkworm, such as Bombyx mori (B. mori) (Li, 2019), wild silkworm cocoons, such as Antheraea pernyi (A. Pernyi), are reared in the open environment require much greater protection from environmental, biotic and physical hazards. The A. pernyi cocoon is one of major source of wild silk fibres. After hundreds of millions of years evolution, the A. Pernyi can produce cocoons composites with special structure and functions to adapt to its living environment. In recent years, much attention has been given to non-mulberry cocoon types such as A. Pernyi, because of its exceptional mechanical, thermal regulation (Zhang, 2017), puncture resistance(Zhou, 2020) and UV screening properties (Kaur, 2013).

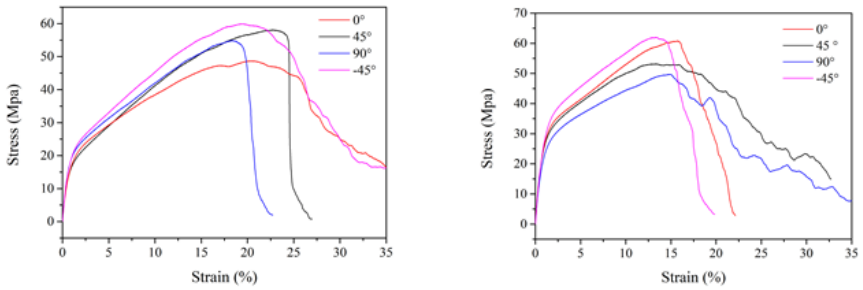
The present paper is aimed mainly to obtain a clear understanding of the mechanical property of silk cocoon. In this study, two A. Pernyi cocoons from different source regions (Liaoning and Henan) were selected as the experimental objects. The specifications, surface morphology, section microstructure were observed and compared. Besides, tensile property tests were carried out by using rectangular specimens cutting from four directions 0°, ±45°, and 90°, seperately. The complete stress-strain curves of rectangular specimens cut in different directions from these cocoons from two source regions were discussed and the relationship between the microstructure and properties were also analyzed.

RESULTS AND CONCLUSIONS

The typical tensile stress-strain curves of rectangular specimens cut from cocoon from 4 different directions are shown in Fig. 1. The stress rises non-linearly with increasing of strain which have more complex stress-strain profiles. The stress rises with strain to a maximum value and the gradient of these curves change twice through apparent yield points until stress falls relatively rapidly after the maximum. Table 1 shows the results of A. pernyi cocoon composites.

Table 1 Tensile property result of A. pernyi cocoon composites

Specimen	Tensile direction	Tensile modulus (MPa)	Maximum load (N)	Ultimate tensile strain (%)	Ultimate tensile stress (MPa)
A. pernyi cocoon (H)	0°	1227.95	95.27	13.33	53.22
	45°	1093.66	108.90	15.76	60.84
	90°	1017.61	89.11	14.74	49.78
	-45°	1475.00	111.10	13.34	62.07
A. pernyi cocoon (L)	0°	483.73	131.81	22.78	58.06
	45°	672.80	110.51	20.47	48.68
	90°	639.06	124.76	18.36	54.96
	-45°	660.35	136.07	19.33	59.94



(a)Liaoning (b)Henan

Fig.1 Typical tensile stress-strain curves of rectangular specimens cut from cocoon.

This study shows that there are substantial differences on the tensile properties from different directions of cocoon composites. These A. Pernyi cocoons from two source regions also showed different mechanical peroperties.

ACKNOWLEDGMENTS

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ID198

THE EFFECT OF FIBER ORIENTATION AND FIBER VOLUME ON IMPACT STRENGTH OF ADDITIVELY MANUFACTURED COMPOSITE SPECIMEN

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ABSTRACT

Additive Manufacturing (AM), also known as 3D Printing, has been there for more than two decades and has recently gained importance for manufacturing functional products. AM has excellent developments in recent days with a huge number of applications in industry, automotive, aerospace, medical, architecture, food, fashion, etc. Composite materials are widely used in structures with weight as a critical factor, especially in the aerospace industry. In recent periods, AM has gained a lot of importance in fabricating composite material. Fused Deposition Modelling (FDM) is one of the promising AM technology used for the fabrication of complex geometry products using continuous fiber-reinforced composite material. There is a lot of research on the effect of fiber orientation on the impact strength of composite materials made using conventional manufacturing processes. It will be interesting and significant to study the effect of fiber orientation (0°, 0°/90°, +45°/-45°, 0°/+45°/90°/-45°) and fiber volume (73%, 52%, 26%) on the impact strength of additively manufactured continuous fiber-reinforced composite materials. Now-a-days, continuous fiber-reinforced thermoplastic composite materials are becoming more important in industrial applications due to inherent advantages such as excellent mechanical performance, recycling, and potential lightweight structures. In the present study, Kevlar was used as a continuous fiber-reinforced material that has high impact resistance. The FDM-based 3D printer named Markforged Mark Two was used to fabricate the test specimen. This work aims to investigate and find out the best fiber orientation and volume fraction of fiber that has better impact strength for additively manufactured composite materials. The results show that the 0° fiber orientation with a 72% fiber volume fraction has the highest impact strength of 1671.60 J/m and the 0°/90° fiber orientation with a 72% fiber volume fraction has the lowest impact strength of 489.52 J/m. Moreover, as the fiber volume increases the impact strength also increases for all fiber orientation specimens.

Keywords: additive manufacturing, 3D printing, composite material, Kevlar fiber, impact testing

INTRODUCTION

Now-a-days functional products with complex geometry are widely manufactured through additive manufacturing techniques. The various additive manufacturing techniques are Vat Photopolymerisation, Material Extrusion, Binder Jetting, Material Jetting, Powder Bed Fusion, Direct Energy Deposition, and Sheet Lamination. Among these techniques, the Fused Deposition Modelling (FDM) technique which is a material extrusion technique is commonly used to fabricate components. The components 3D printed with polymer lack strength which results in the restricted application of 3D printed components in the industry. 3D Printing of polymer composite can overcome the previous drawback. Recently, FDM is used to fabricate fiber reinforced polymer composite components. Continuous fiber-reinforced polymer composite can be easily fabricated by the FDM

technique. Based on the literature review, it was observed that most of the research was done to investigate the effect of printing parameters such as fiber orientation, fiber volume and fiber fill type on tensile and flexural properties of 3D printed composite parts [1-5]. Very few studies were found investigating the izod impact properties of the 3D printed composite. Therefore, in the present study, the effect of fiber orientation and fiber volume on izod impact strength is studied. The izod impact composite specimen is fabricated by Markforged Mark Two 3D composite printer. The 0°, 0°/90°, +45°/-45° and 0°/+45°/90°/-45° fiber orientation and 72%, 52%, and 26% fiber volume were considered during the printing of composite specimen. Three specimens of each fiber orientation and fiber volume were 3D printed. A total of 36 specimens were 3D printed. The 3D geometry of the specimen was based on the ASTM D256 standard. The impact specimens were tested on an IT 503 izod impact testing machine. The Izod impact strength of specimens was noted as a result of testing.

RESULTS AND CONCLUSIONS

In the present research, the effect of fiber orientation and fiber volume on the impact strength of 3D printed polymer composite specimens is studied. Table 1 represents the impact strength for different fiber orientations and fiber volume of 3D printed polymer composite specimens.

Table 1 Impact Strength of 3D printed composite specimen for different fiber orientations and fiber volume

Fiber Volume Fraction	Impact Strength (J/m)			
	0°	0°/90°	45°/-45°	0°/45°/90°/-45°
73%	1671.60	489.52	638.73	507.50
52%	1384.10	401.82	608.09	474.92
26%	906.90	205.27	300.53	260.79

From the results, it is observed that the 0° fiber orientation specimen has the highest impact strength and the 0°/90° fiber orientation specimen has the lowest impact strength. The fiber orientation from 0°, 0°/90°, 45°/-45°, and 0°/45°/90°/-45° shows descending impact strength. Also, it is observed that as fiber volume fraction increases the impact strength also increases for all fiberorientationmensnation specimens. In 0° fiber orientation, the fiber is aligned along the length direction and the impact force is perpendicular to the fiber orientation, which resulted in more impact energy absorption. In the case of 0°/90° fiber orientation, 0° fibers are perpendicular and 90° fibers are parallel to the impact force, which has resulted in minimum
energy absorption by the specimen.

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ID199

INDUCING HYDROPHOBICITY ON CELLULOSE-BASED NATURAL FIBERS THROUGH MODIFIED METAL OXIDE COATINGS

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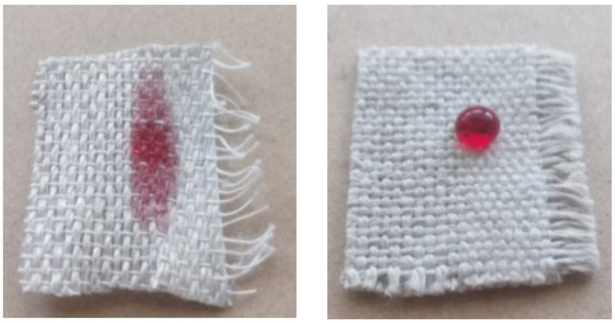
ABSTRACT
This work validates the application of a fluorine-free and easily cast zinc oxide coating decorated with hydrophobic aliphatic molecules to hydrophobize the surface of natural fibers for the application as composite reinforcement for large scale construction industry. The treated fibers can be employed as long fibers or as randomly orientated short fibers, e.g., shrinkage reinforcements, to reinforce lime- or cement-based matrices. The experimental results support the effectiveness of this protocol for large scale manufacturing with the desired hydrophobicity.

INTRODUCTION
The fast degradation of natural fibers in moist and alkaline environments hampers their longterm serviceability as reinforcement in inorganic composites. The challenges in such media arise from fibers´ high hydrophilicity that enables the migration of hydration salts, produced in lime or cement, to the inner parts of the fibers throughout pore water uptake [1]. This damaging phenomenon results in fiber dimensional instability, degrades the natural fibers´ structure and reduces their mechanical properties and can be even more abrasive after wet/drying cycles depending on their exposure to different weathering conditions. For short natural fiber composites it is probable that the hydrophilic fibers absorb part of the water content used in matrix mixture, thus compromising the water/solid ratio. Thus, the mixture requires a higher water content, an issue that results in several complications at the workability level of the matrix particularly for strengthening of masonry substrates. In this work, the coating of natural cellulose-based fibers with zinc oxide (ZnO) crosslinked with hydrophobic molecules such as stearic acid (adapted by Wang et al. [3]) was studied, aiming at enhancing the fibers hydrophobicity, hence their durability as reinforcement, using a scalable procedure for large scale applications. The use of metallic oxides-based coatings has been reported in the literature to improve physical properties such as wettability, UV resistance and fire retardancy of the underlying substrates [2] [3]. The present work extends the potential of the referred coating to tailor the surfaces of lignocellulosic materials aiming at their engagement as durable reinforcements for structural composites. The proposed protocol starts with casting ZnO microlamellas on hemp and flax fibers selecting zinc acetate dihydrate as a precursor for ZnO grafting. Then ZnO as-coated fibers undergo surface decorating via stearic acid in ethanol, followed by drying in a convection oven at 60°C. The surface treated fibers were designated as Hemp-ZnO-SA and Flax-ZnO-SA. Physical, chemical and mechanical characterization was carried out to assess the aptness of the proposed protocol.

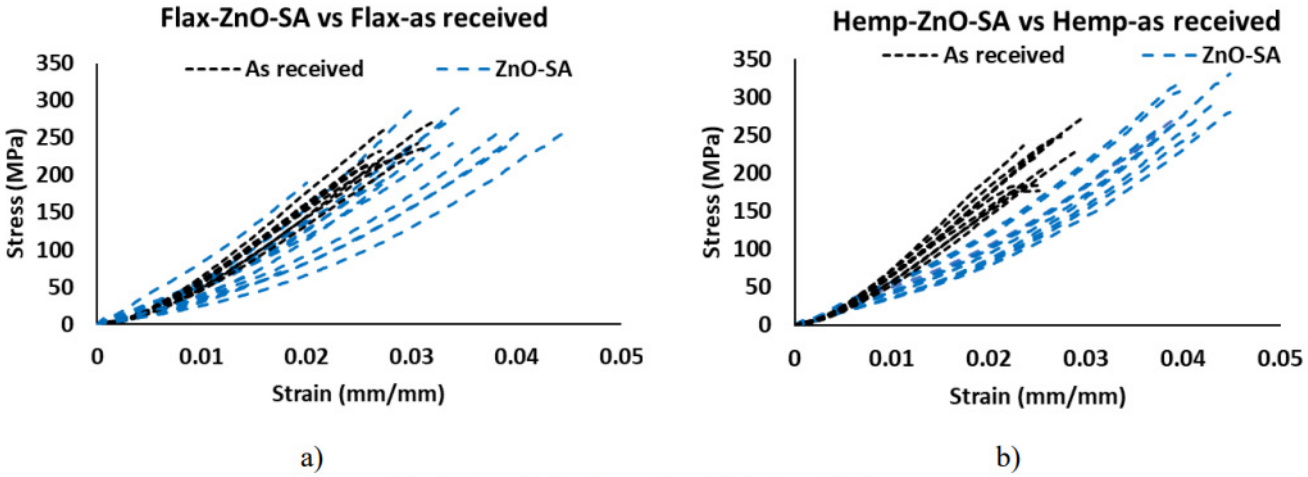
RESULTS AND CONCLUSIONS
In order to check the wettability of the coated fibers, the static sessile drop contact angle test was carried out. As can be seen in Fig. 1, the coated flax fibers depict a superhydrophobic response as compared to their counterpart superhydrophilic fibers. The results from the tensile tests on yarns are shown in Fig. 2. The coated yarns showed limited drop in Young´s modulus which can be attributed to the alkalinity of the solution needed to grow ZnO.

However, higher tensile strength was delivered, more evident in the case of hemp, if compared to the as-received fibers. Further investigation on fiber-to-matrix bond behavior is crucial to examine the mechanical interlocking upon the microroughness conveyed via ZnO coating.



a) b)

Fig. 1 a) before hydrophobization, b) after hydrophobization



a) b)

Fig.2 Tensile test results of (a) flax, (b) hemp

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ID201

FUNCTIONALIZATION OF COTTON FABRIC THROUGH COATING FOR HEAT DISSIPATION

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ABSTRACT

This work aimed to evaluate the heat dissipation ability of cotton fabrics when functionalised with carbon-based nanomaterials. The cotton fabric was knife-coated with a paste prepared by using polyurethane-based commercial polymers, thickener, and graphene nanoplatelets (GNPs) at different concentrations. This study also investigated the influence of the number of layers on the electrical conductivity and heat-dissipating capability of the coated fabric.

INTRODUCTION

Heating textiles can be produced by various techniques that go from fabricating the textile with conductive fibres to post-functionalisation with conductive polymers or nanoparticles through spray coating, knife coating, screen printing, dip coating, among others. These textiles, incorporated with heating elements, are promising to be applied in several different applications like smart and wearable textiles, defreezing and defrosting applications (Moreira et al., 2021). The production of active heaters based on Joule heating with the use of nanomaterials and various fabrication techniques has created a paradigm shift in smart clothing systems (Repon et al., 2021).

RAW MATERIAL AND EXPERIMENTAL WORK

Edolan CM and Tanapur EP3061 polyurethane-based commercial polymers and thickener A 02 were purchased from Tanatex Chemicals, Netherlands. Graphene nanoplatelets (GNPs) were purchased from Graphenest, Portugal. The cotton fabric was obtained from Lameirinho, Portugal. The paste was prepared by combining GNPs with Edolan CM and Tanapur EP3061 in a 50:50 ratio. The thickener was added in low proportions (~ 0.02 to 0.07 % w/v) to obtain the required viscosity for knife coating. The paste was prepared with different concentrations of GNPs i.e., 2, 3, 5, 7, 10, and 12 % w/v in the polymer. 1, 2, or 3 layers were coated on the cotton fabric, by drying between layers at 100 for 3 min and by curing in the end at 160 ºC for 3 min. The electrical conductivity of the samples was investigated using a Keitley 487 Picoammeter/Voltage setup. For the samples that showed the highest electrical conductivity values, Joule heating performance measurements were carried out by applying 12 V on them and the temperature rise in the fabric was recorded by a thermographic camera from Testo 885. Temperature readings were done at specific time points during the application of the voltage for 5 min and after stopping the supply for another 5 min, to understand the temperature change behaviour.

The electrical conductivity was measured by obtaining the resistance of the sample by using Keitley 487 Piccoammeter/voltage source. The voltage in the range of -0.8 V to 0.8 V was passed through the samples with the help of copper electrodes with a step of 0.1 V. The resistance can be determined by the slope of the graph drawn between voltage and current. Then the following formula was used to calculate the resistivity and the inverse of resistivity gives the electrical conductivity (Moreira et al., 2021).

Resistivity == R × A/L (Ωm) Where R = Resistance (Ω), A = Cross sectional area (m2), L = Distance between the electrodes (m)

RESULTS AND CONCLUSIONS

The electrical conductivity of the coated samples (Figure 1a) was improved with the addition of GNPs in the paste and also with the increase in the number of layers. The addition of larger quantities of GNPs creates more contacts, allowing the formation of a conductive network, which endows the free movement of electrons. To obtain Joule´s heating effectively, it is necessary to have a reasonable resistivity value and heating values will not be significant for a highly conductive material with a low resistivity value (Repon et al., 2021). Joule´s heating analysis when applying 12 V to the samples with 3 layers (Figure 1b) showed that the temperature attained by the samples also improved with the concentration.

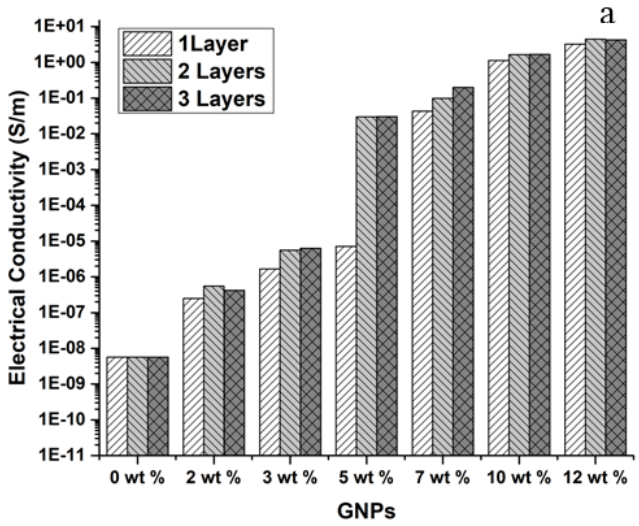

Fig.1a Conductivity values of the coated samples

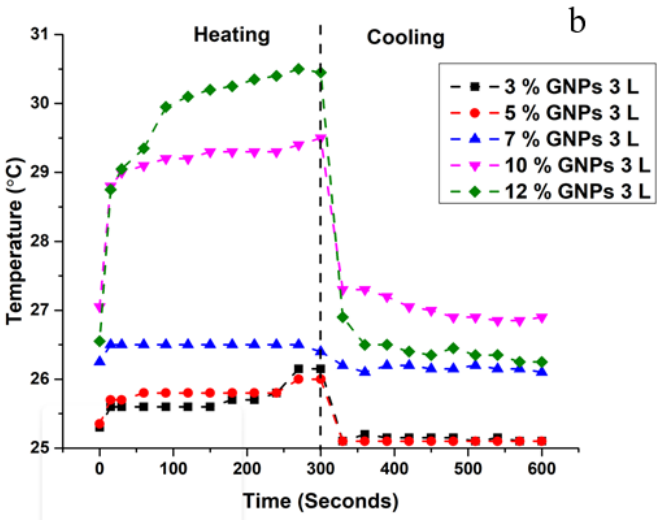

Fig.1b Joule heating of sample with 3 Layers

This study shows that the conductivity and heat-dissipating capability of the cotton fabrics can be enhanced with coatings, with the concentration of nanomaterials and the number of layers playing a crucial role. The temperatures achieved were not so high, requiring large GNP concentrations or high applied voltages. Since 12 V is the maximum possible voltage in the automotive sector, future work will be to add carbon nanotubes (CNTs) to GNPs to obtain a hybrid conductive network.

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ID202

THE INFLUENCE OF YARN ABRASION RESISTANCE ON WOVEN FABRIC ABRASION RESISTANCE

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ABSTRACT

In this research, the influence of structural parameters of yarn and fibre composition on its abrasion resistance is investigated. Furthermore, the influence of the mentioned yarn abrasion property on the fabric abrasion property was also analysed.

INTRODUCTION

Woven fabric abrasion is the physical destruction of fibers, yarns and fabrics that result from the friction of a textile surface against the surface of an abrasive object. In everyday use, textiles are exposed to abrasion, e.g. when worn (textiles to textiles friction, skin on textiles, various objects in textiles) and during the maintenance process (washing). Constant friction results in a decrease of the textile material strength which impairs both appearance and functionality. The abrasion resistance of woven fabrics is influenced by its structural and constructional characteristics, raw materials and finishing processes.

A higher value of yarn fineness will result in greater abrasion resistance. Plied yarns will have greater wear resistance due to their rein-forced structure. Weave, thickness, mass, density and crimp of the woven fabric have a direct impact on the topographic characteristics of the surface and thus on the abrasion resistance.

In general, fabrics woven in plain weave with maximum yarn interlacements, and consequently high compactness, are more resistant to abrasion. Therefore, they are often the choice for making protective clothing (firefighters, army) that have high requirements for abrasion resistance.

RESULTS AND CONCLUSIONS

In the investigation, three different yarns were used for weft: AR - 95% Meta Aramid Conex NEO; 5% Para Aramid Twaron raw, fineness 17x2 tex; MAC/CO - 45% Cotton Long Stapel Combed, 55% Modacrylic Sevel FRSA/L, fineness 20x2 tex and 25 tex. The same AR yarn was used in warp. Table 1 shows specifications of yarns and produced woven fabric samples.

Table 1 Woven fabric specifications

	Sample	Weft 1	Tt (tex)	Weft 2	Tt (tex)
	D1	MAC/CO x1	20x2	-	-
S1	**D4**	MAC/CO x2	20x2	AR x1	17x2
	D5	MAC/CO x4	20x2	AR x1	17x2
	D2	MAC/CO x1	25	-	-
S2	**D3**	MAC/CO x2	25	AR x1	17x2
	D6	MAC/CO x4	25	AR x1	17x2

Figure 1 shows yarn and woven fabric abrasion resistance, where: the blue bars show the number of cycles till rupture while testing fabric abrasion; the orange bullets show the number of cycles till rupture while testing yarn abrasion proportionally in mass ratio. Comparing the abrasion resistance of single and plied MAC/CO yarns, fineness 25 tex and 20x2 tex respectively, a significant impact of fineness and plying on the yarn abrasion resistance is noticeable. Plied, coarser MAC/CO yarn has 411.2% higher abrasion resistance than the single one. At the same time, the difference in abrasion resistance of woven fabrics with the same weft yarns is only 15.5% (in favor of fabrics with MAC/CO yarn).

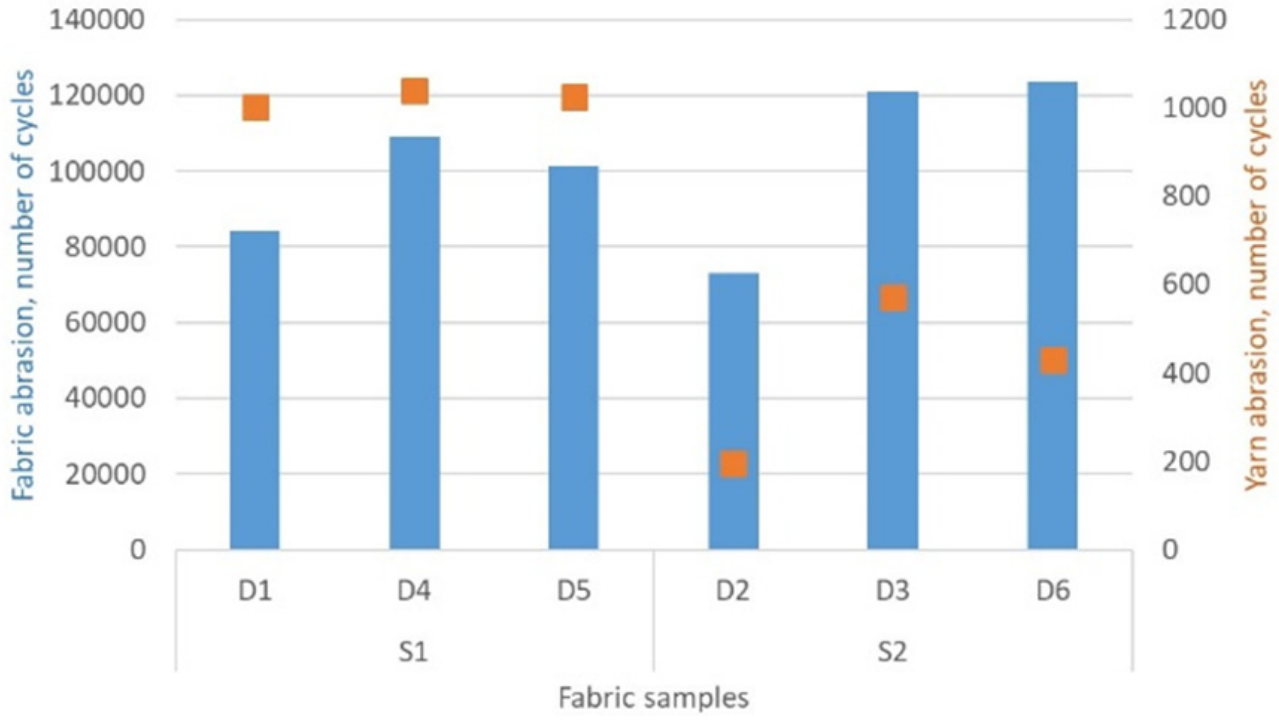

Fig.1 Yarn and fabric abrasion resistance

From the above it can be concluded that the abrasion resistance of yarns slightly affects the abrasion resistance of woven fabrics made from them. The same was confirmed by comparing other samples of fabrics and yarns from groups S1 and S2. For D3 and D6, the statistical difference in abrasion resistance is not significant (in the range of standard deviation). It can be concluded that although AR threads in the weft contribute to the woven fabric abrasion resistance, by increasing their share the impact on abrasion resistance weakens, i.e. is not proportional to the share of AR in the weft.

ACKNOWLEDGMENTS

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ID203

INFLUENCE OF WOVEN FABRIC STRUCTURE AND TYPE OF DYE ON IMPRINT DEFORMATION

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ABSTRACT

IPrinted camouflage fabrics are most commonly used to make military clothing. The printing process, as well as the quality of printing, is influenced by the properties of fibers and yarns, as well as the constructional and structural characteristics of fabrics. Based on the raw material composition of the yarns in a fabric, accordingly dyes are chosen for printing. Reactive dyes are used for cotton yarns, and disperse dye for polyester yarns. Pigment dyes that require a binder or adhesive to adhere to the fabric surface may also be used. Unlike dyes, pigments are not specific to certain raw material compositions, so a cotton/polyester blend can be printed with a single pigment. The pigments work equally well on 100% cotton fabrics and on different blends.

Printing is also affected by the type and construction of the yarn. Since the color of the print is applied on one side of the fabric, the uniformity, brightness and depth of the color are very sensitive to the hairiness, curl and shine of the yarn. If the luster of the yarn is higher the print will be lighter. Very twisted yarn may not allow the paste to penetrate deeply into the bundle of yarn, resulting in poor color fastness of the print.

The structural properties of textiles also influence the printing process itself as well as the properties of the final printed material. Eg woven fabrics are usually easier to print than knitted fabrics. The main reason is that woven fabrics are dimensionally more stable than knitted ones.

For the purpose of this research, fabrics in four different weaves - plain, twill 2/2, twill 1/3 and satin 4/1 were woven. Cotton yarn, fineness Nm 65/2, with 750 twists/m (S direction) was used to make the samples. Reactive and pigment dye were used for printing.

After sample preparation, changes in the shape of the print on different fabric weaves were noticed. Images taken with a Dino lite microscope at 62x magnification were analyzed using the ImageJ program. Images of round foil motifs, pattern, and fabrics were analyzed, and deformation properties were determined: roundness, solidity, and surface of the motif. Figure 1 shows changes in the shape and dimensions of the round motif prepared on the foil, transferred to the pattern and printed with dye and pigment on the fabric surface. The solidity (S) of printed motif stands for distortion of the motif edge. At the same time, edge distortion is larger with a lower value of solidity. The roundness (R) parameter indicates the deviation of the motif shape from the ideal circular shape. Figure 2 shows the change in the dimensions of the circular print, especially for dye and pigment, on samples with different fabric weave. The change in dimensions is most noticeable in pigment printing, mostly on the pattern in the plain weave.

Keywords: woven fabric, textile printing, dye, pigments

Figure 1: Changes in the shape and dimen-sions of the roundness motif

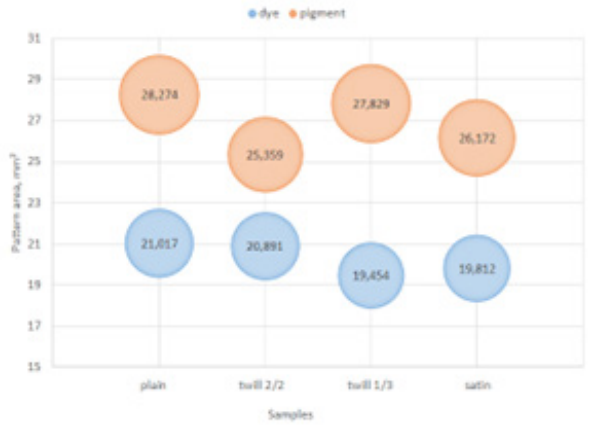

Figure 2: Change in the surface of printed motifs on different fabric weaves

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ID204

PVDF HOLLOW FIBER MEMBRANE FOR CO_2 REMOVAL FROM CONFINED SPACES

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ABSTRACT

Polyvinylidene fluoride (PVDF) hollow fiber membranes were obtained using adipic acid (AD) as additive in dope solution, and this membrane exhibit nanopores at the outer surface (40 to 100 nm). The PVDF hollow fibers produced were used in the gas–liquid membrane contactors process, aiming CO2 absorption in confined spaces. PVDF hollow fibers had better performance CO2 flux than commercial polypropylene hollow fibers.

INTRODUCTION

Polypropylene (PP) and polytetrafluoroethylene (PTFE) are the most used polymers to produce hollow fibers to membrane contactors in CO2 removal process. However, some disadvantages related to these polymers can be highlighted: PTFE, despite having great hydrophobicity, has a high production cost and PP, despite being cheaper and widely found commercially, has low chemical resistance to commonly used absorbent liquids.

Besides the two polymers cited above, polyvinylidene fluoride (PVDF) is widely used in hollow fibers manufacture. Its chemical structure is formed by a repeated chain of –(C2H2F2)– and exhibits great properties such as thermal, chemical and mechanical stabilities. PVDF membranes can be produced by different synthesis technics, such as, thermally induced phase separation (TIPS), non-solvent induced phase separation (NIPS), and vapor-induced phase separation (VIPS).

The PVDF hollow fibers produced were used in the gas–liquid membrane contactors process, aiming CO2 capture absorption in confined spaces. Adipic acid (AD) was selected as additive based on the results of Pereira et al., 2020 with propionic acid (PA). The authors observed that PA promoted a porous structure due to the capacity of forming Lewis acid-base complex with NMP.

RESULTS AND CONCLUSIONS

SEM analysis shown in figure 1 indicates that PVDF hollow fibers had outer and inner diameter of 1126 and 836 µm, respectively. From the photomicrographs, it can be also seen an anisotropic morphology. There are different porous regions in the cross section of the membrane. In the inner region, the pores are interconnected and exhibit a sponge-like morphology. In the region near to the outer surface, the presence of macropores is evident, where pores have finger-like morphology. The membrane exhibits outer surface porous with diameter ranging from 40 to 100 nm.

As shown in table 1, PVDF modules 1 and 2 present almost the same CO2 removal value, whereas PP module presented a much lower value, i.e. approximately 10 times lower. These results indicate the satisfactory performance of the PVDF hollow fiber membranes.

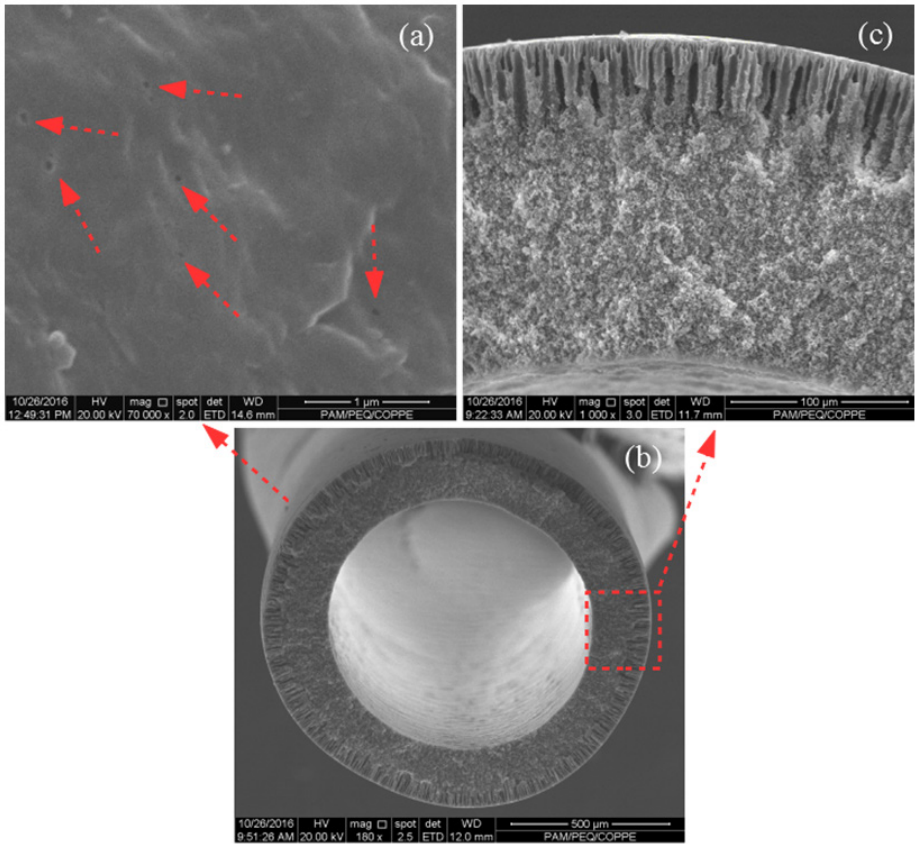

Fig.1 SEM analysis of PVDF hollow fiber: (a) Outer surface; (b) Cross Section; (c) Cross section detail

Table 1 Performance of PVDF hollow fiber and PP commercial module.

Module	polymer	Absorbent liquid flow (L/h)	Gas residence time (s)	CO_2 flux (x 10^4mol/m^2s)	CO_2 removal (%)	CO_2 removal (% m/fiber)
1	PVDF	50	0.5	1.18	4.95	3.31
2	PVDF	30	2	1.11	18.49	3.08
3*	PP	50	6	0.47	69.10	0.31

*Commercial module

PVDF module 1 presented CO2 flux of 118 x 10−6mol/m2.s, whereas PVDF module 2 had CO2 flux of 111 x 10−6mol/m2.s, i.e. flux values were quite similar. On the other hand, PP commercial module had flux of 47 x 10−6mol/m2.s, which is 2.5 times lower than PVDF modules.

ACKNOWLEDGMENTS

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ID205

METHODOLOGY TO OPTIMISE BALLISTIC PROTECTION SYSTEMS BASED ON AN EXPERIMENT/SIMULATION CORRELATION

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ABSTRACT
This work presents a methodology aimed to optimise multi-layer and multi-material ballistic protection systems using an experiment/simulation correlation. This methodology is applied to minimise the mass of an armour steel-aluminium alloy protection system.

INTRODUCTION
Ballistic protections usually result from an incremental and empirical approach and accordingly strongly depend on the experience and know-how of the manufacturer. Yet, in order to improve their specific ballistic resistance, current ballistic protections are more and more complex, based on multi-layer and multi-material systems, see Crouch (2017), and thus require the optimisation of a great number of parameters (e.g. layering order, thicknesses, number of layers, etc). In this context, numerical simulation-aided design has become indispensable, see for example Paman (2019). The methodology developed in the present work relies on a correlation between experiments and simulations following three steps: (i) calibration and verification of a numerical model, (ii) validation of the model and (iii) use of the model in an optimisation process.
Results of impact experiments involving simple configurations are used to feed an automatic calibration process based on numerical simulations performed with the explicit commercial finite element code Abaqus coupled to the Isight optimisation software. More specifically, the model parameters that depend on the strain rate and related to damage and rupture are identified at this stage (step (i)). Step (ii) validates the parameters of the previously calibrated model, comparing the experimental and numerical results obtained by impact tests on more complex configurations (not used in step (i)). If the correlation fails, a corrective loop is added between step (i) and step (ii) until the results match. As mentioned above, step (iii) aims to optimise a multi-component ballistic protection system (stacking order, layer thickness, etc.) for a given threat, in order to determine the best ballistic performance-mass ratio compromise.

RESULTS AND CONCLUSIONS
This procedure has been applied to a bi-layered protection system, composed of an armour steel (MARS 380) plate and an aluminium alloy plate, impacted by a tungsten carbide projectile similar to a 7,62×51 AP8 ammunition core. Impact tests are carried out with a single stage gas launcher available in STIMPACT platform of Institut Clément Ader Lab. Model parameters were calibrated and verified in step (i) with a single plate (armour steel and aluminium alloy separately), and validated in step (ii) in a bi-layered configuration. Fig. 1 shows a good agreement between experimental and numerical results (8.8 mm MARS 380 armour steel (“MS8.8”) as front layer and 8.0 mm aluminium alloy (“AA8”) as rear layer, “MS8.8-AA8”). According to Fig.1, the ballistic limit velocity (BL v) is close to 720 m/s.
Finally, the position and thickness of each plate were optimised in step (iii). Table 1 reports some final optimised

designs for an arbitrary v_{BL} of 345 m/s

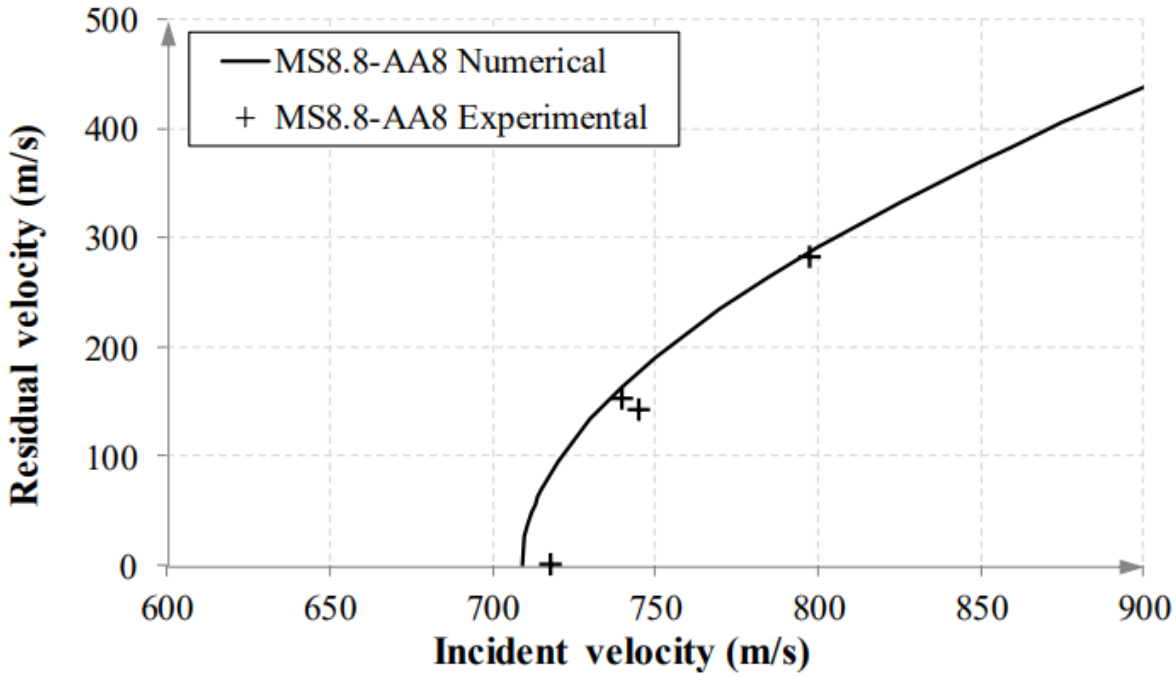

Fig.1 Comparison between experiments and simulations of a tungsten carbide projectile impacting a bi-layered protection system: 8.8 mm-thick MARS 380 armour steel as front layer and 8.0 mm-thick aluminium alloy as rear layer ("MS8.8-AA8")

Table 1 Optimisation results. Threat: tungsten carbide projectile at 345 m/s

Ballistic protection system	Front plate thickness (mm)	Rear plate thickness (mm)	Mass per unit area (kg/m²)
MS8.8-AA8	2.00	4.73	28.4
AA8-MS8.8	3.96	2.01	26.5

According to Table 1, a ballistic protection with an aluminium alloy as a front plate and an armour steel plate as a rear plate could be 7% lighter than the opposite configuration against the considered threat (tungsten carbide projectile at 345 m/s). This study allowed to optimise a ballistic protection system with a relatively low number of experiments, and paves to way to more complex optimisations (e.g. regarding materials, number of layers, air gaps, etc).

ACKNOWLEDGMENTS

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ID206

DEVELOPMENT OF AN ELECTROLUMINESCENT DEVICE BY SPRAY COATING OF FUNCTIONAL LAYERS

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ABSTRACT

The main objective of the present study is to develop an electroluminescent device by applying a set of specific layers. For that, a polymeric substrate was functionalized by spray-coating with commercial products, solvent-based and water-based inks. A thorough study was carried out on the different parameters of application in order to optimize and fully control the process for further developments.

INTRODUCTION

In recent years, automotive industry is developing efficient lighting technology and providing better light quality to improve the user experience inside the car. The development of lighting solutions over these recent years has been driven by a number of factors, namely increased brightness, longer lifetime, lowcost, and more efficient devices that use more environmentally-sustainable materials (Kathirgamanathan et al., 2015).

In this context, some lighting technologies, as LED, OLED or EL have been recently developed in the market. Electroluminescence is gathering further highlight due to its versatility and can be defined as “the phenomenon whereby light is emitted from a material following the application of an electric field to it.” (Kathirgamanathan et al., 2015).

The production of EL devices can be achieved by various techniques such as spray coating, knife coating, screen printing, inkjet printing, among others.

In this present work, the used technique is spray coating. All layers are applied on a polymeric substrate, allowing to create an electroluminescent device system, according to the materials below:

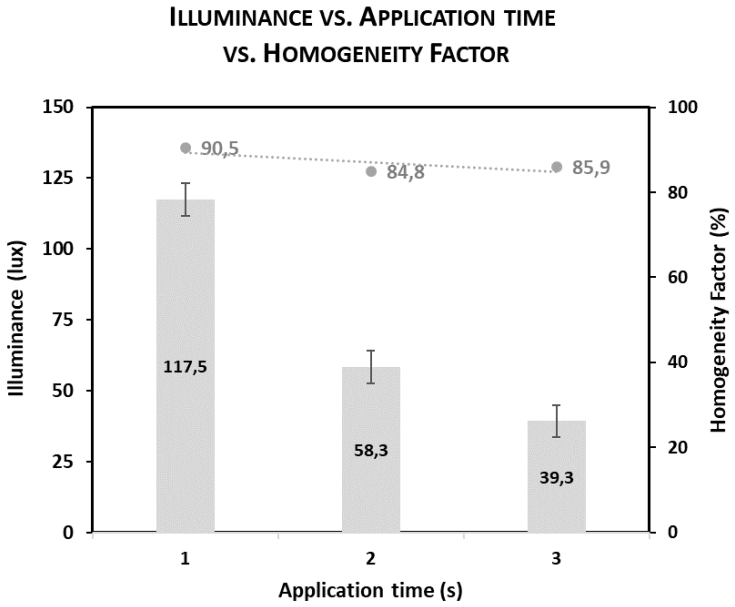
- Back electrode –Highly conductive low resistance first layer;
- Dielectric – Electrical insulator that is polarized by an applied electric field;
- Phosphor – Luminescent material that emits light when excited by electricity;
- Busbar – Conductive layer that provides a low resistance path for better current distribution;
- Front electrode – Translucent conductive material sprayed over the entire surface.

Commercial inks were purchased from supplier Lumilor, Germany. In order to understand their composition, some characterization methods were used for each ink, such as water contact angle, FTIR and SEM-EDS. The deposition of ink layers was performed on a PC/ABS substrate, with a flat surface or a 3D curved surface, in various sequential phases and using two different HVLP spray guns with a nozzle diameter of 0.8 and 1 mm.

In order to optimize the illuminance values and distribution on the substrate, the samples were produced according to different parameters, more precisely: variation of distance between the spray gun nozzle and the surface substrate, different application modes and different application times per sprayed line.
At the end, the samples were investigated regarding their illuminance with a lux meter, in different points of the sample, to evaluate the homogeneity level of ink layers on the substrate. These measurements were performed by applying a voltage of 12 V DC, which must be converted in AC voltage using an inverter, in order to make the EL device functional.

RESULTS AND CONCLUSIONS

The main conclusions are that the deposition time of 1 s per sprayed line gave the best illuminance and homogeneity values (Figure 1a). It is crucial to achieve a thin coating (Figure 1b), which allows to reduce the amount of material. In turn, the optimal distance between the surface and the nozzle diameter showed to be 20-25 cm and the best application mode is horizontal and vertical, covering the whole area between 50% and 75%.



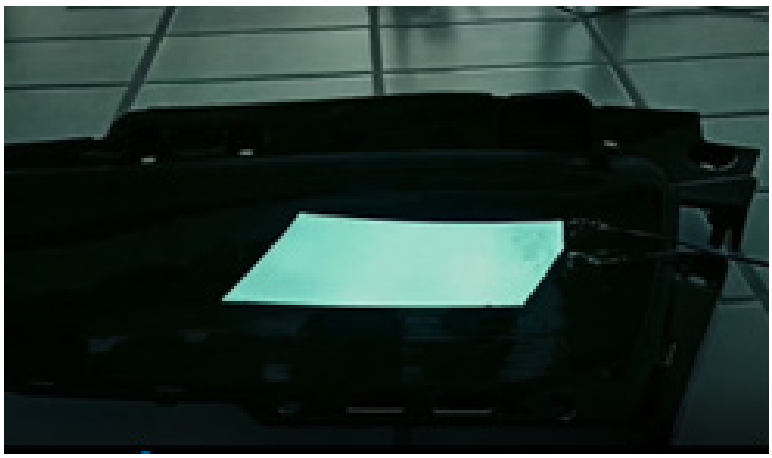


Figure 1. (a) Illuminance vs. Application time vs. Homogeneity Factor; (b) EL device.

An innovative composition for the back electrode is currently in progress in our lab, which is tested with the other commercial inks in order to evaluate the overall EL device performance.

ACKNOWLEDGMENTS

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ID207

A DATA PROCESSING TO IMPROVE THE CAPABILITIES IN DEFENSE VIA PLASMONIC CHEMICAL SENSORS IN MULTIMODE OPTICAL FIBERS

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ABSTRACT

Bio/Chemical pre-analysis for the detection of danger substances in water could be obtained via plasmonic polymer optical fiber (POF) sensors. These sensor configurations are based on a Surface Plasmon Resonance (SPR) platform in POFs combined with specific receptors, such as Molecularly Imprinted Polymers (MIPs). The multimode optical fibers produce spectra with large full width at half maximum (FWHM) of the SPR curve. To mitigate such a drawback, here, we propose a spectral estimation signal processing method that could be used in favour of a reduction in the FWHM, by improving, thus, the capability to read the SPR minimum.

INTRODUCTION

SPR and Localized SPR are widely used as detection principles for many sensors operating in different application fields, such as bio and chemical sensing in defense. When artificial receptors are used for bio/chemicals detection, the thin dielectric layer on the metal surface (usually a gold surface) selectively recognizes and captures the analyte present in a liquid sample, so producing a local change in the refractive index at the metal surface of the plasmonic surface. In the literature, several different sensing configurations based on SPR in silica optical fibers and POFs have been described (Wang, 2016). When artificial receptors as MIPs are used for bio/chemicals detection, low-cost plasmonic POF platforms are suitable for different application fields; e.g. for the TNT detection in water solutions (Cennamo, 2013; Cennamo, 2015). The SPR-POF-MIPs-based sensors, however, generally produce spectra with large full width at half maximum of the SPR curve. To counteract this drawback, signal processing methods can be exploited (Buonanno, 2021; Buonanno, 2022). Here, in particular, we propose a processing scheme based on the MUSIC spectral estimation algorithm. It is shown that this allows to decrease the FWHM of the SPR spectra, even by employing a reduced set of measurements. The FWHM reduction is extremely interesting because it could improve the capability to read the SPR minimum, making this kind of sensor simple to use in several application fields (e.g. defense and security), exploiting friendly software interfaces.characterization methods were used for each ink, such as water contact angle, FTIR and SEM-EDS. The deposition of ink layers was performed on a PC/ABS substrate, with a flat surface or a 3D curved surface, in various sequential phases and using two different HVLP spray guns with a nozzle diameter of 0.8 and 1 mm.

RESULTS AND CONCLUSIONS

The experimental setup is arranged to measure the light spectrum transmitted through the SPR-POF-MIP sensor and consists of a halogen lamp, illuminating the POF sensor, and a spectrometer (Cennamo, 2013). The SPR-PO-

F-MIP sensor system is shown in Fig. 1.
Once the transmitted spectra have been collected, after normalizing transmitted spectra with a reference spectrum (SPRref) corresponding to air, sensing is achieved by picking up the wavelength corresponding to the extreme (minimum or maximum depending on whether IM=SPRtransmitted/ SPRref or IM=SPRref/SPRtransmitted is considered) of the normalized spectra.

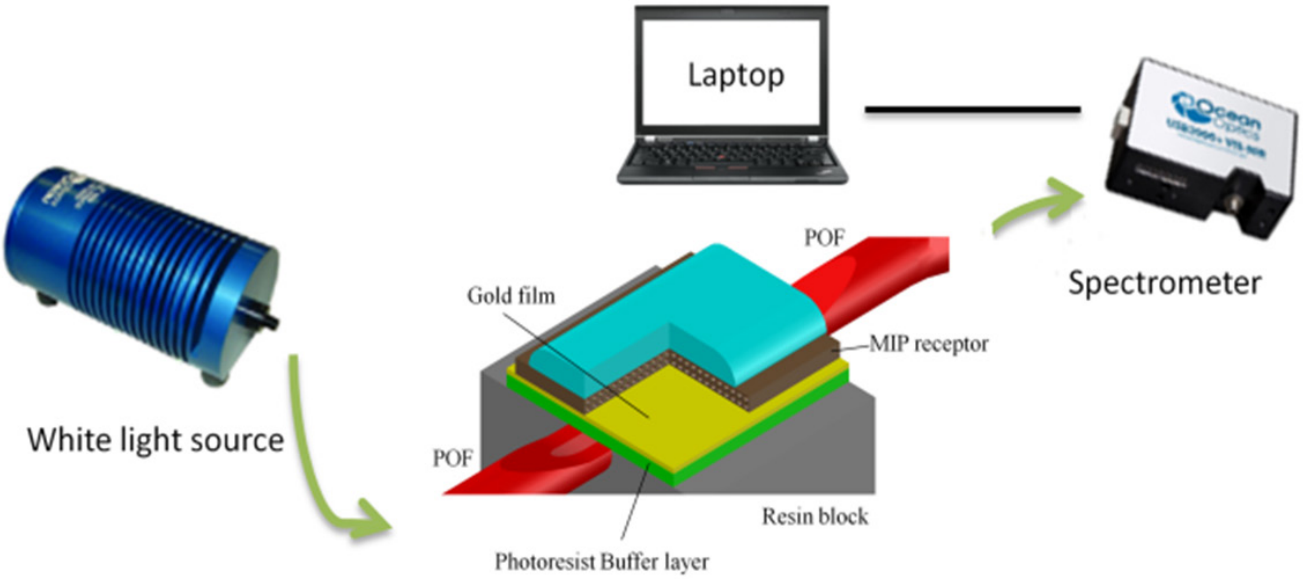

Fig.1 SPR-POF-MIP sensor system.

This is a critical task whose precision can be impaired due to noise, to the smoothness of the curve around the local extreme (related to the FWHM) and to the sampling interval in the wavelength. This can be appreciated by the blue curve depicted in Fig. 2, which shows IM/max(IM) in dB scale collected over 2048 wavelength data (at a water solution with a refractive index (n) equal to 1.341). In the same figure, the estimation returned by the proposed method is as well reported. As can be seen, the automatic identification of the maximum is much sharper and what is more it has been obtained by employing only 250 data. Hence, the method proves to be able to reduces the FWHM even by employing much less data.

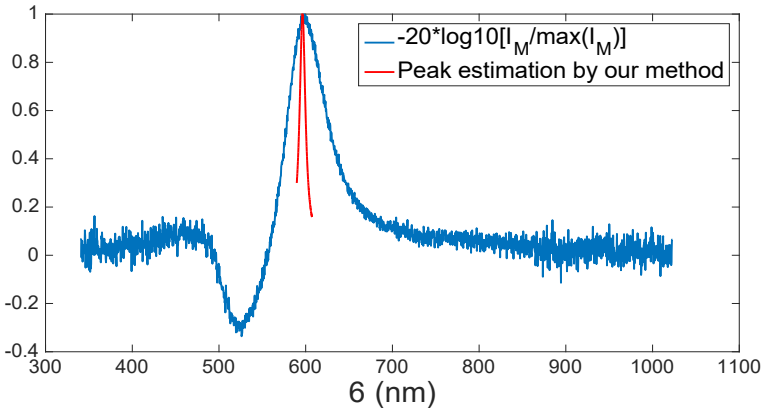

Fig.2 Comparison between normalized IM (blue curve) and the estimation returned by our algorithm (red curve) at a solution with n=1.341.

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ID208

AUXETIC MATERIALS AND STRUCTURES FOR POTENTIAL DEFENSE APPLICATIONS

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ABSTRACT

An auxetic material exhibits exceptional features compared to conventional material. It gets broadened when it is stretched or becomes smaller when it is compressed because it has a negative Poisson's ratio. Moreover, auxetic materials possess some enhanced properties, such as shear resistance, indentation resistance, fracture toughness, energy absorption, etc. These enhanced properties make the auxetic materials very attractive for many potential applications. This paper reviews the latest advances in research work in structures, mechanical properties, the manufacturing methods of auxetic materials used for defense applications, including armor systems. The results obtained here serve as additional guidelines to assist engineers and designers in the use of auxetic materials for military personnel protective clothing.

INTRODUCTION

Auxetic materials and structures, which produced based on woven structures, knitted structures, nonwoven structures, and braided structures (Alderson et al., 2005; Hu et al., 2019), can exhibit a negative Poisson's ratio (NPR) (Boakye et al., 2019; Wang & Hu, 2014). Each auxetic structure can exhibit different deformation mechanisms and auxetic performance (Evans, 1991; Hu et al., 2019). Therefore, military personnel protective clothing including jackets, shirts, pants, helmets, boots, gloves, and even body armor is a necessity. A special material that is used to fabricate armour system must absorb energy locally and be able to spread the energy out fast and efficiently is necessary for protection purposes. This article comprehensively demonstrates an organizational integration of (i) mechanical properties of auxetic materials and structures (Boakye et al., 2019; Chan & Evans, 1999; Francisco et al., 2021; Hu et al., 2019; Jiang et al., 2022; Li et al., 2020; Liu, 2006; Luo et al., 2021; Scarpa et al., 2006; Steffens et al., 2016; Wang & Hu, 2014), (ii) manufacturing methods (Hu et al., 2019; Jiang et al., 2022; Liu, 2006; Underhill, 2014) and (iii) potential applications in defense (Hu et al., 2019; Jiang et al., 2022; Steffens et al., 2017; Steffens et al., 2016).

RESULTS AND CONCLUSIONS

Some auxetic materials and structures, mechanical properties, manufacturing methods, and potential defense applications are covered in this report. This is the premise for our further studies in the design and production of auxetic materials for protective clothing.

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ID209

MECHANICAL RESPONSE OF HYPERELASTIC HONEYCOMB BASED STRUCTURES MANUFACTURED ADDITIVELY

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ABSTRACT

This work presents the results of experimental and numerical studies related to the mechanical response of regular cellular structures subjected to in-plane compression under quasistatic and dynamic loading conditions. Structure samples were developed based on the honeycomb topology taking into account variants where the unit cell size was gradually changed. Subsequently, structure samples were manufactured additively using the FFF technique and TPU 95 flexible thermoplastic polyurethane TPU 95 with hyperelastic mechanical properties. Based on the carried out tests it was revealed that applied material indicate a strain rate sensitivity and proposed bidirectional gradient structure sample results in the highest energy absorption capacity.

INTRODUCTION

Structural materials are a very prospective group of engineering materials that exhibit specific mechanical properties like low mass and high mechanical strength [1]. Observed over the last ten years growing popularity of additive manufacturing techniques caused increased interest in structural materials [2]. A wide group of available AM techniques and a variety of available materials (polymers, resins, metal powders, metal wires) used in the manufacturing process enable defining structures with complex topologies that were not possible to obtain. Moreover, depending on the adopted unit cell topology and mechanical properties of the original material used in the manufacturing process, it is possible to define the mechanical response of regular cellular structures. Programming the mechanical response of structure materials is especially crucial in terms of energy absorption application. The main aim of conducted studies discussed in the paper is a presentation of results related to the energy absorption capacity of regular cellular structures subjected to mechanical compression tests under quasi-static and dynamic loading conditions.

RESULTS AND CONCLUSIONS

Experimental tests were conducted with the use of additively manufactured 2D specimens presented in Fig.1. Standard honeycomb topology and its modifications with gradually changed unit cell size resulting in different values of the relative density were designed and manufactured via fused filament fabrication (FFF) 3D printing technique. The material used in the fabrication process was TPU 95 flexible thermoplastic polyurethane filament which indicates high flexibility. The specimen fabrication process was carried out with the use of a Prime 3D (MonkeyFab) 3D printer. Furthermore, it was preceded by technological studies necessary to optimize the parameters of the 3D printing process. The main view of manufactured specimens is presented in Fig.1. The applied technological process parameters allowed for obtaining a good agreement between the assumed and real dimensions of the manufactured samples. Discontinuities of the material structure, voids, and other imperfections were not observed in the walls of specimens. Furthermore, quality control measurements with the use

of digital microscopy were carried.

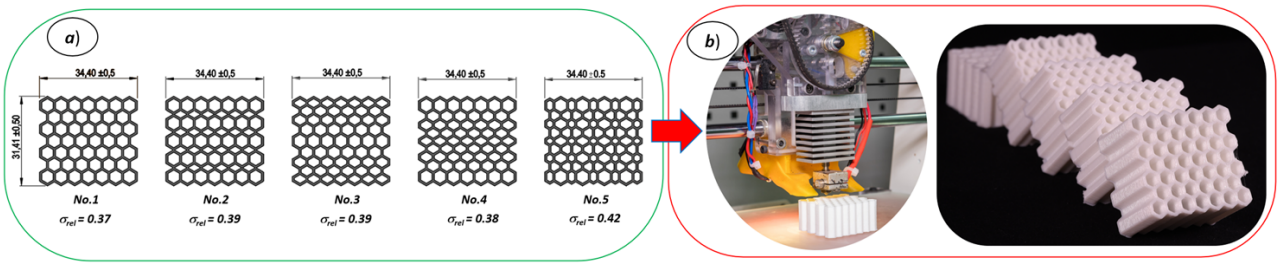

Fig.1. The main view of structure specimens subjected to studies: a) proposed topologies, b) manufacturing process with the use of the FFF technique

The subsequent stage of carried out investigations was related to compression tests under quasistatic and dynamic loading conditions. The main aim of these tests was the evaluation of the mechanical response of specimens in terms of various relative densities, as well as the influence of quasi-static and dynamic loading conditions on the deformation process. Exemplary results obtained in the case of typical honeycomb topology are presented in Fig.2-3. Figure 2 illustrates the mechanical behaviour of the structure samples under compression tests. In turn, Figure 4 contains graphs presenting the deformation force-shortening relation for the honeycomb structure under quasistatic and dynamic loading conditions.

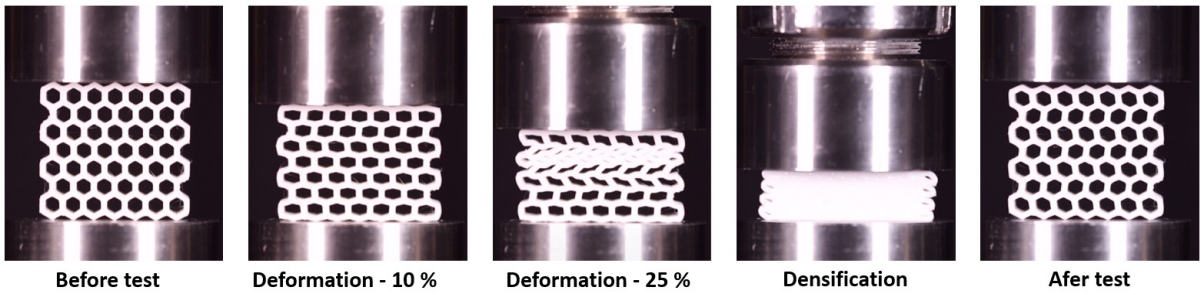

Fig.3. The main stages of honeycomb specimen deformation process under quasi-static compression test

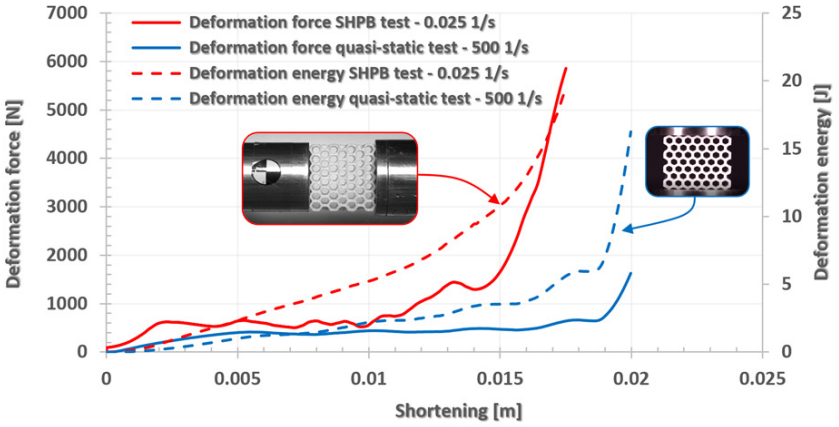

Fig.4. The history of deformation force and deformation energy vs shortening obtained for honeycomb structure topology

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ID210

NATURAL AND SYNTHETIC FIBRES TO ENHANCE THERMOPHYSIOLOGICAL PROPERTIES IN THE PREVENTION MEDICAL FIELD

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ABSTRACT

This study aims to analyse the complementarity of natural and synthetic fibres to improve the thermal physiological properties of knitted fabrics used in clothing for bedridden patients. To this end, a 100% cotton (CO) yarn, a mixture yarn composed of CO and Viscose outlast (CV), a Modal yarn (MO) and a Polyamide yarn (PA), generated 8 different combinations of platted knitted fabrics. Structural characterization of the samples, permeability analyses (EN ISO 9237 and BS 7209: 1990), and Moisture Management tests (AATCC Method 195) were carried out, and their thermal properties were compared to pyjamas normally used in hospitals, made of 100% CO.

INTRODUCTION

Bedridden patients need special attention regarding skin care to avoid the development of bedsores. In this context, The Clinical Practice Guideline 2019 considers that excess moisture can lead to maceration and contribute to skin degradation, as well as the impact of oxygenation impairment and increased body temperature interferes with pressure injuries (Kottner et al., 2019). Therefore, regarding the technical quality of clothing for bedridden, thermoregulatory properties are an important requirement that provides a comfortable thermal and humid state, and therefore contributes to preventing the development of the aforementioned pressure sores. Given the above, many efforts have been made so that textile substrates can regulate the body microclimate, through phase change materials incorporated into fibres, that allow the storage, release, or absorption of energy in the form of heat. Some studies have shown the superior thermoregulation capacity of such fibres (Fangueiro et al., 2010). However, at the same time, slow moisture drying is noted (Hussain et al., 2015). This assumption reinforces that for the elaboration of a textile structure for thermophysiological control purposes, it is necessary to dedicate efforts to the bi-layer textile structures, with the use of multiple fibres that have complementary properties.

That said, on the face in direct contact with the skin, the priority was a fibre capable of keeping the microclimate between the skin and clothing balanced, and the composition CO and CV outlast was chosen. The choice of fibres for the external part is in line with previously published studies, where Muhammad et al., (2021) indicate that the use of MO fibre has a high radius of moistening, good absorption rate and good sweat spreading speed. And, on the other side, Ahmed Babar et al., (2020) suggest that PA is more suitable for the external side of the knitted fabric due to its intrinsic hydrophilic nature and low swelling characteristics.

RESULTS AND CONCLUSIONS

As we can see in Fig. 1, the hospital pyjamas has rapid and high wettability, but poor one-way transport capacity. Being made 100% of intrinsically hydrophilic fibres, a constant sensation of wetness can be caused to the wearer.

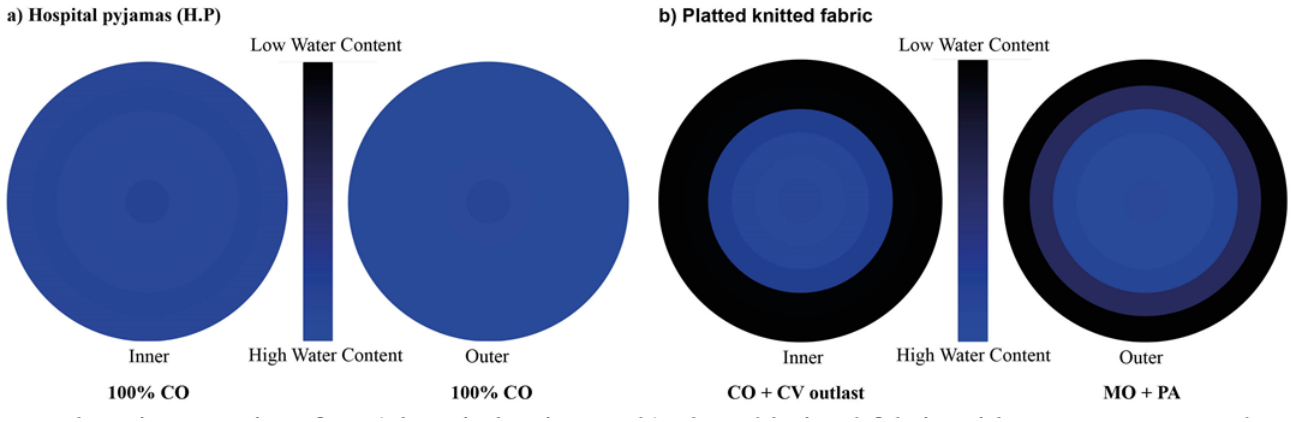

Fig. 1 Water location vs. Time for: a) hospital pyjamas; b) platted knitted fabric with CO, CV, MO and PA

However, the presence of the outlast CO/CV in direct contact with the skin gave rise to remarkable Moisture Management capacity, superior to the 100% CO sample, which confirms its use on the inner side of the knitted fabric. The absorption rate improved considerably by adding MO on the outside of the sample. In addition, the one-sided transport capability is made excellent by adding PA on the outside of the fabric. Furthermore, when the categories absorption and transport are analyzed together, the junction between MO and PA on the outside of the knitted fabric improves its moisture management, increasing the absorption rate by more than 60%. We can conclude from the results obtained, that the junction between cotton with PA and MO significantly improves moisture management, and, consequently, contributes to maintaining a balanced microclimate between the patient's skin and clothing. In future works, it is expected to expand the study of these knitted fabrics for health care, with the incorporation of microcapsules with essential oils for hydration and antibacterial purposes.

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ID211

SMART PERSONAL PROTECTIVE EQUIPMENT: FROM NANO TO MACRO FUNCTIONAL FIBERS

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ABSTRACT

One of the most recent and interesting strategies for the development of multifunctional personal protective textiles is the functionalization of natural fibers and micro/nanofibers with nanoparticles (NPs). In this work, several examples of fibers structures at macro, micro and nanoscale will be presented functionalized with several nanomaterials, like silver (Ag), zinc oxide (ZnO), calcium oxide (CaO), silica (SiO2) and graphene nanoplatelets (GNPs) in order to introduce several functions, namely antibacterial activity, hydrophobicity and especially electrical properties (electrical conductivity and piezoresistive effect).

INTRODUCTION

Natural fibers, including cellulosic, protein, and mineral fibers are collected directly from nature and are considered eco-friendly materials. Compared with synthetic fibers, they present numerous advantages, including high abundance, low-cost, biodegradability, biocompatibility, low-weight, and good mechanical properties [1].

One of the most recent strategies for the natural fibers surface treatment is the incorporation of nanoparticles. Several types of metal and metal oxide nanoparticles can be used (silver-Ag, zinc oxide-ZnO, calcium oxide-CaO, silica-SiO2, magnesium oxide-MgO and graphene nanoplatelets, between others) to introduce different functions such as antimicrobial activity, degradation of harmful chemicals, antistatic capability, self-cleaning, UV protection, flame retardancy, thermoregulation, electrical conductivity and piezoresistivity to natural fibers. The fibers' functionalization with these materials (doped and co-doped), allow the development of new fibrous systems with applications in several areas [2][3][4][5].

In the military sector those can be used for: monitoring vital biological signs of soldiers, chemical/biological protection and self-decontaminating systems [6]. They can also be used for the development of therapeutic solutions (wound healing, wound dressing, second skin systems and drug delivery systems.

Micro/nanofibers produced by electrospinning are acquiring great interest for the development of innovative smart fibrous structures, due to their remarkable characteristics, such as high surface-volume ratio, high porosity, lightness and high flexibility. The functionalization of polymeric nano/microfibers with nanomaterials has been revealed a promising strategy to create flexible systems for monitoring/sensing applications, without adding extra weight to the systems [7]. Due to the surface properties of the fibers at nano/microscale they arise as a great alternative to replace the macro fibers in applications such as filtering membranes for personal protective equipment (ex: facemasks) [8].

RESULTS AND CONCLUSIONS

Natural-based fabrics, such as jute and flax, were functionalized with several types of NPs, Ag, ZnO, CaO, SiO2 and GNPs. GNPs were used to functionalize flax fabrics and PCL electrospun microfibers, which resulted in conductivity values of 0.04 S/m and 0.079 S/m using 2 % of GNPs and gauge factor (GF) values of 1.89 and 3.20 using 0.5 % GNPs, respectively, demonstrating the potential of these samples to be used as piezoresistive sensors (Fig. 1 a-d). NPs of Ag, ZnO, CaO and SiO2 were successfully synthesized always considering the methodologies' sustainability, allowing the development of systems with electric conductivity, piezoresistive behavior, antibacterial activity against Gram-positive and Gram-negative bacteria and hydrophobicity (Fig. 1 e-g). Other

properties like UV-protection and degradation of harmful chemicals were also obtained.

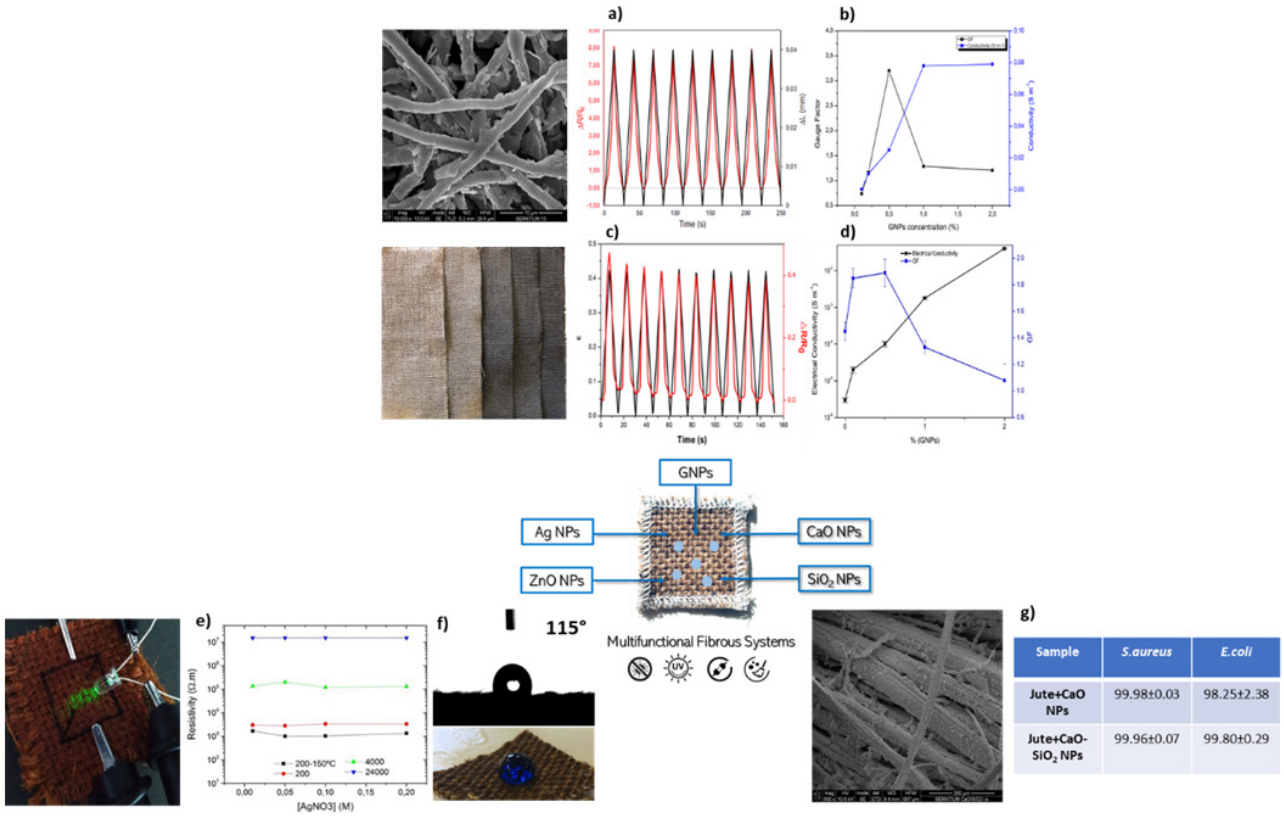

Fig. 1 Piezoresistive response of GNPs-PCL membrane (a) GNPs-flax ecomposite (c) and electrical conductivity and GF in relation to the GNPs concentration of GNPs-PCL membrane (b) and GNPs-flax ecomposite (d). Dependence of the resistivity values on AgNO3 concentration for jute fabrics with Ag NPs (e). Water contact angle of flax fabrics with Ag-ZnO NPs (f) and antibacterial activity of jute fabrics with CaO and SiO2 NPs (g).

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ID212

FUNCTIONALIZATION OF FIBROUS SUBSTRATES WITH MESOPOROUS SILICA NANOPARTICLES AS A STRATEGY TO OBTAIN PHOTODYNAMIC ANTIMICROBIAL TEXTILES

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ABSTRACT

This work presents the development of antimicrobial textiles through the use of Photodynamic Inactivation, a new promising approach that inactivates microorganisms in a very efficient way. To achieve that, we firstly synthesized amino functionalized mesoporous silica nanoparticles that were loaded with Azure A or Rose Bengal. Further the nanoparticles were incorporated into Cotton fabrics by pad-dry cure and exhaustion methodologies. The antimicrobial textiles were characterized by ATR-FTIR, Diffuse-Reflectance, Fluorescence Microscopy, Scanning Electronic Microscopy and singlet oxygen generation. The results showed that the antimicrobial textiles efficiently produce singlet oxygen being a promising new approach in the design of antimicrobial substrates.

INTRODUCTION

Although many of antimicrobial textiles have been developed, the design of safe, scalable, low-cost and robust antimicrobial textile, that covers all the spectra of microorganisms, continue to be a challenge. A new promising approach that can circumvent this issue is Photodynamic Inactivation (PDI), a technique that combines two individually non-toxic components (photosensitizer and light) that in the presence of molecular oxygen produces reactive oxygen species (ROS), including singlet oxygen ($^1O_2$) that inactivates the microorganisms. One of the main advantages of PDI is their non-specificity, since ROS attacks multiple molecular targets as lipids, proteins and nucleic acids, providing cell lysis and death (Cieplik et al., 2018). Additionally, PDI itself does not cause resistance and inactivates the microorganisms in a very short time (Hamblim, 2016). Despite that, due to its short lifetime (3-4 μs), singlet oxygen diffusibility is limited (< 300 nm) (Cieplik et al., 2018). Whit this in mind, in this study we functionalize fibrous substrates with amino functionalized mesoporous silica nanoparticle (MCM) containing phenothiazine and xanthene dyes aiming to produce antimicrobial textiles. Firstly, MCM was synthesized according to the procedure adopted by Silva and co-workers (Silva et al, 2019) followed by the loading of Azure A (AA, physically adsorbed) and Rose Bengal (RB, chemically adsorbed following the procedure used by Estevão and co-workers (Estevão et al, 2015)). Finally, the nanoparticles labeled as MCMAA and MCMRB (0.2 % w/w) were incorporated on a Cotton fabric (CO), supplied by Lameirinho, Portugal, by pad-dry cure (wet pickup 80) and exhaustion (60 °C, 30 min.) methodologies. The samples were characterized by ATR-FTIR, Diffuse-Reflectance, Fluorescence Microscopy, Scanning Electronic Microscopy and singlet oxygen generation.

RESULTS AND CONCLUSIONS

Among the methods utilized, the exhaustion showed to be the best one. The ATR-FTIR spectra (not shown) presents the characteristic Si-O and Si-O-Si stretching of silica at, respectively, 860 and 790 cm-1. Diffusive reflectance UV-Vis spectra (Fig.1A) depicted the characteristic bands of AA and RB, which are bathochromically shifted regarding the aqueous solution. This effect is ascribed to a change in the chemical microenvironment of the dyes due to their confinement inside the pores (Estevão et al., 2015). Figure 1B showed images of the substrates treated with AA (left), MCMAA (middle) and MCMRB (right), as well as SEM of the CO_MCMAA, where it is possible to see the silica nanoparticles (~150 nm).

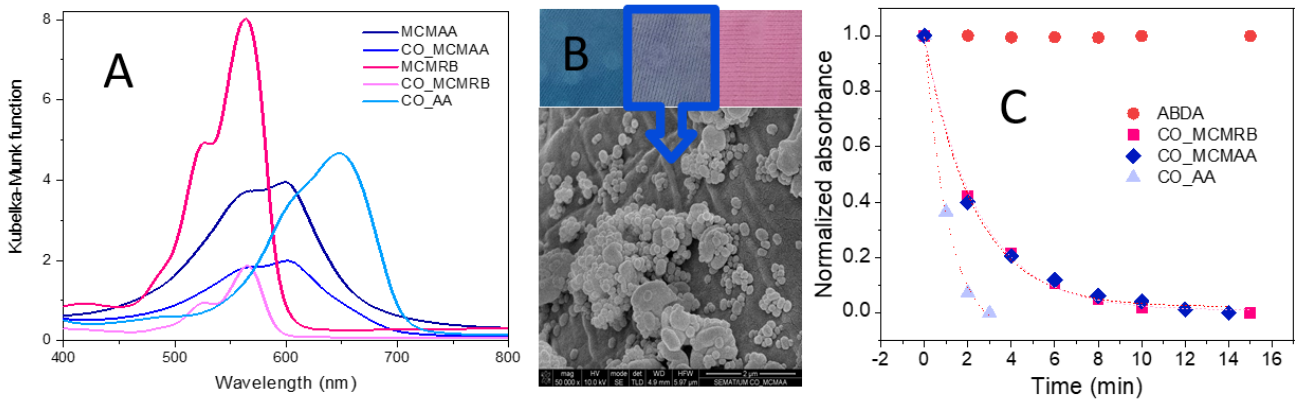

Fig.1 A. DR UV-Vis spectra of MCMAA, MCMRB, CO_MCMAA, CO_MCMRB and CO_AA. B. Picture of the treated fiber and SEM micrography of CO_ MCMAA. C. Kinetic of degradation of ABDA.

In order to evaluate the 1O2 production, the established ABDA assay (Entradas, 2020) was done irradiating (white led, 46.6 J cm-2) a fraction of 0.8x0.8 cm2 of the fibers. The kinetic degradation of ABDA caused by attack of 1O2 (Fig. 1C) assures that the singlet oxygen is efficiently produced from the modified fibers. This study shows the photodynamic potentiality of the designed fibers in order to achieve antimicrobial textiles. Further microbiologic assays should be performed in order to analyze the in vitro efficiency of the material.

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ID213

FUNCTIONALISED TEXTILES WITH ZNO NANOPARTICLES FOR ACTIVE BIOLOGICAL PROTECTION

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ABSTRACT

The present study assessed the antiviral and antibacterial performance of zinc oxide (ZnO) nanofibers integrated onto both reusable (woven fabric) and disposable (non-woven fabric) face masks. The goal of the research is to produce a face mask that can be reused while maintaining durable antimicrobial effects, thereby reducing the waste of the market-dominant polypropylene masks, which represent a significant threat to the environment. Our preliminary results show an effective degradation of both virus and bacteria, while maintaining filtration and breathability performance of the manufactured face masks, which are paramount indicators for users' acceptance.

INTRODUCTION

As occurring with the COVID-19 pandemics, all recent virus' outbreaks – SARS-CoV coronavirus (2002), Swine influenza (2009), Mers-CoV (2012) – were air-borne and have been associated with severe pulmonary disorders and/or damage. Right after social distancing, face masks were the most cost-effective solution in the battle against COVID-19. Despite the many developments triggered by this calamity, there is still a large unmet need for a face mask made from smart materials that can actively repel, ideally degrade, viruses and bacteria, while maintaining high breathability. Such face masks could significantly improve healthcare readiness for coping with the next pandemic. Different non-woven and woven fabric materials were tested with the deposition of electrospun nanofibers enriched with ZnO nanoparticles (NPs), namely regarding antimicrobial activity and breathability of the face masks produced. The different fibrous macrostructures were placed over an electrospinning flat collector, where a functionalised randomly-oriented nanofibrous matt was deposited. For that, a polyamide (PA) solution composed of 20 wt% PA in formic acid (90%) and acetic acid (10%) added with 0.5 wt% ZnO NPs was used in the injection syringe. A fixed voltage of 28 kV was applied to the steel capillary needle (22G), a feeding rate of 0.4 mL/h was used with a needle-to-collector distance of 10 cm. Temperature and relative humidity were kept constant at 25°C and 58% respectively.

RESULTS AND CONCLUSIONS

The results show that the filtrating layer of the face mask can effectively entrap the ZnO NPs within the deposited electrospun PA fibers (diameters of 758.5 ± 69.1 nm) (see Fig.1a), exhibiting strong and dose-dependent (70-100% growth inhibition) antimicrobial potency against reference strains of bacteria such as the Staphylococcus aureus and the bacteriophage MS2 as a surrogate of the SARS-CoV-2 virus. By evaluating the performance of different multi-layered structures, we can conclude that the combination of nanofibrous with macrofibrous structures can significantly enhance the filtration capacity of the non-woven masks (0,073-5,769% penetration of filter material) without compromising breathability efficiency. Future studies should prove that the masks totally built with woven fabric can replicate the promising results observed in non-woven masks, which is expected to

facilitate a prolonged use of the face masks (reusable masks, having durable performance status). These encouraging results are expected to lead to the creation of innovative facemasks that can play a crucial role in the health care systems' preparedness to counteract future threats like the one we are facing now.

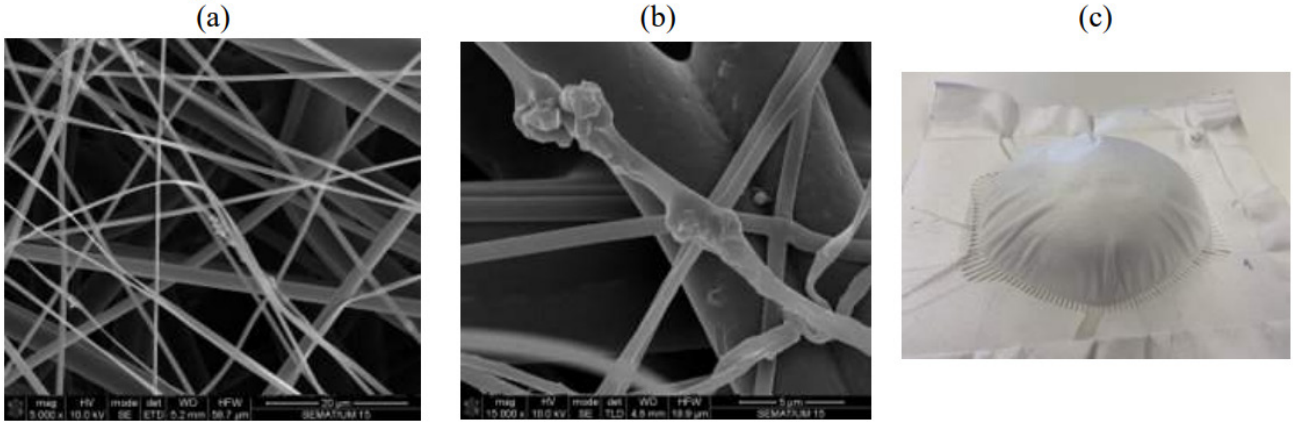

Fig.1 (a) (b) Fibres´ deposition in non-woven fabric with 0.5% of ZnO NPs; (c) thermoformed nonwoven face mask.

ACKNOWLEDGMENTS

Authors acknowledge the Portuguese Foundation for Science and Technology (FCT), FEDER funds by means of Portugal 2020 Competitive Factors Operational Program (POCI) and the Portuguese Government (OE) for funding the project PluriProtech— "Desenvolvimentos de soluções multicamada para proteção ativa contra ameaças NBQR", ref. POCI-01-0247-FEDER-047012. Authors also acknowledge strategic funding of UID/CTM/00264/2020 of 2C2T and UIDB/04469/2020 of CEB.

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ID214
VIBRATION TRANSMISSIBILITY IN AXISYMMETRIC AUXETICS

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ABSTRACT
This work details the influence of rib angle in the vibration transmissibility of axisymmetric auxetic (re-entrant) lattices. The dynamic behaviour of auxetic samples is also compared with axisymmetric zero and positive Poisson's ratio topologies to compare their performance. Results show that at frequencies lower than the eigenfrequency, samples with zero Poisson's ratio display the lower transmissibility. However, above the eigenfrequency, auxetic axisymmetric lattices (negative rib angles) are able to mitigate the transmission of vibrations.

INTRODUCTION
The recent design of lattices with axisymmetric topologies has revealed a novel radial deformation mechanism that is apparently extremely beneficial when coupled to auxetic behavior (Carneiro, 2018). Indeed, axisymmetric auxetics reveal a uniform circumferential contraction in compression, that generates an increase in stiffness relatively to common plane-strain (i.e. 2D) lattices (Yang, 2020). As a novel lattice configuration, there is a wide range of applications in which these axisymmetric auxetics are expected to generate a significant impact. Vibration damping, for instance, seems to be a particularly relevant field, as the cylindrical shapes that this topology generates may be easily used to insulate vibration in equipment/machinery. As the internal geometry (e.g. cell angle – α) of the lattices may easily change stiffness (K) and damping (ξ), these may be useful to tailor their vibration transmissibility (X/Y), according to Fig.1.

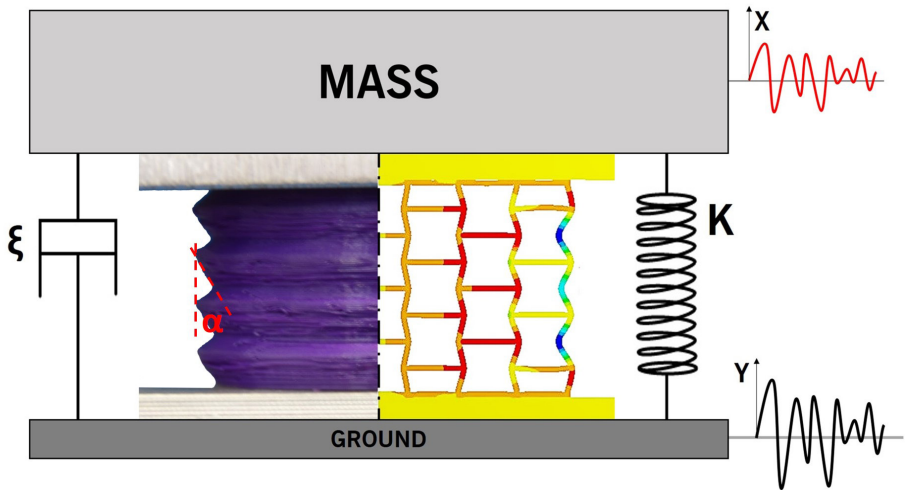

Fig.1 Graphical representation of vibration transmissibility with axisymmetric auxetic lattices acting as a spring-dashpot system.

Axisymmetric lattices with negative (α={-45º;-30º;-10º}), zero (α=0º) and positive (α=10º) Poisson's ratios were 3D-printed (FFF, using Filaflex filament) according to the method in (Carneiro, 2018). Samples were subjected to quasi-static compression to determine their stiffness at a 50N load. Stiffness values were used to determine their 1DOF eigenfrequency (ωn=sqrt(K/m)), assuming the samples were acting as the spring-dashpot element in Fig.1 under a 5kg mass. Transmissibility (X/Y) in the frequency domain (ω) was determined by the classic relation X/Y=sqrt[(1+(2ξβ)2)/((1-β2)2+(2ξβ)2)], where β= ω/ωn.

RESULTS AND CONCLUSIONS

Table 1 shows the stiffness of the samples under a 50N compression load. Results show that, as expected, near α=0º samples tend to become more stiff due to the transition between a flexure to an axial dominated deformation mechanism. Also, auxetic samples tend to display a higher stiffness then their positive Poisson's ratio counterpart (i.e. -10º vs 10º).

Sample	Poisson's ratio	Stiffness (N/mm)
-45º		17.0
-30º	Negative	26.7
-10º		47.6
0º	Zero	57.7
10º	Positive	44.1

Based on the results of Table 1, the transmissibility response in the frequency domain of the axisymmetric lattices is plotted in Fig.2. Considering that the samples have been additively manufactured with the same base material and parameters, it is evident that the sample topology displays a prominent effect in their dynamic response.

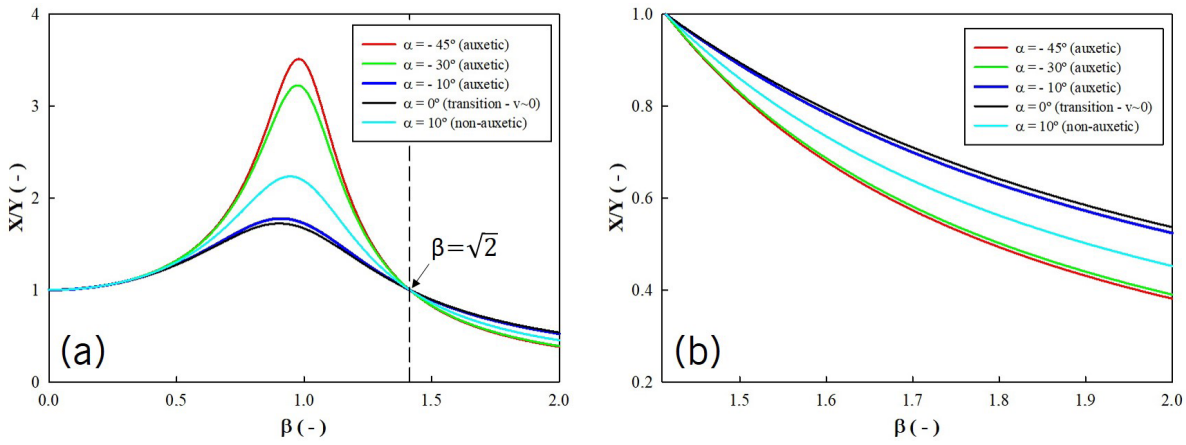

Fig.2 Transmissibility (X/Y) of the samples in the frequency domain: (a) full range and (b) magnified region (β>sqrt(2)).-

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ID215

EXPERIMENTAL AND NUMERICAL BALLISTIC BEHAVIOUR OF STAINLESS-STEEL AND FIBER GLASS FML PLATES

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ABSTRACT

In this work the mechanical behaviour of Fiber Metal Laminates (FML) under ballistic impact is analysed. Constitutive models for the involved materials were developed and implemented in a commercial FEM code. The final model developed, predict successfully the ballistic curve, trauma and damage extension in FML plates with a different number of layers.

INTRODUCTION

The combined use of advanced materials such as steels and composites forming FML, can provide more efficient and lighter solutions than monolithic armors. The combination of their properties allows that, in addition to a high energy absorption capacity, presents adequate structural resistance (Sadighi et al., 2012).

The combined methodology used (manufacturing, empirical and numerical) allows to develop calibrated numerical models than can predict the ballistic behavior of FML plates of different number of layers.)

Combining stainless-steel (X5CrNi18-10) layers of 0.3 mm thickness and fiber-glass composite (S2-glass/epoxy) layers of 0.15 mm thickness, FML1 (Steel/0/90/Steel/90/0/Steel) and FML2 (Steel/0/90/Steel/0/90/0/Steel/90/0/Steel) stacking sequences with 1.5 and 2.25 mm total thickness, respectively, were manufactured by using the autoclave technique (pressure 0.4 MPa, temperature 150 C, vacuum bag assistance -0.08 MPa). To achieve the appropriate steel-composite interaction and effective interface strength, the mixed mechanical-chemical surface preparation of steel sheets was made (Jakubczak et al., 2019).

An experimental ballistic impact campaign with 7.5 mm tempered steel spheres is performed using a Sabre ballistic gas-gun. A Photron Ultima SZ1 fastcam is used to measure the projectile velocity during impact, obtaining the ballistic curve for every thickness considered (Rodríguez-Millan et al., 2016). Ballistic limit and energy absorbed is determined for FML coupons. Additionally, the back-face deformation, petalling, damage extension in terms of delamination of the metal-composite interfaces, matrix, and fibers cracks is analyzed.

Numerical modelling is performed in the FEM commercial code ABAQUS/Explicit. Constitutive models have been developed for both materials independently, using a VUMAT Fortran subroutine for the composite. Basic mechanical properties are obtained from the scientific literature. Models for both stacking sequences have been developed, including cohesive interfaces between different materials. The numerical predictions of the FML plates under impact conditions are compared with the corresponding experimental results.

RESULTS AND CONCLUSIONS

Experimental and numerical ballistic curves are shown in Fig. 1. Results show a very good agreement in the

curve prediction. The ballistic limit increases with the thickness sequence, being 235 and 315 m/s for FML1 and FML2, respectively.

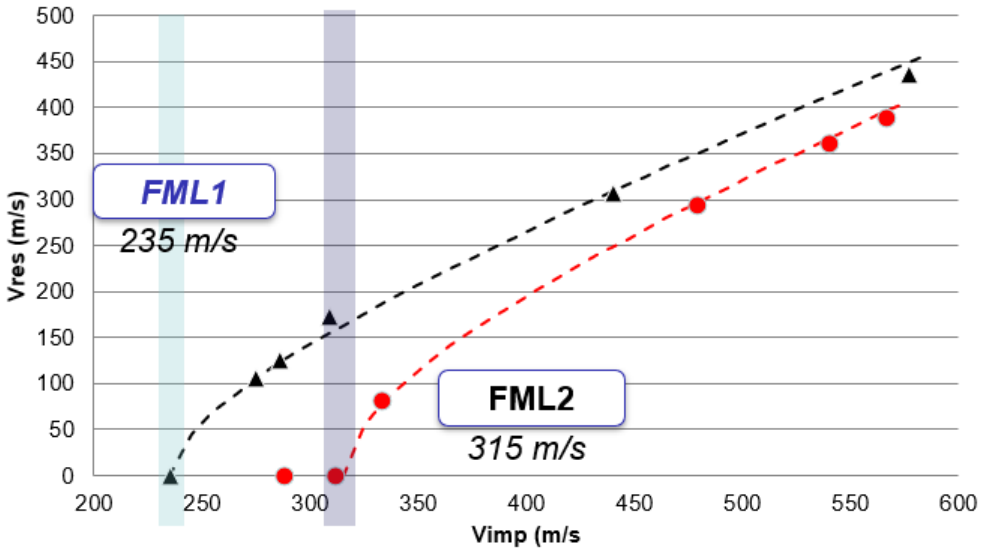

Fig.1 Experimental and numerical ballistic curves for both FML sequences.

The back-face deformation, petalling and damage extension is also successfully compared in both sequences (see Fig.2, for instance).

Fig.2 Back-face deformation for FML1 at 315m/s. Left: Numerical. Right: Experimental).

The FML numerical model achieved leads to prediction that agree with experimental tests performed on the manufactured plates. The correlations terms to parameters of impact-correlated phenomena as well as final damage state of the impacted FML.

ACKNOWLEDGMENTS

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ID216

MEMBRANE DISTILLATION DEMONSTRATION UNIT WITH WASTE HEAT RECOVERY FOR WATER DESALINATION

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ABSTRACT

A demonstration unit for direct contact membrane distillation (DCMD) has been designed and assembled for the analysis of water desalination with low grade waste heat under wide ranges of operational parameters, such as feed and permeate temperatures and mass flow rates. The aim is to recover waste heat from different sources, such as thermal engines, with emphasis in naval applications. The proposed configuration includes an additional heat exchanger for recovering heat from the permeate current that leaves the membrane module, and was installed for model validation and parametric analysis towards enhanced energy efficiency.

INTRODUCTION

Waste heat harvesting in different processes is a topic of growing interest in engineering, with significant investments in technologies to increase energy efficiency in recent years, in particular for low-grade thermal energy processes. Membrane distillation (MD) is an essentially thermal process that emerged in the 1960s, but has become more interesting recently, with its association to rejected heat recovery towards more sustainable systems. The Aqua Vitae project is a research initiative of the Brazilian Navy Research Institute (IPqM), jointly with the Federal University of Rio de Janeiro (UFRJ), dedicated to the modeling and analysis of membrane distillation processes, aiming at the desalination of water using heat harvesting from different sources, such as marine internal combustion engines in ships or solar energy and diesel generators in onshore installations. In addition to proposing improved models for the simultaneous heat and mass transfer in MD, both at the single membrane and module scales (Lisboa et al., 2019; Lisboa et al., 2021), the research advanced towards the experimental validation of the models and the parametric analysis of the different operational parameters. Commercial membranes are tested in a single membrane experimental apparatus for the membrane characterization and evaluation of the process efficiency, installed at LabMEMS/UFRJ. Besides, membrane modules are assembled or acquired for testing in a modified distillation unit, installed at LATES/IPqM, with hot water provided by an industrial boiler, to emulate a thermal engine or other thermal process. This work provides an overview of the design and assembly of this demonstration distillation unit.

RESULTS AND CONCLUSIONS

A theoretical analysis of the desalination process in the DCMD (Direct Contact Membrane Distillation) configuration was prepared and used for a commercial spiral module (Aqua Still) with 7.2 m² of membrane area. The Matlab-Simulink simulation for the nominal conditions described in Table 1, resulted in a distillate flux of 6.2 kg/m²h, which compares quite well to the simulated and experimental results presented in (Hitsov et al., 2018), which finds a value of 5.6 kg/m²h, thus around 10% difference. Experimental analyses are being carried out to

demonstrate the MD process for seawater desalination with heat recovery from the distillate flow, as highlighted in the red square in Fig 1. The experimental results shall be compared against a modified theoretical model that accounts for the heat recovery.

Table 1 Nominal conditions simulated with estimated value of distillate flux

Inlet feed temperature TT11 [°C]	Inlet distillate temperature TT21 [°C]	Inlet flow rate of feed FI11 [l/h]	Inlet flow rate of distillate FI21 [l/h]	Concentration of NaCl [g/l]	Distillate Flux [kg/m²h]
80	20	1500	1500	13	6.2

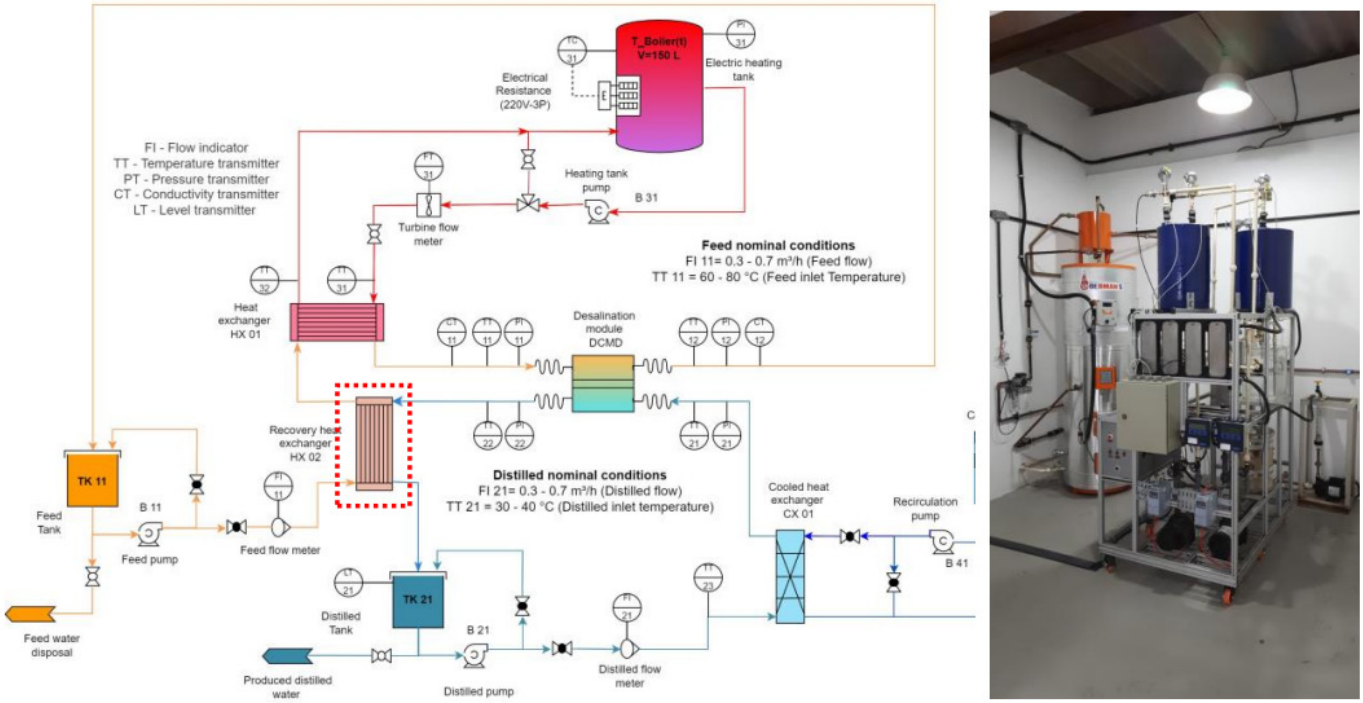

Fig.1 Technical drawing and nominal conditions of MD demonstration unit (LATES/IPqM)

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ID217

HIGH STRAIN RATE TENSILE RESPONSE OF ADDITIVE MANUFACTURED TI–6AL–4V

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ABSTRACT

The development of additive manufactured materials in the early 1990's has rapidly expanded over the last five years, providing engineers with a whole new range of technologies with which to develop innovative protection solutions (Muiruri, 2020). Additive manufacturing technology with the ability to "print" materials such as ceramics, titanium, steels enable the designer to combine different materials with unique shapes to provide higher--performing solutions. The titanium alloy Ti–6Al–4V is widely used in the aerospace, military and automobile sectors as well as biomedical applications (Sun, 2017). This work presents the results of additive manufactured titanium (Ti–6Al–4V) test samples subjected to high strain rate tensile loading using Split Hopkinson Pressure Bar (SHPB).

INTRODUCTION

The Ti–6Al–4V has high temperature resistance, high strength and corrosion resistance and has made it the most popular titanium alloy used in military applications. To be able to understand and computationally model these additive manufactured materials for the military as well as space applications, it is imperative to determine how these materials respond dynamically under high strain rate loading. Cylindrical Ti–6Al–4V (Grade 5) specimens with diameter of 6.25 mm were additively manufactured into dog-bone samples and were subjected to high strain rate tensile loading using Tensile SHPB. The test was carried at a room temperature of 20°C, and the strain of 3x103 s-1. The samples were produced using the Aeroswift platform using Selective Laser Melting process. A set of high-speed video cameras were setup to record the dynamic test event for each test. The loading of the specimen during the tensile test involves a collar placed over the threaded specimen. This is method that has been used previously and it is effective in loading the specimen (Nicholas, 1981). Fig.1 shows that the specimen is threaded in order to fix it to the pressure bars. It is surrounded by the collar assembly.

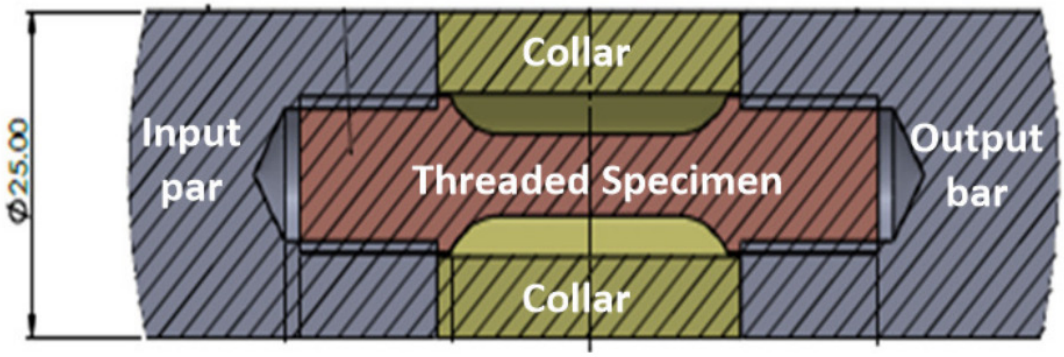

Fig.1 Collar/specimen assembly

RESULTS AND CONCLUSIONS

The stress–strain curves for the tensile SHPB high strain rate test at 3x103 s-1 for 3 samples tested are presented in Fig. 2. The average value of yield stress was 1174 MPa required to initiate plastic deformation. The results show a smooth transition between the elastic and plastic portions of the test with distinct yield point visible. When a Ti–6Al–4V material deforms under high strain rate conditions, its flow behaviour is dominated by a competitive process between the work hardening rate and the thermal softening rate. Normally, the highrate deformations can enhance a material's strength due to the high work hardening rate (Zhou, 2012). For the present study, the plastic deformation is a result of the strain rate that it has on strength of the material.

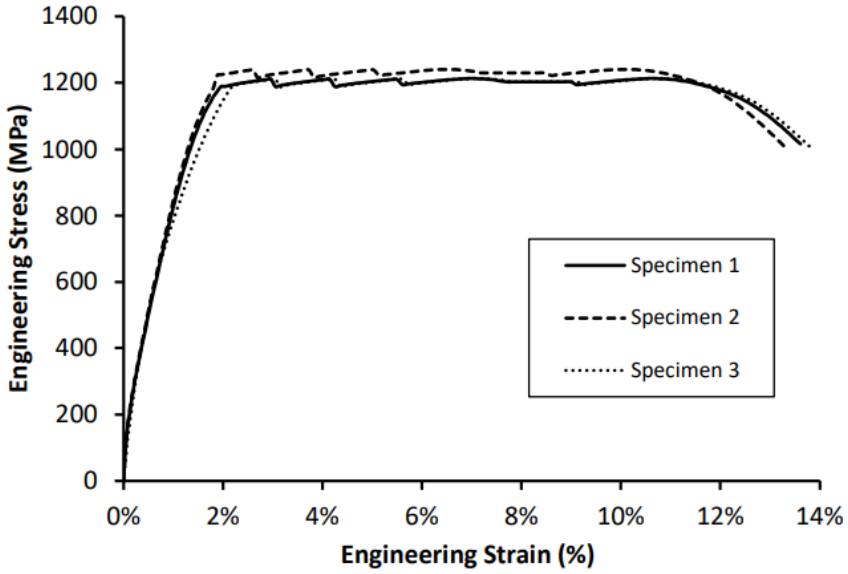

Fig.2 SHPB Tensile test results

The flow stress curve of Ti64 alloy slops down slightly as the strain increases from 0% to 2%. The high impact loading on the specimens loads the material to exceed the elastic limit, thus leading to instantaneous strain hardening. This is attributed to the dynamic recrystallization, which takes up the main deformation mechanism during the high-strain-rate loading process (Zhou, 2012). Once the processes of strain softening and strain hardening reach the state of dynamic equilibrium as the strain increases further to 12%, the flow stress curve becomes almost flat under high-strain-rate loading conditions. As the material starts to fail beyond 12% strain, there is a sharp decrease in flow stress. These results enhances the mechanical properties knowledge of Ti–6Al–4V under high strain rate loading.

ACKNOWLEDGMENTS

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ID218

MULTIFUNCTIONAL TEXTILES AGAINST BIOLOGICAL THREATS: THE ROLE OF ACTIVE PROTECTION

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ABSTRACT

The rising threats to the worldwide security (military, first-responders and civilians) urges us to develop efficient and versatile technological solutions to protect the human being, particularly those who put themselves in situations of most exposure — soldiers, medical personnel, firefighters, and law enforcement officers. Current bioprotective military garments only offer passive protection. Innovative materials and selectively-permeable layered fibrous structures with bioactive agents are highly needed, offering efficient filtering capability and biocidal skills. Our proposal uses multilayered textile-based macro-to-nanoscale fibrous structures, with a hydrophobic camouflage-patterned outer layer, and a microbicidal coating on its back side with a polyurethane-based paste, zinc oxide nanoparticles (ZnO NPs) and/or graphene nanoplatelets (GnPs), spread by knife coating. The inner layer of the suit will confine the active protective elements within, constituting a physical barrier to the soldier's undergarments. Collectively, this strategy should open new perspectives for our safety, namely those under the wheel of bioterrorism.

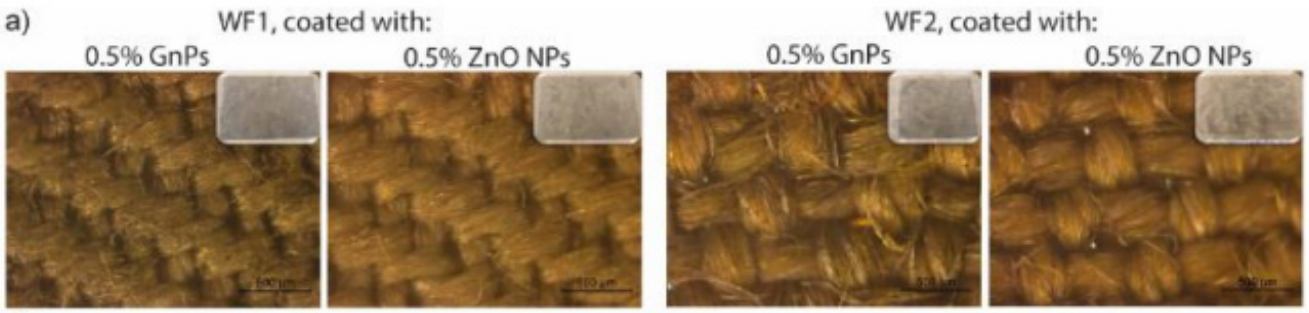
INTRODUCTION

Biological warfare agents (BWA) are some of the threats that put our well-being and health at risk (Araújo, 2021). These include bacteria, viruses, fungi and biological toxins, and are responsible for anthrax, plague, tularemia, botulism, smallpox, and viral hemorrhagic fever, among others. Research about development and application of protective textiles in military with rapid biocidal effects is in high demand. Most of the available protective clothing systems rely on passive protection, acting as a full barrier against air, vapors and liquids (Schreuder-Gibson, 2003). An active protection can detect and inactivate/degrade BWAs (Araújo, 2021), which can be achieved by functionalizing textiles with nanomaterials that possess those capabilities. ZnO NPs are well-known for their low cost, availability, biocompatibility, biodegradability and hexagonal prism shape, which allows an increase in surface roughness that enhances cell anchorage points. Its UV protection, photocatalytic activity, antimicrobial, self-cleaning, energy harvesting and biosafety features can confer multiple functionalities to their substrates: water resistance, antimicrobial action, UV blocking, fame retardancy, corrosion inhibitor and electrical conductivity (Boticas, 2019). Reference strains like Staphylococcus aureus (Gram-positive bacteria) and Escherichia coli (Gram-negative bacteria) are normally used to evaluate the biocidal capacity of proposed textiles (Song, 2021).

RESULTS AND CONCLUSIONS

Two different twill woven fabrics, one composed of cotton and polyamide fibres (woven fabric 1, WF1) and the other one of flame-retardant viscose and aramid fibres (WF2), both highly hydrophobic but breathable, were tested as the first passive protective barrier. Internally, by resorting to ZnO NPs, GnPs and a polyurethane-based paste, a thin but active protective barrier was spread by knife coating, resulting in coating thicknesses of 12-14 nm or 28-32 nm, respectively. Parameters such as fabric wettability (water contact angle of ≈130°) and breathability (air permeability of ≈30 L/m2/s) remained unaffected, with the exception of WF2 that became unbreathable. Qualitative and quantitative tests (JIS L 1902 standard) using S. aureus and E. coli evaluated the front and back sides of the coated textiles following 24 h of incubation, as typically done to screen technical textiles' action against biological threats, revealing that those with ZnO NPs successfully eradicated all S. aureus and E. coli colonies in WF1.

a)



b) antibacterial tests performed with:

S. aureus

Army fabrics| BS	S	L	Activity
Coated WF2 fabric:0.5% ZnO NPs	4,12±1.61	3.0±0.0	Bacteriostatic and bactericide
Coated WF2 fabric:0.5%GNPs	-	-	No activity
Coated WF1 fabric:0.5%ZnO NPs	6,26±0.07	3.0±0.0	Bacteriostatic and bactericide
Coated WF1 fabric:0.5%GNPs	0,22±0.06	-	Bacteriostatic

E. coli

Army fabrics| BS	S	L	Activity
Coated WF2 fabric:0.5% ZnO NPs	6,39	3.00	Bacteriostatic and bactericide
Coated WF2 fabric:0.5%GNPs	0,12	-	Bacteriostatic
Coated WF1 fabric:0.5%ZnO NPs	1,34	-	Bacteriostatic
Coated WF1 fabric:0.5%GNPs	0,78	-	Bacteriostatic

Fig.1 (a) Morphology of WF1, uncoated and coated with 0.5% ZnO NPs.(b) Coated fabric showed bacteriostatic and bactericidal activity against S. aureus and E. coli.

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Authors acknowledge the Portuguese Foundation for Science and Technology (FCT), FEDER funds by means of Portugal 2020 Competitive Factors Operational Program (POCI) and the Portuguese Government (OE) for funding the project PluriProtech— "Desenvolvimentos de soluções multicamada para proteção ativa contra ameaças NBQR", ref. POCI-01-0247-FEDER-047012. Authors also acknowledge strategic funding of UID/CTM/00264/2020 of 2C2T and UIDB/04469/2020 of CEB.

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ID219

AUXETIC MULTI-LAYERED MOLECULAR MODEL FOR FULLY ISOTROPIC DISCRETE MATERIALS

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ABSTRACT

This work presents a new discrete auxetic material composed of rigid multi-layered bodies connected by springs. The stiffness of each spring is determined by imposing the energy equivalence between the discrete material and the equivalent micropolar continuum. The basic element of the discrete media (designated as molecule) is placed in a periodic manner, and able to reproduce the full range of negative Poisson's ratio. The elastic behaviour results isotropic under small strain and quasi-isotropic under finite strains. As a result, the presented discrete material is suited for analyses in the non-linear strain field for the next application on impact loading problems.

INTRODUCTION

Macroscopic representation of solid materials through continuous numerical strategies has a strong literature background. Nonetheless, strain localization issues are still hardly faced by such approaches and enrichments are needed to cope the latter, such as through explicit crack representations, interface and/or cohesive elements, extended or concurrent FE strategies (Fries and Belytschko, 2010), or phase-field models (Ansari et al., 2021), among others. Discretebased approaches are a possible alternative. This study introduces a discrete system developed for 2D type of analysis within plane-stress (PS) and plane-strain (PE) conditions. Its geometry was found in a heuristic fashion by Casolo (2021) and follows a periodicity assumption. The basic element (hereafter molecule) is composed by a rigid muti-layered body whose connections are provided by four types of springs. The associated elastic stiffness terms are found by guaranteeing the energy equivalence with the corresponding micropolar continuum; mode-I, mode-II and micro-rotation are, therefore, eligible deformation modes for each molecule. Such kinematics was mathematically formulated according to both small (linear) and finite (non-linear) strain theories. The molecule is found to exhibit a fully isotropic response within the range of Poisson's values given by $(-1, 1/3]$ for PS and $(-1, 1/4]$ for PE; the latter is yet conditioned by the adopted axial stiffness of the media (stiff to soft materials). A validation procedure is presented for a benchmark study of a plate subjected to an impact load.

RESULTS AND CONCLUSIONS

The proposed molecule has been compared with a standard continuous FE model. The selected case study corresponds to a 2D problem within a PE formulation. Static conditions and a linear physical and geometrical behaviour have been assumed. A concentrated load, modelled by three centred loads of magnitude 100 kN, is applied in the centre of a beam aiming to catch the response under an impulsive load. A simply supported rectangular beam with section area of 1.0×0.5 m2 was assumed, see Fig. 1(a). A shear modulus G = 5·104 MPa and a Poisson ratio $\nu = -0.99$ were assigned as macroscopic elastic parameters. Results given in terms of vertical displacement

map in Fig. 1(b) show a good agreement (lower than 1% relative difference).
The molecule can be used to evaluate the response of systems within different scales of analysis and for either auxetic or regular materials. From the latter, one can capture the applicability of the molecule to the structure of metamaterials aiming to reproduce pre-defined responses. Herein, it has been found the ability to absorb impact energy due to its auxetic feature.

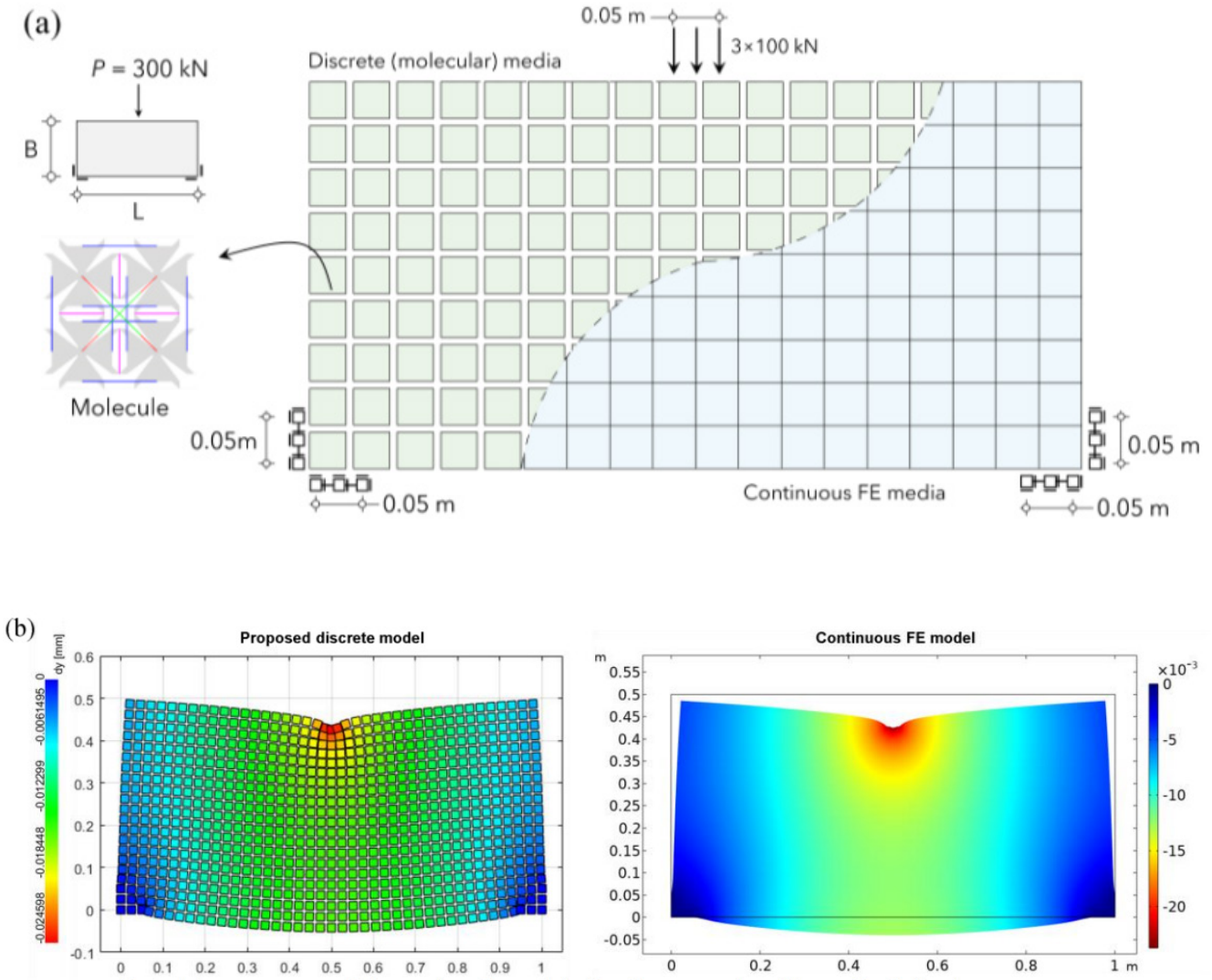

Fig.1 (a) Geometry of the molecule and defined case study, (b) vertical displacement map.

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First author gratefully acknowledges the funding by Ministry of University and Research, MUR, Italy, within the Italian Ministerial Decree 10.8.2021 no. 1062, and under a Research program included in Innovation Theme and project code given by (CUP) D45F21003530001.

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ID220

A NEW TESTING SYSTEM TO DETERMINE THE FIBRE-MATRIX ADHESION STRENGTH BY MEANS OF SINGLE-FIBRE PULL-OUT TESTS

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ABSTRACT

In this article we discuss the measurement of the fibre-matrix adhesion strength by means of a novel testing system which has been developed between, the Leibniz-Institut für Polymerforschung (IPF) in Dresden, the Faserinstitut Bremen (FIBRE) and Textechno H. Stein GmbH & Co. KG. The system determines the adhesion between fibre and matrix in terms of the local interfacial shear strength, the interfacial toughness, and further parameters through a reproducible single-fibre pull-out test [Zhandarov et al.]. A first standardization of the test method has recently been accomplished as DIN SPEC 19289. Our discussion introduces the novel testing system and includes hands-on examples on its application for various fibre-matrix combinations.

INTRODUCTION

Fibre-reinforced composites have become an indispensable part of modern high-tech applications due to the excellent tensile properties of the reinforcement fibres incorporated in the composite. For this to have an effect, the loads need to be distributed evenly to all fibres by means of a matrix. Therefore, a high interfacial shear strength is required for a good load transfer. Hence, the interfacial shear strength is one of the key parameters in composite technology.

To characterize the interfacial shear strength, most commonly composites with unidirectional aligned fibres are manufactured: A tensile test is then performed perpendicular to the fibre orientation (transverse tensile test) or a short beam shear strength test (as defined for instance in DIN EN ISO 14130 or ASTM D2344) is performed to measure the apparent interlaminary shear strength (ILSS).

However, the maximum stress found in such macromechanical tests does not only depend on the fibre-matrix adhesion strength but is also governed by the following additional factors: the fibre content, orientation, length, diameter and fibre distribution homogeneity, the pore void of the test specimens, and the mechanical properties of the fibre and the matrix. To achieve repeatable results for the fibre-matrix adhesion strength through macromechanical tests, it is hence necessary to keep a rigid control of the manufacturing process of the specimen, making the overall testing procedure laborious and difficult to compare across laboratories.

Micromechanical testing techniques have several advantages over the macromechanical methods. By involving only single fibres in the test, most dependencies on the manufacturing process of the test specimen listed above are avoided. Whereas macroscopic methods can only

determine the apparent interfacial shear strength, the single-fibre pull-out test as a micromechanical test method also determines the local interfacial shear strength, the interfacial frictional stress, and the critical interfacial energy release rate.

Here, the local interfacial shear strength is essential for applications with cyclic load, since it characterizes to

which stress a composite can be loaded before the interface between fibre and matrix is damaged. Moreover, the critical interfacial energy release rate and the interfacial frictional stress have a strong impact on the energy absorption of composites, which is important in crash situations as for example in mobility applications and other impact scenarios.

RESULTS AND CONCLUSIONS

The single-fibre pull-out technique has been implemented in the so-called FIMATEST system. We use this system to determine the local interfacial shear strength τd and other parameters for various fibre-matrix combinations. Fig. 1 shows exemplary results for standard and treated fibres of both carbon (CF) and glass (GF) embedded in different matrices – polyetheretherketone (PEEK), polyamide (PA) and an epoxy resin (Epoxy). We note that in all cases a significant improvement of the adhesion strength by treating the fibres or modifying the matrix can be detected. The well-known effect of the aging of sizing for epoxy-resins is observed, too. We conclude that with the implemented system differences in the fibre-matrix adhesion can be traced on all kinds of fibre materials in combination with various thermoplastic, thermoset and other matrices.

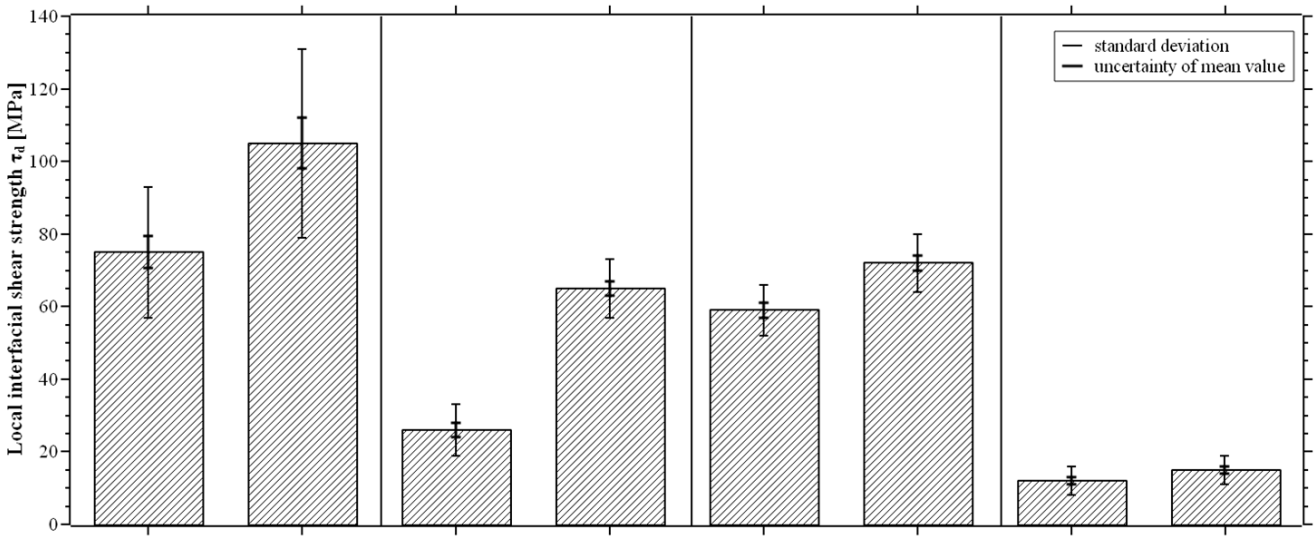

Figure 1: Local interfacial shear strength τd of standard and treated fibres in PEEK and PA, the effect of aging of the sizing of glass fibres (GF in Epoxy) as well as modification of PP with Maleic anhydride.

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ID221

THERMAL CONDUCTIVITY AND HELIUM GAS BARRIER PROPERTIES OF BORON NITRIDE BASED THERMOPLASTIC POLYURETHANE NANOCOMPOSITES FOR DEFENCE APPLICATIONS

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ABSTRACT

The present work is comparing the thermal and gas barrier properties of thermoplastic polyurethane matrices incorporated with Boron nitride nanosheets at different weight percentage loading (1, 2, 3, 5, 7, 9 and 11 wt.%). These different nanocomposites will be analysed for thermal properties such as thermal conductivity and helium gas barrier properties which can be used as in aerospace application such as aerostats/airships and electronic circuits etc.

INTRODUCTION

In the current scenario, light weight nanocomposites with superior thermal conductivity properties promise great potential application towards thermal management system. There are major challenges and also opportunities in the development of TPU/ BN nanocomposites with much improved performance, especially with respect to the need for lightweight composite materials with extreme ratios of thermal to electrical conductivity to exploit the electrically insulating nature of BN (Song et al., 2012).

It is reported that the thermal conductivity of suspended eleven layered h-BN has a thermal conductivity of 360 W/mK at room temperature close to the room temperature thermal conductivity value of bulk h-BN(Jo et al., 2013)(Table, 1976). There is an possibility to reduce gas permeation by 50 to 500 times even with small loading of nanofillers and the relevant studies are carried out mostly on oxygen, carbon dioxide and nitrogen gas(Joshi, Adak and Butola, 2018).

The formation or processing of nanocomposite itself faces some technical difficulties such as distribution and dispersion of nanofillers (Boron nitride nanosheets). Twin screw extruder (process 11) can make uniform nanocomposite with uniform distribution and dispersion of the nanoparticles.

RESULTS AND CONCLUSIONS

The helium barrier test showing trend corresponding to the weight percent loading of the boron nitride in the TPU1 matrix.

Table 1 Helium gas barrier results of the TPU nanocomposite films

films	GTR value ($L/m^2/day$)	Thickness (micron)
Neat TPU1	2.61	195
TPU1-1%BN	2.52	183
TPU1-2%BN	2.48	189
TPU1-3%BN	2.31	188

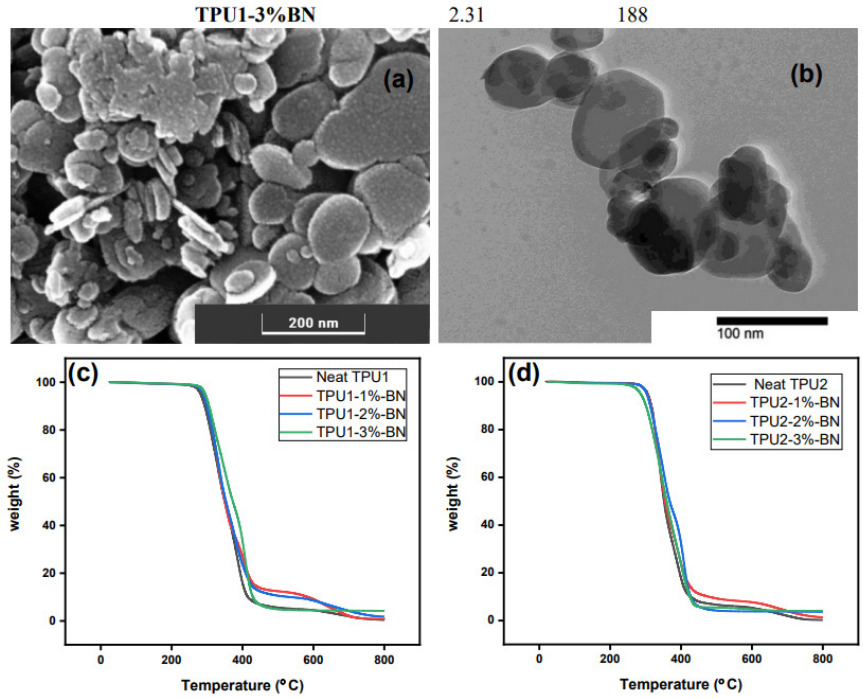

Fig.1 (a) FE-Sem image of the Boron nitride nanosheets, (b) TEM image of the Boron nitride nanosheets (c) and (d) Thermo graph of the two different TPU nanocomposites

The FE-SEM and TEM images shows that geometry of the boron nitride nanosheets is disk like structure (avg. 100 to 200 nm) can introduce tortuous path in the TPU nanocomposites to bring significant helium barrier and the inherent thermal conductivity of the boron nitride will provide thermal conductivity to the nanocomposite which will be performed and presented in the upcoming conference.

ACKNOWLEDGMENTS

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ID222

HALOCHROMIC TEXTILES FOR REAL-TIME SENSING OF HAZARDOUS CHEMICALS AND PERSONAL PROTECTION

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ABSTRACT

The main goal of the presented work was based on the development of halochromic textiles capable of detecting chemicals and generating a colour response easily perceived by the user. Three different dual sensors were stamped on cotton and polyester knits and their ability to detect acidic and basic chemicals, both in liquid and gaseous form, was evaluated. The performed tests proved the functionality of the sensors and showed a visible response of all the samples when the fabrics came in contact with different chemicals. The results show great potential for the application of this technology in personal protective equipment capable of detecting a chemical threat.

INTRODUCTION

In the current scenario, light weight nanocomposites with superior thermal conductivity properties promise great Access to the development and diffusion of warfare agents has risen significantly as a result of increased technological innovation and the global spread of knowledge (Singh, 2020). In this sense, the use of protective equipment has become mandatory when performing several functions, and from these several studies have emerged around non-conventional textile markets, such as personal protection. Chemical protective clothing (CPC) is equipment made to be the last line of defence against hazardous compounds, preventing contact with the skin and avoiding severe injuries (Zhou, 2005). CPC is essential whenever there is a risk of exposure, such as military and law enforcement personnel, laboratory workers or chemical industries (Mao, 2014).

In addition to protection, another inherent need of CPC is related to the ability of the equipment itself to detect and alert the user to the presence of chemical agents that may pose a risk to his health (Institute of Medicine (US) Committee on R&D Needs for Improving Civilian Medical Response to Chemical and Biological Terrorism Incidents, 1999). One approach that can be used for chemical sensing is based on a change of the optical response, for example using halochromic molecules capable of shifting colours in response to a variation of pH (Bilgin, 2021). Even though systems based on pH-sensitive compounds lack specificity, they are cheap, easy to produce and generate a rapid colour change.

This work aims to develop cotton and polyester textiles that can be attached to CPC and be capable of sensing chemicals, both liquid and gaseous. For this purpose, a dual-sensor approach was tested, using compounds with sensitivity for different areas of the pH scale. The sensors analysed were: methyl red and bromothymol blue (MR:BB) at 0,51:1 g/L; methyl red and methyl red sodium (MR:MR) at 0,48:0,51 g/L; methyl orange and bromocresol purple (MO:BP) at 0,6:1 g/L. After a first screening to ensure the functionality of the pH-sensitive sensors, the compounds were applied to the textiles by stamping. To understand the sensitivity of the samples to different

chemicals in the liquid state, a test using three different acids and two bases was carried out. The acids used were 30 % citric acid, 30 % acetic acid and 10 % formic acid, and the bases were 1 M sodium hydroxide and 35 % ammonia. Furthermore, many chemical threats are often invisible thus, in a scenario where there is a risk of exposure to toxic chemicals, the detection of gaseous atmospheres is also of great importance. Consequently, the sensitivity of the samples to gaseous chemicals was evaluated using hydrochloric acid and 35 % ammonia.

RESULTS AND CONCLUSIONS

The obtained results for liquids, presented in Figure 1a, show that for both substrates - cotton and polyester - a notorious difference has been seen after the textile comes in contact with basic and acidic solutions. Additionally, for gaseous atmospheres (Figure 1b), cotton and polyester knits have exhibited a significant colour change after exposure to acid and basic environment. For example, the dual-sensor MO:BP changes from green to orange/red in the presence of acids and from green to blue when in contact with bases.

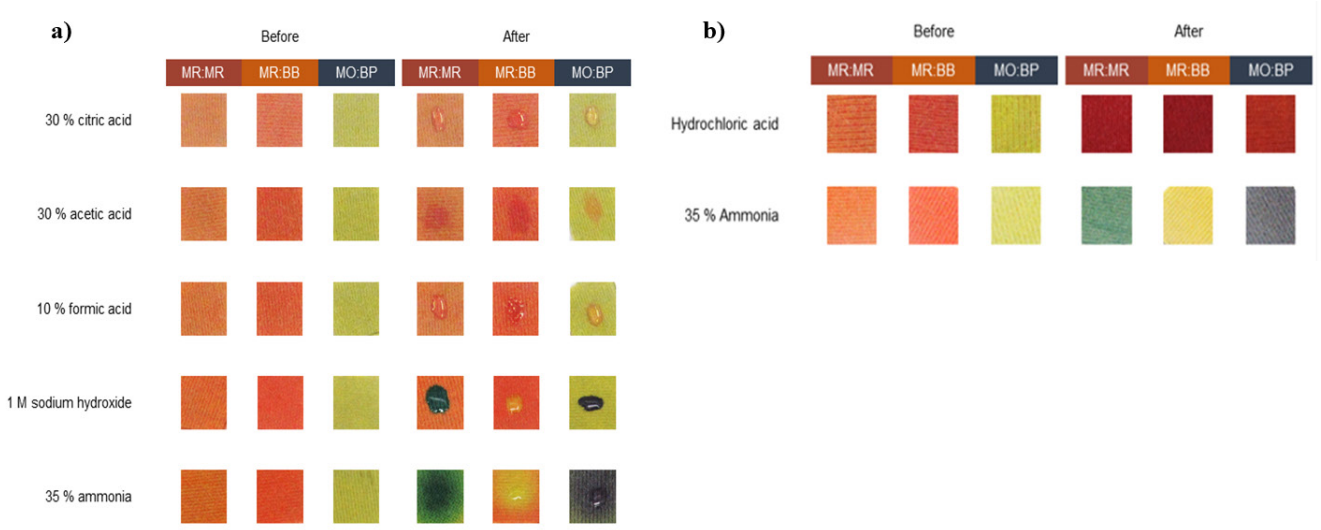

Fig.1 Obtained results for the sensitivity of polyester to (a) liquid and (b) gaseous chemicals.

The pH-sensitive compounds exhibit extremely different colours according to the chemicals being acidic or basic, allowing the user to identify the type of chemical he has been in contact with and act accordingly. Comparing the colour spectrum, the variation exhibited by MO:BP is more preeminent, displaying opposite/distant colours before and after exposure to chemicals. Hence, these compounds may be of more interest for future applications since they allow an easier perception of the risk.

ACKNOWLEDGMENTS

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ID223

INFLUENCE OF BIOMIMETIC FUNCTIONALLY GRADED MATERIALS AND BOULIGAND STRUCTURES IN THE BALLISTIC COMPOSITES PERFORMANCE

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ABSTRACT

The aim of this work was to compare the ballistic performance of hybrid composites, developed using several combinations of high-performance fibres, such as carbon, aramid, E-glass or UHMWPE, and considering functional gradient concepts as well as Bouligand structures in its development, in order to create new solutions with higher impact resistance, through biomimetics. To evaluate the composites performance to this purpose, ballistics tests were performed using a gas gun that fired a solid steel sphere fragment with 7.92 mm and 2 g, at a speed of 400 ± 15 m/s, into ~2 mm thickness samples, in order to verify the residual impact velocity of a projectile fired into each panel surface at a velocity of 400±10 m/s. The addition of a steel layer in the panel impact surface is better than a carbon fibre composite layer due its lower flexural shear resistance when hit by a projectile. Using UHMWPE increases the impact energy absorption comparing to using a glass fiber composite. The using of a Bouligand structure in these functional gradient concepts does not bring improvements, and in some cases reduces the properties.

INTRODUCTION

During the last decades, several polymer composites combinations have been explored for protective applications by processing different kinds of fibres, such as aramid, E-glass and UHMWPE (Ultra high molecular weight polyethylene), due to their high specific energy absorption and dissipation under impact. Common fields of applications are related with personal and vehicles protection in different scenarios (ground, air, marine and space). In this sense, one of the most requirements intends to achieve a lightweight solution without compromising the protection levels. In this way, several approaches have been studied, like as the functionally graded materials concepts, in order to get better impact resistance [1].

The principle of protection against an impact is popular in different biological organisms. In this context, and considering the different principles of energy dissipation and absorption (damping), biological models of the green coconut pericarp, Cocos nucifera, and the peacock mantis shimp dactyl clubs, Odontodactylus scyllarus, can be considered as an interesting example for this purpose. From this biological models it is possible to verify a functionally graded materials concept and a Bouligand structure alignment, which allows to inspire new impact resistance solutions by biomimetic procedures. [2].

In a hybrid composite, the functional gradient due to the different materials composition, allows to create a mechanical properties gradient, along its thickness, in which the tensile strength, Young modulus and elongation at break vary. In the Bouligand structure, a crack propagation along the twist between the fibre layers through the matrix instead of in a straight path, results in higher energy dissipation. So, the idea of this biomimetic models is to increase the ballistic resistance for producing hybrid fibre composites.

In this context, the main goal of this work was to study the influence of biomimetic approach and bouligand misalignment of [0/90]º fabric layers by 15º to each other, considering different high-performance materials, such as carbon (C), aramid (A), E-glass (G) or UHMWPE (U) materials, embedded in an epoxy matrix. To better understand the functional gradient, it were produced samples using a steel (S) sheet instead of carbon fibers. These composite materials were developed through hand lay-up followed by hot compressing moulding process (25 min at 90ºC). After that, it was analysed the ballistic performance of eight different combinations: Carbon/Aramid/E-glass or UHMWPE (C/A/G or U) with 0/90º and Boulignad orientation; and Steel/Aramid/E-glass or UHMWPE (S/A/G or U) with 0/90º and Boulignad orientation, then they were tested through ballistic tests performed according to the MIL-STD-662F standard.

RESULTS AND CONCLUSIONS

The obtained results are shown in Fig. 2 and Fig. 3.

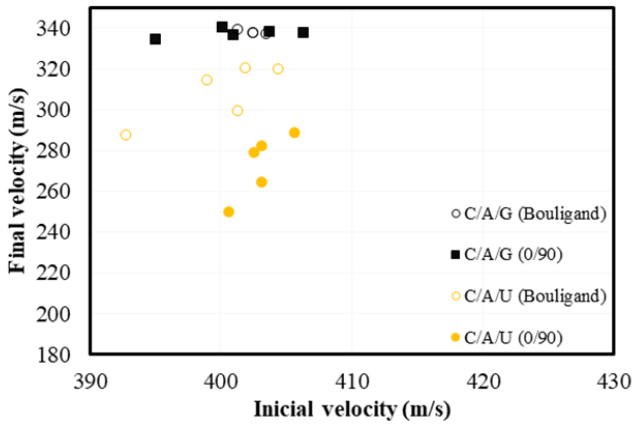

Fig.1. Ballistic results for samples with carbon.

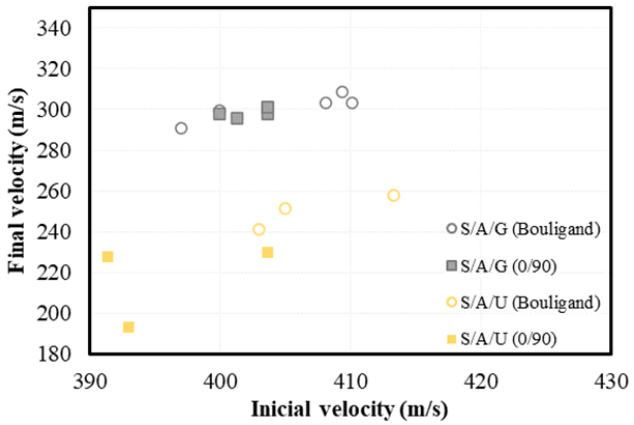

Fig.2. Ballistic results for samples with steel.

Analyzing the obtained results, in the first place it is important to stand out that projectile hits the multi-layer composites on the surface with the high modulus material, as the carbon and steel. From Fig.1, it is possible to verify that the samples with UHMWPE in its composition, presented better impact absorption comparing to the ones that use E-Glass due to the projectile lower final velocities registered (below 320 m/s). This shows the better ballistic properties of the UHMWPE fibre comparing the E-Glass. On the other hand, regarding to the fabrics orientation, the samples with (0/90)º finished in UHMWPE presented lower exit velocities, representing better ballistic performance. However, to the samples finished with E-glass, the results for both orientations lay-out were similar (around 340 m/s).

Now looking to the results of samples with a steel layer, as show in Fig.2, it was verified better ballistic performance when used steel (between 190 to 310 m/s) instead of carbon fibers (between 250 to 340 m/s), due to its better mechanical properties when subjected to an impact and shear forces. In this samples, (0/90)º orientation samples presented better results to the samples with UHMWPE (between 190 to 230 m/s), instead of Bouligand orientation ones (between 240 to 260 m/s), but for the ones with E-glass the results were similar. This may happen due to the low mechanical properties of the thermoplastic matrix used in the UHMWPE prepegs, where the fabrics misalignment decreases the ballistic performance. In conclusion, based on the study carried out the steel layer in the panel impact surface is better due to its high mechanical resistance, and to improve the ballistic performance the UHMWPE fibres increases the impact energy absorption when compared to the E-glass fibres. In this case of study, the 0/90º orientation of the fabric fibres presented better ballistic impact resistance, com-

pared to the Bouligand structures.

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ID224

STUDY OF SEAMLESS PRODUCTION PARAMETERS FOR THE DEVELOPMENT OF KNITS WITH AUXETIC BEHAVIOUR

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ABSTRACT

The main goal of this work consisted in the analysis of production parameters on seamless looms to obtain knits with auxetic behaviour. In this sense, several parameters were studied, such as the type of polyamide, stitch tightening and the type of yarns, as well as different auxetic patterns. The obtained results show that the use of denser polyamide increases the auxetic behaviour of the samples, and this result is more noticeable in 4 of the 19 studied patterns.

INTRODUCTION

Auxetic structures are a special type of materials with a unique behaviour – when they are axially extended, the perpendicular direction also expands. The auxetic properties of a material are confirmed with a negative Poisson ratio (Duncan, 2018). These materials exhibit increased mechanical properties such as shear resistance, indentation resistance, surface fitting ability and increased breaking tenacity and energy absorption. Due to the mentioned topics, auxetic materials are widely applied in protective equipment, aerospace, automotive, and national defence industries (Xu, 2020). Also, due to the structural rearrangement ability of these materials when tension is being applied, its application in the fashion sector is an attractive approach. Seamless knitting is a specialized type of technology that allows the production of complete garments with minimal seams. The garments produced in seamless looms are comfortable and have a better fitting when compared with the conventional ones (Choi, 2005).

The combination of both technologies, i.e. auxetic structures and seamless knits, makes it possible to obtain functional knits that can be applied in fields such as protective clothing or fashion. In this work, the influence of different parameters such as type of polyamide (PA), type of yarns and stitch tightening on the production of seamless knits was studied to obtain knits with auxetic behaviour. In this way, two distinct PA were tested – PA 50/40x2 and PA 78/68x2 –, as well as two degrees of stitch tightening – P0 and P15, being P0 the tightest –, and two types of yarns production – conventional and air-jet spinning. The combination of the mentioned conditions resulted in a total of 8 different samples. Furthermore, for each set of combinations, 19 auxetic patterns were studied. These patterns were created based on scientific reports. The auxetic behaviour of the obtained knits was evaluated by stretching the knits in one direction and then observing the behaviour in the opposite direction.

RESULTS AND CONCLUSIONS

After the development of the combinations above mentioned, the possible auxetic effect of knits was studied by stretching the knits in one direction and observing the obtained dimensions in the opposite direction. The negative value of the ratio between the extension in both directions was calculated. Thus, when a negative value is obtained it means that the knit has an auxetic behaviour since the expansion in one direction is accompanied by an expansion in the opposite direction. Based on the obtained results, it was observed that the two combinations of production knit conditions with a higher number of patterns having an auxetic behaviour were developed with PA 50/40x2. The knits produced with this PA had smaller weights and, consequently, had less raw material per unit of area. Hence, the knits had a higher degree of flexibility, allowing the auxetic structure to easily undergo the structural readjustment with the tension movement. Additionally, for the production of seamless knits, it was observed that 4 of the 19 auxetic patterns studied presented auxetic behaviour in almost all combinations of production parameters. The mentioned patterns are represented in Figure 1. The patterns Q, L, P and S are very similar to each other, with the only difference between them being the distance among the empty points The values of the ratios between both displacements are somewhat variable for the same pattern, depending on the conditions under which the knit was produced. However, most of the obtained values are negative or equal to zero. For example, the L pattern has values changing from -0,04 to 0,02, having one positive value, two equal to zero and 5 negative values.

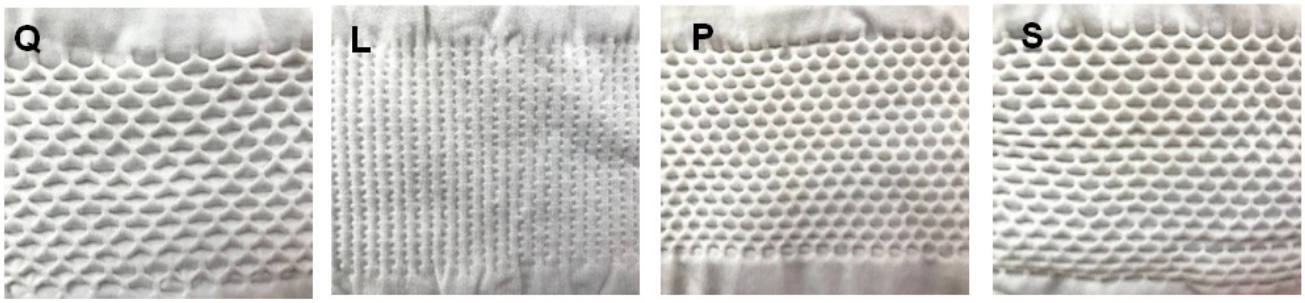

Figure 1: Auxetic knit patterns.

In conclusion, this study establishes the potential of developing knits with auxetic behaviour through seamless technologies. The obtained samples demonstrated auxetic behaviour once it was possible to obtain knits that expand perpendicularly when they are extended axially. These knits can be applied in the field of personal protection or the fashion sector with the advantage of being very light with a perfect fitting.

ACKNOWLEDGMENTS

The authors would like to express appreciation for the support of the sponsors of the individual project nº 45211 entitled “Aux_Seamless: Nova geração de vestuário seamless de proteção ao impacto a baixa velocidade”.

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ID225
UNIFORM AS A SYSTEM OF GARMENTS, GEAR AND PPE

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ABSTRACT
Uniform as a holistic object can be perceived as a set of different items - garment, gear and other elements of personal protective equipment (PPE). Their compatibility and other preconditions for the successful performance of a specific task are closely related to the morphology of the human body, anthropometric features, statistical quantities, and individual characteristics. The acquisition of anthropometric measurements by new technologies, such as 3D scanning, needs to be integrated into the existing production system, which is often limited by the level of technology of the manufacturers. Also, the usage of new materials and the usefulness/functionality of their layers are often limited to the capabilities of manufacturers, the public procurement process and price vs value proportion.

INTRODUCTION
A uniform is a significant set of clothing and its accessories designed to unambiguously identify the professional or other occupation, regulated public status or affiliation of any of its wearers. To this end, a set of uniform clothing of uniform appearance and design shall be developed from components of uniform materials and decorative parts, accompanied by rules on the regulated wearability of their different configurations.
Protective clothing is a set of clothing that replaces or covers an employee's personal clothing to protect him or her from exposure to environmental hazards that are hazardous or harmful to his or her health. There are anti-dirt, anti-shock, heat-resistant, cold-resistant, radiation-resistant, water-resistant, acid-resistant (anti-acid), alkali-resistant (anti-alkali), bio-safe, anti-fatigue, warning, etc. c. protective clothing. Protection against: ionising radiation, moving parts, cold, foul weather, chemicals, static electricity, chain saw, cuts and stubs, particulate radioactive contamination, micro-organism hazards, welding. Also, protective clothing (equipment) for firefighters, high visibility clothing, protective clothing for motorcycle riders etc. Standard ISO 13688 includes basic requirement sections for protective clothing: basic health and ergonomic requirements, ageing (cleaning), size designations, marking and information supplied by the manufacturer [ISO 13688].

METHODS
One of the phenomena of uniform fit and holistic is comfort [Williams, 2009]. Comfort can be seen in different aspects (see Fig. 1), it is most often defined as that which does not cause discomfort. Therefore, it is considered to be a complex research object. Of the physical aspects, three are emphasized - thermophysiological, sensory and ergonomic comfort [Zhong et.al., 2009], [ISO 15831]. In turn, psychological comfort includes aesthetics, ethics and design. The latter is especially important for uniform wearers. If a person can choose a design in everyday clothing, then the design of a uniform is predefined and other aspects of the uniform are often subject to this design. Analysis of human body measurements and movements – usage of laser scanning 3D technologies for gaining measurements, movement amplitudes and biomechanical parameters in interaction with PPE is a way to have results at least at the laboratory level and to see possibilities for improvements.

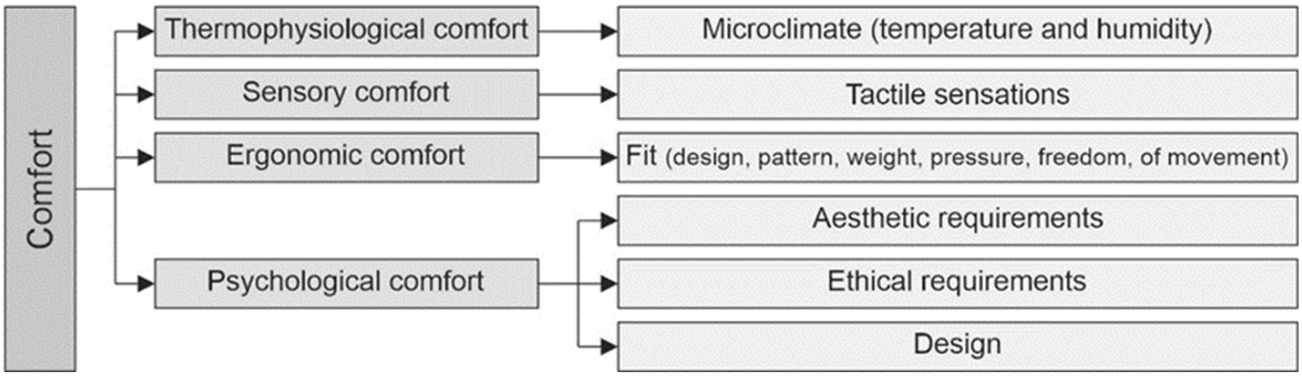

Fig. 1. The components of the comfort concept [Lapkovska et.al. 2019].

Such measurements show that anthropometrics are key issues for good fit and comfort as well. In practice, variations exist between different manufacturers' approaches to a compilation of sizing systems and size coding. Access to adequate and extensive anthropometric data is the basis for creating an appropriate sizing system. The further interpretation and operation of the data depend on the objectives of the product - what is the level of functionality, appearance, fit, and ergonomic requirements.

RESULTS AND CONCLUSIONS

Development of garment designing methods is enhanced along with the introduction of new materials and technologies. Traditional 2D methods still take a great place in the clothing industry. Computer software is used to replace monotonous/routine work. Without access to the target-group anthropometric data, manufacturers are forced to adapt and vary with existing databases to create sizing systems and come to a certain size range and its distribution. If the provision takes place regularly - every year, then an approach is also allowed from the point of view of delivery and distribution, when the actual size distribution is predictable from the experience of previous years. However, such an approach may have significant shortcomings - for example, the inconsistencies and discomfort caused by uniforms due to design deficiencies (pattern configuration, sewing technology, gear adaptation, etc.) cannot be identified without a comprehensive anthropometric survey accompanied by wear tests.

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ID226
PROTECTION AND COMFORT, CONFLICTING PROPERTIES?

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ABSTRACT

Protective textiles find applications in a broad range of fields, ranging from daily life to high end professional environments. They protect the wearer from straightforward factors such as the elements, but also from more advanced threats such as impact, radiation and chemical agents. In such products, the focus is mainly on effective protection, the impact on comfort commonly being ignored. This presentation will address how protection is jeopardising various types of comfort. It will describe methods to measure and model comfort of high end protective products, targeting improved balance between protection and comfort. The focus will be on personal protection.

INTRODUCTION

People have always been using textiles to protect them against cold, wind and precipitation. Not only clothes but also products which we would now consider as technical textiles, such as tents and tarpaulins, have been around for a very long time. Nowadays, textile products protect against a broad range of factors in addition to the traditional weather conditions. Today, textiles may protect against liquid or gaseous chemicals or biomaterials, including microorganisms, EM radiation, extreme heat or cold, mechanical effects such as impact, cut, perforation, and many more.Comfort in itself is a broad concept including various factors that are often interrelated. Common types of comfort include tactile, physiological and ergonomic. Other than that we can also mention aesthetic and psychological comfort. Protection is commonly achieved by adding layers that may be thin and light, but that are often tick, impermeable, heavy, harsh and stiff. Protection being the prime target, little attention is payed to the impact of protective materials on various types of comfort. In addition, the various factors related to protection and comfort are interrelated through complex connections, in some cases leading to adverse effects, even in terms of protection.

As a result, high end applications of effective and comfortable protective textiles require careful design, based on understanding of the complex interrelationships, supported by adequate validation methods and facilities. Smart and nanomaterials are key elements in the design and testing of improved products.

RESULTS AND CONCLUSIONS

Combining comfort and protection being a future oriented challenge that requires the combination of various fields of expertise and high end facilities, UGent has decided to set up the valorisation consortium TEX IS MORE, which links a multidisciplinary team of research groups that address scientific fields for understanding, designing, making and testing advanced and smart textiles for improved balance between protection and comfort, taking into account sustainability aspects as well.

Modelling of transport of heat and moisture through textile structures is a first step in

understanding the thermal behaviour of a textile product. Models exist at micro, meso and macro scale.
They take into consideration material properties as well as construction parameter. They may also include active elements such as heating, cooling, ventilation, absorption or release.
At the Sport Science Lab Jacques Rogge, thermo physiological analyses as well as effort tests can be conducted based on physiological responses at cardiovascular, pulmonal and muscular level. Core and skin temperature at different body locations, sweating ratio, heart rate, electrolyte concentration, hydration status and their evolution are just a few parameters that indicate the body response on effort in different heat stress conditions. In addition questionnaires are used as well (thermal sensation, thermal comfort).

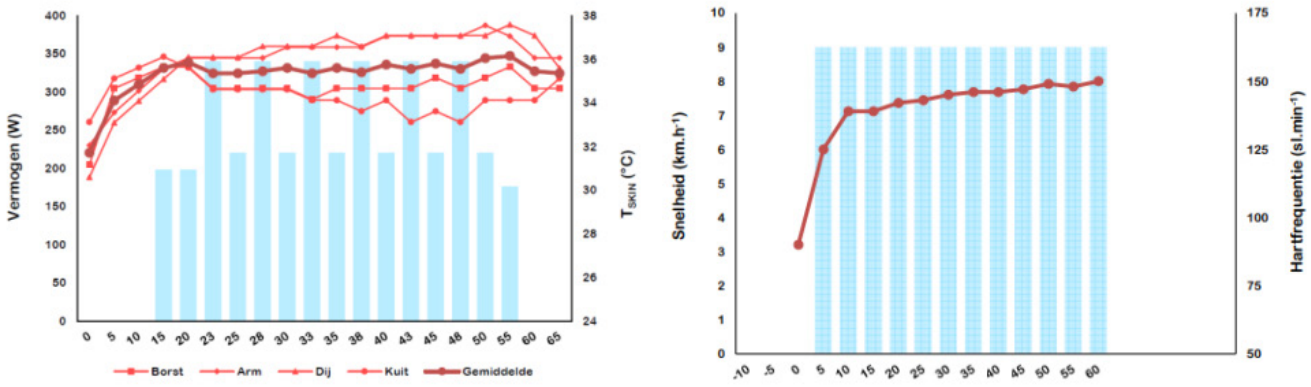

Fig. 1 – Evolution of skin temperature at various body positions (left) resp. heart rate (right)

Previous research for instance has compared different cooling strategies and types of clothing.

Smart textiles with integrated heating and cooling can be evaluated by such test set up.

Apart from thermophysiological comfort, ergonomic comfort is also very important.

Indirectly, ergonomic comfort will have an impact on effort and as such it will be reflected in thermophysiological parameters too.

Fit and ergonomic comfort can be modelled using finite element models, providing a virtual tool for optimisation of the design.

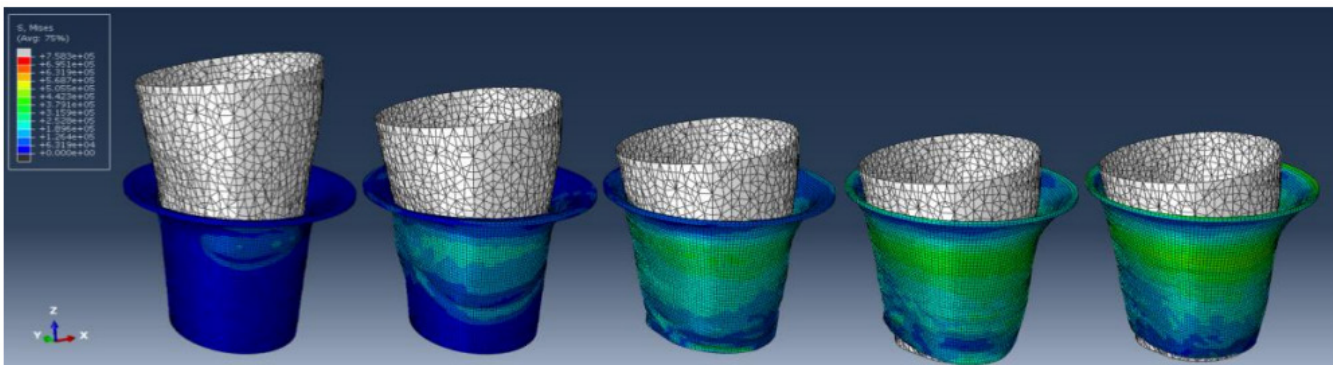

Fig. 2 – Fit and comfort of knee brace

3D analysis tools allow to monitor movements while for instance monitoring different types of clothes. Markers are applied to fix reference points out of which details of movement can be derived. The information can also be converted into biomechanical models for further simulations of the behavior of fabrics. With this approach, fabric properties and construction can be optimized for the targeted application.

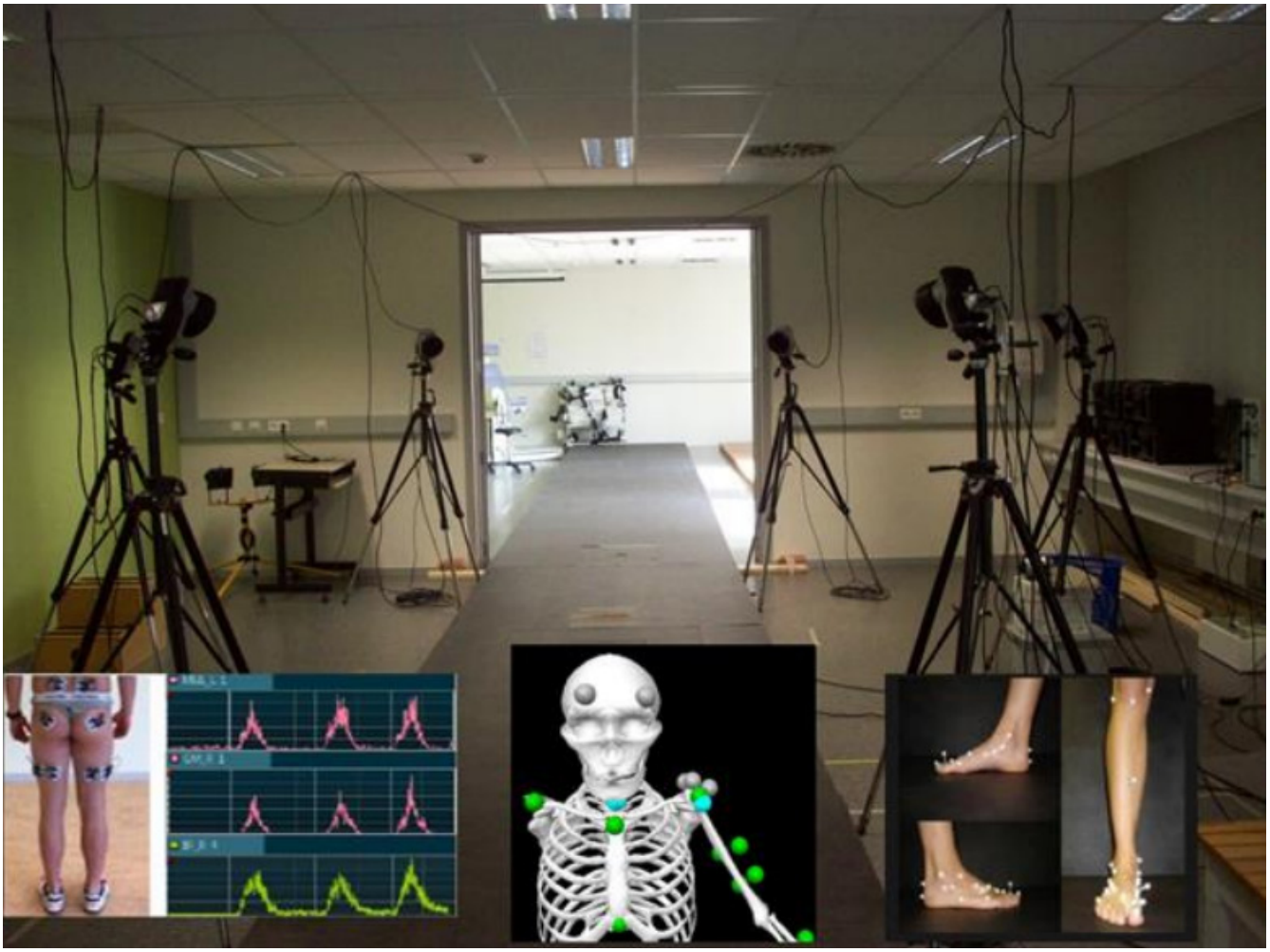

Fig. 3 – 3D monitoring and marking for conversion to biomechanical model

Movement analysis for various types of clothes can highlight relevant differences, as illustrated in the following graph that represents knee flexion for 4 different types of clothes:

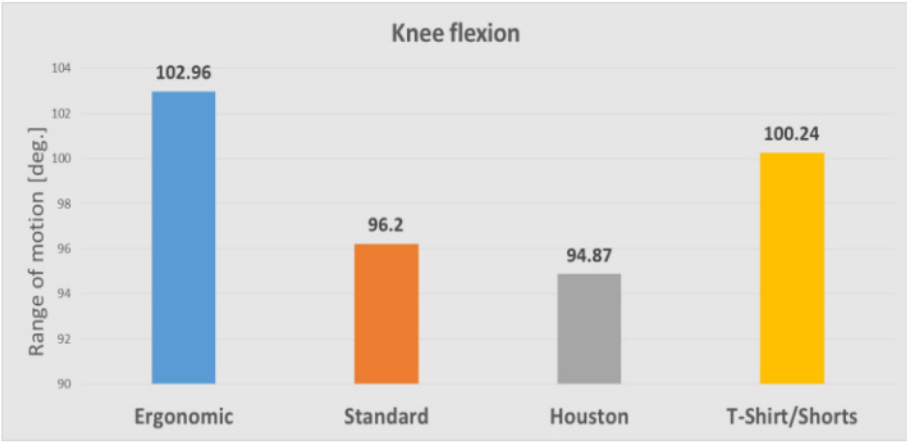

Fig. 4 – Range of knee flexion for different types of protective suits

Apart from movement, muscle activity can be monitored by EMG using for instance smart textiles. This provides a direct measure of effort needed for a specific movement while wearing different textile products.
In conclusion we can say that many theoretical and experimental tools are available for measuring various comfort parameters. They support the design of advanced protective textiles, whilst taking into consideration comfort as well. This will lead to the development of improved products that provide a better balance between comfort and protection.

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ID227

ELECTRICALLY CONDUCTIVE ADHESIVES FOR HIGH PERFORMANCE APPLICATIONS

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ABSTRACT

The increasing integration of electronics into communication and control systems has boosted the development of electrically and thermally conductive adhesives (ECAs) that enable the connection between an increasing number of electronic components and the printed circuit board (PCB). The aim is to replace traditional metal solders to reduce the weight, the production complexity, the processing temperature, and lower the thermo-mechanical residual stress inflicted on the substrate as well as the overall production costs. The present work reports the preparation of ECAs based on epoxy/carbon nanomaterials (single walled carbon nanotubes and exfoliated graphite) and the study of their morphology, curing process, electrical and thermal conductivity and rheology. A selected ECA composition was successfully placed on a test PCB using stencil printing. The ECA's shelf life was assessed by evaluating the cure of the resin before and after freezing for a time span up to nine months.

INTRODUCTION

The development of ECAs based on carbon nanomaterials such as carbon nanotubes (CNTs) and graphene dispersed in epoxy has been the focus of research along the past years. Q. S. Meng et al. [1] reached electrical percolation for epoxy/graphite nanoplatelets (GnP) at 1.2 wt.% GnP, and maximum electrical conductivity of 10-3 S/m and thermal conductivity of 0.33 W/m•K at 4 wt.% of GnP. Y. C. Li et al. [2] reported a percolation threshold of 1.2 wt.% for epoxy/functionalized graphene composites. R. Morishe et al. [3] dispersed NH2- functionalized graphene nanoplates in epoxy and achieve a conductivity of 10-4 S/m at a concentration of 12 wt.%. However, most of the ECA developments reported in the literature still include high amounts of metal particles. In the present work the epoxy Biresin® system CR141 with hardener CH141 and accelerator CA141, from Sika, was used to prepare conductive adhesives based on composites with single wall carbon nanotubes TuballTM from OCSiAl (SWCNT) and micronized graphite Micrograf® HC11 from Nacional de Grafite (EG). The composites were processed on a three-roll mill EXAKT 80E [4]. The composite pastes were rheologically characterized and the cure of the resin was studied by differential scanning calorimetry. The electrical and thermal conductivity of the composites were measured and the composites were characterized by Raman spectroscopy and Atomic Force Microscopy (AFM) as well as High Definition Kelvin Force Microscopy (HD-KFM). The ECAs prepared were applied on a PCB using stencil printing.

RESULTS AND CONCLUSIONS

Selected compositions of SWCNT and EG are listed in Table 1, as well as the electrical volume resistivity (R0) of the composites. The addition of EG had an impact on the electrical resistivity of the SWCNT containing composites, but most important on the thermal conductivity (Figure 1).

Table 1 Electrical volume resistivity of the multiple carbon nanomaterials composites

Composition		R_0 (Ω cm)
SWCNT	EG	
0.2 wt.%	0 wt.%	7.82E+01 ± 0.85E+01
	2 wt.%	2.77E+02 ± 0.33E+02
	5 wt.%	2.80E+02 ± 1.27E+02
1.2 wt.%	2 wt.%	1.94E+01 ± 0.53E+01
	5 wt.%	2.17E+01 ± 0.71E+00

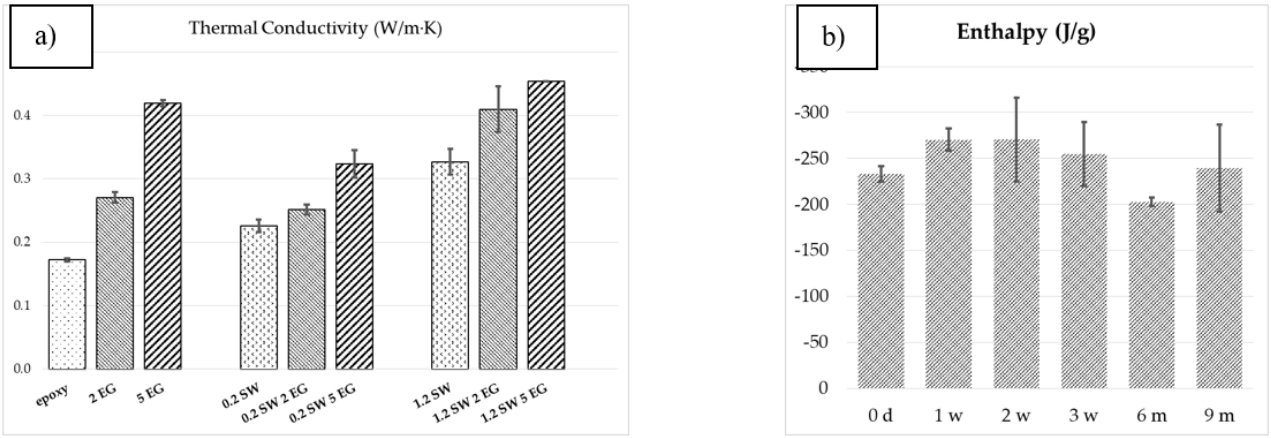

Fig.1 Thermal conductivity of ECAs (a) and enthalpy of cure of 0.5 wt.% SWCNT + 2 wt.% EG composites after storage at -18 ºC up to 9 months (b)

This study demonstrated the potential for ECAs application in PCB component bonding at low filler content, promising thermal and electrical properties, ease of application and large shelf-life. Further work will be carried out to increase electrical conductivity and validate the bonding mechanical performance and reliability.

ACKNOWLEDGMENTS

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ID230

INFLUENCE OF NON-NEWTONIAN MATERIALS IN THE BALLISTIC COMPOSITES PERFORMANCE

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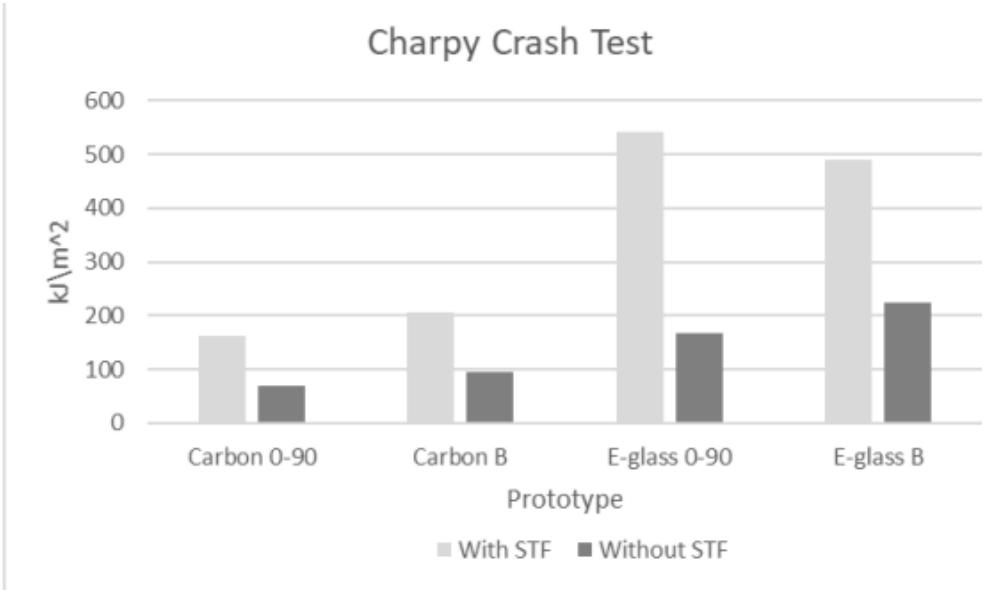
ABSTRACT
The main purpose of this project was applying a non-newtonian material, such as STFs (shear thickening fluids) to a composite structure, and analyse its influence when the prototype is under ballistic efforts. Two fibres were tested, such as carbon and E-glass, displayed in different orientations. To study the impact of the STF material in the prototype, several tests were performed but the one presented in this paper, and the most relevant for the application is the Charpy Crash Test. The intention with this testing was to study the impact of the STF material on the prototype to several applications of efforts, and values of over 200% increase in impact resistance were obtained

INTRODUCTION
The use of composite materials for ballistic or explosive protection is not something new in the industry. Several advances have been made in this area, through the experimentation of numerous materials and different fiber orientations, applications of different resins and additional products to the structure of composites. Therefore, the resistance to damage and wear of military products has increased considerably.
In the matrix of the composite material, a STF was applied which is a non-newtonian material that results from the particle of carbide oxide, such as silica. These particles are then diluted in a base of a Newtonian nature such as water or polyethylene glycol. Non-Newtonian fluids are somewhat incompressible liquids that have changes in viscosity depending on the stress applied to them. The material used on this project is a particular type of non-Newtonian fluid in which it undergoes an increase in viscosity with increasing shear stress, which causes the material to behave as a solid under these conditions, and going back to its original forms once the stress is relieved [1]. Applying this substance to the prototype may increase substantially its impact resistance.
One of the most frequent applications of the STF has been the development of stimulusresponsive materials, sensors and protective materials. In addition, STFs can be used to absorb shock waves from earthquakes or wind and water impacts, being applied in the damping systems of structures. They can also be used for protective applications and used to improve the medical body against external physical shocks and impacts [2].
To test the influence of non-newtonian materials, there were produced 4 different prototypes, two of them consisting only of E-Glass fibers, and the other two made of carbon fibers. Both fibers were selected mainly because of their large-scale applications on these fields. Even though EGlass is heavier than carbon fibers, it is more resistant to impact and has a greater elongation until rupture. On the other hand, carbon fibers are the stiffest of possibly all the other available options. There were produced 4 prototypes, as it was previously stated, because it was intended to compare
the results with other samples without the appliance of the STF. Therefore, each type of fiber was
used to build a plate with an orientation of 0/90º and another with a bouligand misalignment of

[0/90]º fabric layers by 15º to each other. The STF material was mixed with the epoxy matrix to impregnate the fibers. These composite materials were produced through a hand lay-up of the fibers followed by hot compressing molding process for 25 min at 90ºC.

RESULTS AND CONCLUSIONS

To pursue the main purpose of this project, there were carried out several tests, but the most important one is the Charpy Impact test, since it represents the efforts to which the prototype would be subjected in a real application situation. To guarantee that the results were valid, the researchers followed the ISO 179 which describes the method used during the procedure. The results for the Charpy crash test are presented in Figure 1.



Analyzing the obtained results, its visible that the presence of STF largely increases the resistance of the material to the impact. In the prototype made of E-Glass fibers with the 0-90º orientation the resistance increases more than 200%. It is also very notable that E-glass fibers are much more resistant to impact, reaching values of over 500 kJ/m2

.

To conclude, the results were very pleasing, and definitely showed the difference on the impact resistance of both materials, which proves the value of applying a non-newtonian material to the composites prototype.

ACKNOWLEDGMENTS

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ID231
STRUCTURAL COLOR FOR ENHANCED CAMOUFLAGE TEXTILES

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ABSTRACT
Monodisperse latex nanospheres of poly(styrene-methyl methacrylate-acrylic acid) with different sizes were synthesized by soap-free emulsion copolymerization and applied onto polyamide 6,6 fabrics dip-drawing method. Different-sized nanospheres were synthesized by varying temperature and stirring velocity as reaction parameters. Scanning electron microscopy and scanning transmission electron microscopy were used to evaluate nanosphere sizes and deposition structures. Different colors were observed according to particle size, namely, violet, blue, green, yellow, and red. An iridescence effect was also observed, displaying different colors at different observation angles. Furthermore, these fabrics presented different colors depending on whether they are dry or wet, thus making it possible to use them for camouflage purposes.

INTRODUCTION
Smart textiles that exhibit color changes induced by external stimuli such as humidity, light, pH, and electrical and magnetic fields, have gathered great attention recently since they can be applied in anti-counterfeiting materials, wearable functional textiles, sensors, and the automotive industry. (Chen et al., 2020; Wang et al., 2021) These colors can be achieved through structural coloration, where photonic crystals (PCs) (silica or polymer) self-assemble in highly organized nanostructures. (Yavuz et al., 2018) PCs are dielectric materials, capable of controlling the propagation of light due to the photonic bandgap (PBG), can be found in nature in animals, insects, fruits, and plants, and can be used for signaling, communication or camouflage purposes. (Moirangthem and Schenning, 2018) Furthermore, the structural coloration of textiles is more ecological than dye/pigment coloration since the water and chemical consumption can be highly reduced. (Fernandes et al., 2020) Bearing the applications and the great potential of PCs in mind, a new approach for military camouflage garments was envisioned. Poly(styrene-methyl methacrylate-acrylic acid) (P(St-MMA-AA)) PCs with different sizes and colors were synthesized and applied onto polyamide 6,6 fabric (PA), where their ability to be used as humidity sensors was studied. Furthermore, fabrics coated with PCs showed different colors depending on the angles of observation/incidence of light, the iridescent effect.

RESULTS AND CONCLUSIONS
Different sized monodisperse latex nanospheres of P(St-MMA-AA) were possible to obtain by controlling the reaction temperature, stirring speed, or monomer proportion. Then, the resulting colloidal crystals were applied, without any purification, onto a black PA fabric by the dip-drawing method (Figure 1). All produced samples were evaluated for their iridescent effect and capability as humidity sensors. All samples presented iridescence (two samples presented in Figure 2). When wet, the nanospheres swell and the color suffers a bathochromic shift in the visible spectrum. Thus, all colors except red can be used as a humidity sensor, where red PCs just change to a darker shade of red.

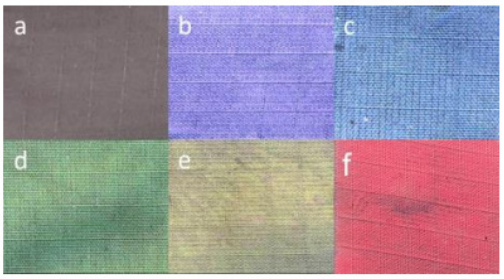

Figure 1 – Photographs of (a) uncoated PA fabric and PA fabric coated with different size P(St-MMA-AA) nanospheres *ca*. (b) 170 nm, (c) 190 nm, (d) 210 nm, (e) 230 nm, and (f) 250 nm.

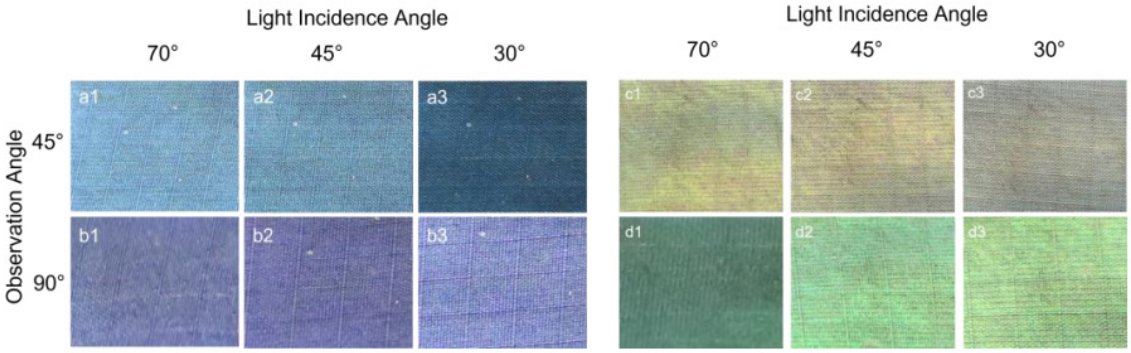

Figure 2 – PA fabric with ~190 nm (left) and ~210 nm (right) nanospheres at different observation angles, 45º (row a and c) and 90º (row b and d), with different angles of incidence of light, 70º (a1/ b1, c1/d1), 45º (a2/b2, c2/d2) and 30º (a3/b3, c3/d3).

These results show the potential of using PCs in military camouflage as they can change color and deceive the enemy with the help of the surrounding environment. PCs can also be obtained without iridescence (silica-based PCs), and used as electrical and/or magnetic sensors, thus modulating and expanding the needs of the military personnel.

ACKNOWLEDGMENTS

This work was funded by FEDER funds through the Operational Competitiveness ProgramCOMPETE and by National Funds through Fundação para a Ciência e Tecnologia (FCT)- under the projects PTDC/CTM-TEX/28295/2017, ARCHKNIT POCI-01-0247-FEDER039733 and UID/CTM/00264/2019. Rui D.V. Fernandes acknowledges FCT, MCTES, FSE, and UE Ph.D. grant SFRH/BD/145269/2019.

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ID233

POLY(BUTYLENE SUCCINATE) HYBRID MULTIWALLED CARBON NANOTUBE/FERRITE COMPOSITES WITH ENHANCED THERMAL AND ELECTRICAL CONDUCTIVITY

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ABSTRACT
This work compares the broadband AC conductivity, thermal conductivity, and surface resistivity values of poly(butylene succinate) hybrid composites filled with several mass fractions of multiwall carbon nanotubes and ferrite nanoparticles. Seven compositions and a neat system were prepared using solvent casting and compression molding techniques. The electrical and thermal tests performed permitted the evaluation of the extent of interaction between the MWCNT network and ferrite particles and their influence on the overall properties of the composite.

INTRODUCTION
Carbonaceous hybrid polymer nanocomposites are one of the most perspective materials for use in electromagnetic interference shielding applications in defense, aerospace, packaging, and electronics sectors, because they combine light weight, easy processing, and adaptability to different requirements. Combining sustainable and high-performance materials will be a key factor in adapting the defense sector to a more climate friendly future while not diminishing its capabilities. Poly(butylene succinate) is a completely biodegradable and partially bio-based polyester with electric conductivity (1.72[11]10-11 S/m) several orders higher than other commodity plastics such as low density polyethylene (Ohki and Hirai, 2007).
MWCNTs have very high aspect ratios and specific surface areas, as well as very high electrical and thermal conductivities, which allows them to form electrically conductive percolated networks in composites at low filler loading values. Spherical fillers such as ferrite nanoparticles have much higher percolation thresholds, however, they have magnetic properties, which aid in electromagnetic radiation and interference absorption and dissipation. Synergy could arise from CNTs becoming arranged on the interfaces of ferrite nanoparticles, decreasing the percolation threshold, and increasing electrical and thermal transfer properties between fillers and matrix, and thus aiding in EMI absorption through multiple inner reflection and providing potential stealth benefits (Ahmad et al. 2019).
AC conductivities were measured using broadband dielectric spectroscopy at RT and frequencies of 10^{-2}-$4 \cdot 10^{7}$ Hz on samples with a diameter of 30 mm and a thickness of ~900 µm. Thermal conductivities were measured using light flash analysis at 25, 35, 45 °C on graphite-covered square samples with an edge length of 12.7 mm and a thickness of ~900 µm. Surface resistivities were measured using a 4-point probe on square samples with an edge length of 60 mm and a thickness of ~100 µm to reduce the impact of sample geometry.

RESULTS AND CONCLUSIONS

Thermal conductivities are shown in Fig.1a., AC conductivity spectra are shown in Fig.1b., surface resistivity values are shown in Fig.1c. As predicted, the results show that the samples with the highest filler fraction have the highest thermal and electrical conductivity values (0.308 W/(mK), 3•10-3 S/m, 5.73•103 Ω/sq for 0.6 vol.% MWCNT 12 vol.% Fe3O4) due to the formation of a percolated network with free electrons and more accessible phonon transport. Surface resistivity is mostly MWCNT dominated, and Rs couldn't be measured for the neat polymer. However, the results from intermediate filler fraction composites aren't as conclusive, and a distinct non-linearity can be observed in composites filled with 0.1 vol.% MWCNT. Thermal conductivity values have a low dependency on temperature due to the relatively low concentration and high mobility of electrons in the composite.

The most significant increase of properties with the smallest increase of filler compared to a neat polymer can be seen in the 0.6% MWCNT and 8% Fe3O4 composite (60% increased λ, σ' at 50Hz increased by 7 orders of magnitude) which could signify a critical value of filler.

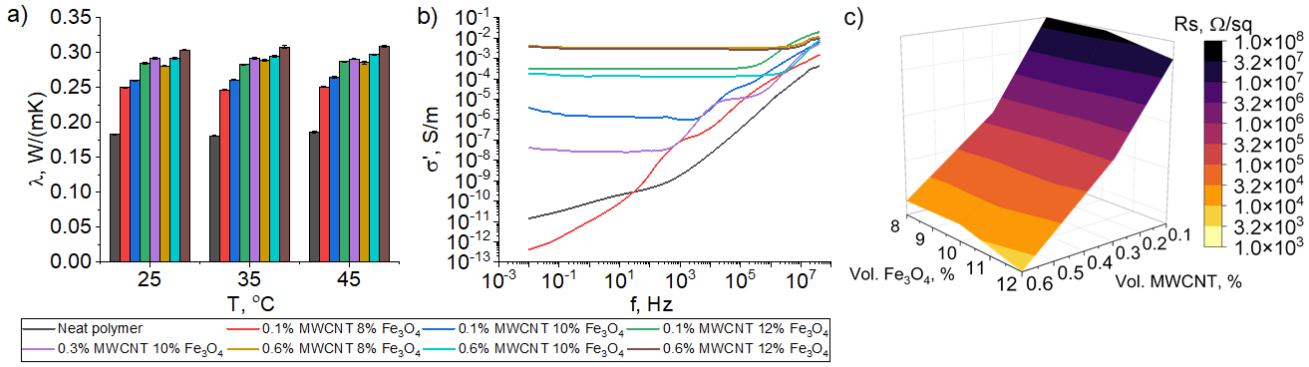

Fig.1 a) Light Flash Analysis, b) Broadband AC conductivity, c) Surface resistivity results

The present work shows a complex relation between fillers in a hybrid composite system. Response surface methodology or other analytical methods could be applied in the future to attain tailored composites with specified properties and high performance for EMI shielding and defense applications.

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ID234

NUMERICAL MODELLING OF POLYUREA COATING SYSTEMS FOR BLAST MITIGATION ON CONCRETE MASONRY WALLS BASED ON MATERIAL MODELLING APPROACH.

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ABSTRACT
In this study, three concrete masonry walls are tested in a blast trial carried out at full-scale, one of them is unreinforced and the other two are reinforced. Then, the numerical model of the walls protected with two different polyurea coating systems is developed using the finite element code LS-DYNA. This work focuses on finding a suitable material model to accurately reproduce the behaviour of the polyurea systems. For this purpose, three different elasto-plastic material models available in LS-DYNA are checked: *plastic_kinematic, *piecewise_linear_plasticity, and *rate_sensitive_polymer. The simulation results are compared with those obtained in the field tests.

INTRODUCTION
Recent research has highlighted the potential of using polyurea for applications based on the reinforcement of structures (Iqbal, 2016). Numerical modelling is commonly used to reproduce experimental tests in a blast environment. A major concern associated with numerical modelling is to correctly represent the behaviour of the different materials involved in the simulation process. In case of materials like concrete blocks or mortar, there are several constitutive models which can be used confidently as they have been used to realistically predict the behaviour of concrete structures under various types of loads. This is not the case for polyurea coatings since the mechanical behaviour of all viscoelastic materials is generally strain rate sensitive (Aghdamy, 2013).
The experimental trial consisted of three different concrete masonry walls, tested at the same time. The charge detonated was 20 kg of TNT. The walls were built with concrete masonry units (CMU) measuring 2.50 m height and 1.66 m width. The numerical model of the wall has been developed reproducing a whole model without considering symmetry planes, using a micro-modelling approach. The type of elements used are 8-nodes solid elements with an element formulation of one point integration plus viscous hourglass control. The mesh size selected for the numerical modelling was the concrete block thickness (20 mm). For masonry construction, this is a suitable mesh size that has been successfully used in other research works (Chiquito, 2021). For a perfect bonding between the different parts of the model, the same mesh size was used coinciding with the CMU mesh and hence, merging nodes.

RESULTS AND CONCLUSIONS
To check the suitability of the three material models, the maximum displacements recorded are compared to the numerical model. In the field test, the maximum displacement was registered by a mechanical measuring device positioned in the centre of the rear face of the wall. For the polyurea 1, the value obtained was 38 mm while for the polyurea 2 was 24 mm. Results from the numerical model are shown in Fig. 1. For the polyurea 1, material

models 024 and 141 performs similarly being the 024 slightly better registering 40 mm. However, material model 003 did not show any correlation with the other two material models nor with the experimental result. In the case of polyurea 2, the behaviour of the three material models is very similar with 46 mm; 46.7 mm; and 45 mm which is almost the double than the maximum displacement obtained in the experimental trial. This discrepancy in the results can be attributed to the irregularities of the polyurea coating. The material model 024 shows a more elastic behaviour than the other two.

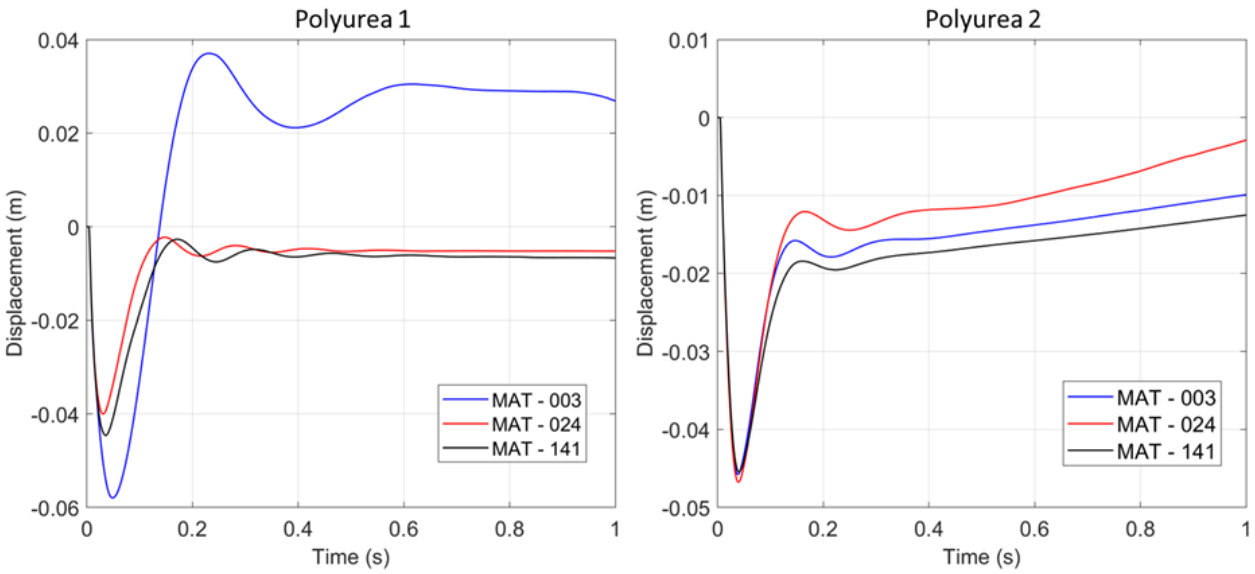

Fig.1 Displacement-time histories.

Results show that not all material models perform well, with the *piecewise_linear_plasticity material model performing the best for the polyurea 1. In the second case, it would be necessary to check other parameters to conclude what material model performs better.

ACKNOWLEDGMENTS

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ID235

ECO-FRIENDLY POLYURETHANE RESINS. FROM SYNTHESIS TO APPLICATIONS

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ABSTRACT

This work presents different synthetic approaches to obtain polyurethane resins through sustainable methodologies. Two types of polyurethanes (PUs) were obtained, from 1K cationic water-based polyurethanes (PUDs) to non-isocyanate polyurethanes (NIPUs), using monomers obtained from renewable sources, and also using CO2 as a C1 building block and novel feedstock. Special attention was paid to this conversion of CO2 to useful building blocks (bio-based cyclic carbonates) with the use of moderated conditions aided by the role of novel heterogenous catalysts, designed and synthetized by us.

The developed polyurethane resins have been validated in multiple industrial applications of interest (adhesives, coatings, foams and elastomers). Coatings prepared with these polyurethane resins were applied to modify surfaces of polymeric composites used in the manufacturing of tidal and wind turbine blades or maritime vessels, or protective textiles to provide properties like antifouling, antimicrobial or cavitation erosion resistance.

INTRODUCTION

Polyurethanes are highly versatile polymers that are widely employed in modern life as rigid or flexible foams, as well as in elastomers, composite materials, paints, coatings, and adhesives. Currently, their annual worldwide production exceeds 20 million tons and accounts for about 7 wt % of all plastic production.1 The polyurethane adhesives market size was estimated at over 18 billion USD in 2020.2 On account of their diverse formulation options, PUs are the preferred choice when it comes to formulating high-quality coatings or adhesives with excellent adhesion, resistance to abrasion, chemical resistance, and low temperature tolerance.3 The vast majority of industrially applied PUs are based on non-sustainable feedstocks including crude oil and gas. Therefore, there is a drive to substitute fossil resources with renewable ones to move toward a more sustainable industry4 and to employ safer routes limiting the use of toxic isocyanates. Thus, in the past decade NIPUs have emerged as alternatives in the search for greener PUs

RESULTS AND CONCLUSIONS

Both, PUDs and NIPUs are synthesized from bio-based intermediates. In the first case the hydroxyl groups of the bio-based polyols are reacted with isophorone diisocyanate (IPDI) and N-methyl diethanolamine (N-MDEA) at 80°C under nitrogen atmosphere until all NCO groups are converted into urethane linkages. The conversion is determined by NCO titration. Then, the reaction is cooled down to 50°C and polyurethane is dissolved in acetone. The calculated amount of acetic acid is added to promote the quaternization of N-MDEA. Finally, the material is dispersed in water at high speed followed by the removal of acetone under vacuum, yielding a white milky polyurethane dispersion. The developed PUDs were applied as coatings on composite substrates and their properties tested. On the other hand, NIPUs are synthesised in two steps that involves the cycloaddition of CO2 to the bio-based intermediate in the presence of a catalyst and later the reaction of the obtained cyclic carbonates with a diamine: ethylenediamine, tert-butylamine, diethylamine and Cardolite NC-540 (a bio-based diamine). The

components were mixed and after 30min under vacuum transfer to a Teflon mould and cured at 100ºC for 12h.

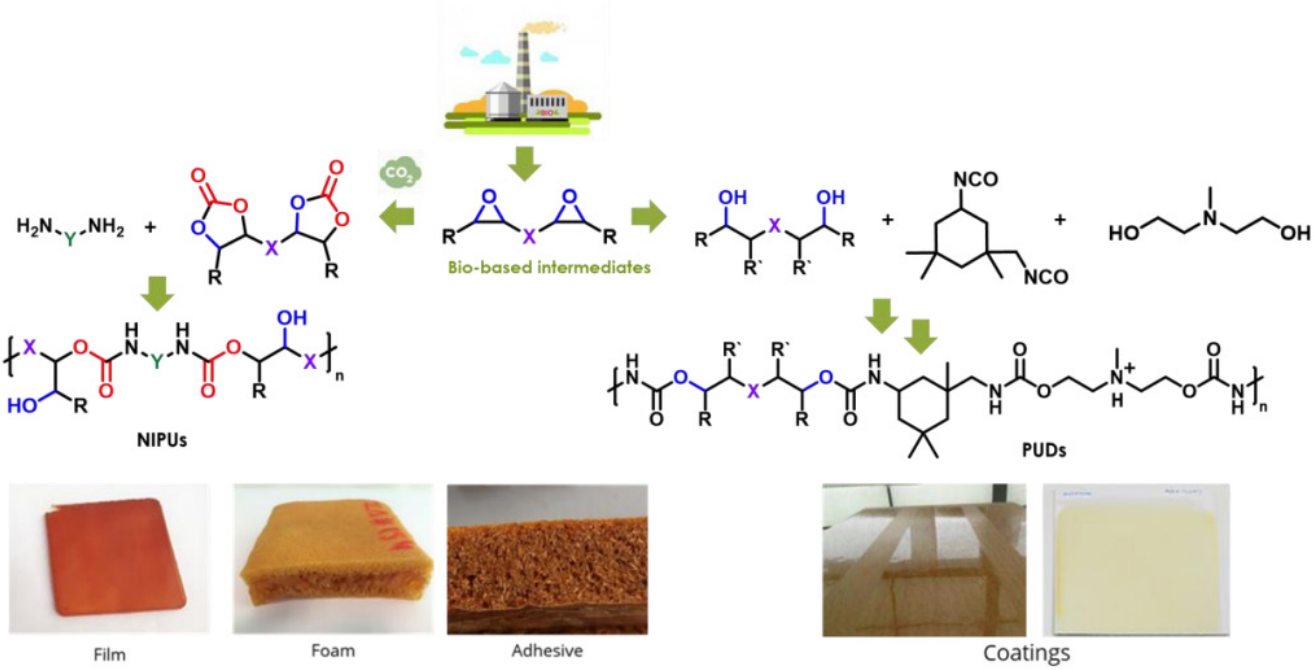

Fig.1. Synthetic approaches to versatile eco-friendly PURs

The synthesize materials showed excellent mechanical properties (Adhesion: 5B, Hardness: 5H), good cavitation erosion resistance (about 0,02% mass loss) and antibacterial properties against Klebsiella pneumoniae and Staphylococcus aureus, among other properties. In addition, the prepared NIPUs showed good compostability under control composting conditions. These materials have been proved as a green and sustainable alternative to traditional polyurethane resins

ACKNOWLEDGMENTS

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ID236

NOVEL HIGH PERFORMANCE HIERARCHICAL COMPOSITES DEVELOPED USING NATURAL FIBRES AND NANO-REINFORCEMENTS

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ABSTRACT

In this work, novel hierarchical composites were developed using natural fibres, a green polymeric resin and natural nano-reinforcements and characterised for mechanical properties such as flexural strength and extension at break, fracture energy and interlaminar shear strength. The performance of the developed hierarchical composites was compared with conventional natural fibre composites developed without nano-reinforcements as well as with carbon fibre composites. The experimental results indicated strong improvements of interfacial strength and mechanical properties in case of hierarchical composites.

INTRODUCTION

Conventional fibre-reinforced composites are developed by combining fibres which provide strength and stiffness with a matrix which holds the fibres together and provide dimensional stability to the composites. Incorporating nanomaterials into a conventional composite as reinforcements or to add other functionalities forms a special class of hybrid composites, known as multi-scale or hierarchical composites (Parveen, 2020; Pichandi, 2018; Parveen, 2017). Nanomaterials can be introduced either within the matrix as nanofillers or in the fibres as sizing or coating or both in the matrix and fibres. They are called multi-scale or hierarchical composites as they contain materials from different length scales, i.e., macro, micro or nano which are hierarchically organised in the composite structure. Hierarchical composites are abundant in nature such as wood, bone, plant fibres, etc. and each component of hierarchical composites is specially organised to provide a specific set of properties. Inspired by nature, hierarchical composites have also been developed by various researchers using different types of fibres and matrices with the incorporation of a wide varieties of nanomaterials such as carbon nanotubes, graphene, nanoclay, nanocellulose, etc. (Parveen, 2017).

Although the existing hierarchical composites exhibited superior mechanical, thermal and electrical properties over conventional composites, huge demand is still expected in near future for completely green and eco-friendly hierarchical composites in various industrial applications due to increasing concern on environment and climate change. In this work, three different types of green hierarchical composites were developed using same natural fibre and green resin and under the same processing conditions but varying the loading of nanomaterial. Interlaminar shear strength and flexural properties of these composites were characterised and compared with conventional natural fibre and carbon fibre-reinforced composites.

RESULTS AND CONCLUSIONS

The results obtained from the flexural testing is provided in Fig. 1. It can be noticed that the green hierarchical composites exhibited up to 35% higher flexural strength as compared to the conventional composite. The fle-

xural strength of hierarchical composites, however, was significantly lower as compared to carbon fibre composites. Nevertheless, the hierarchical composites showed significantly higher interfacial shear strength, flexural strain, and fracture energy over carbon fibre composites and conventional composites (these results are not presented here).

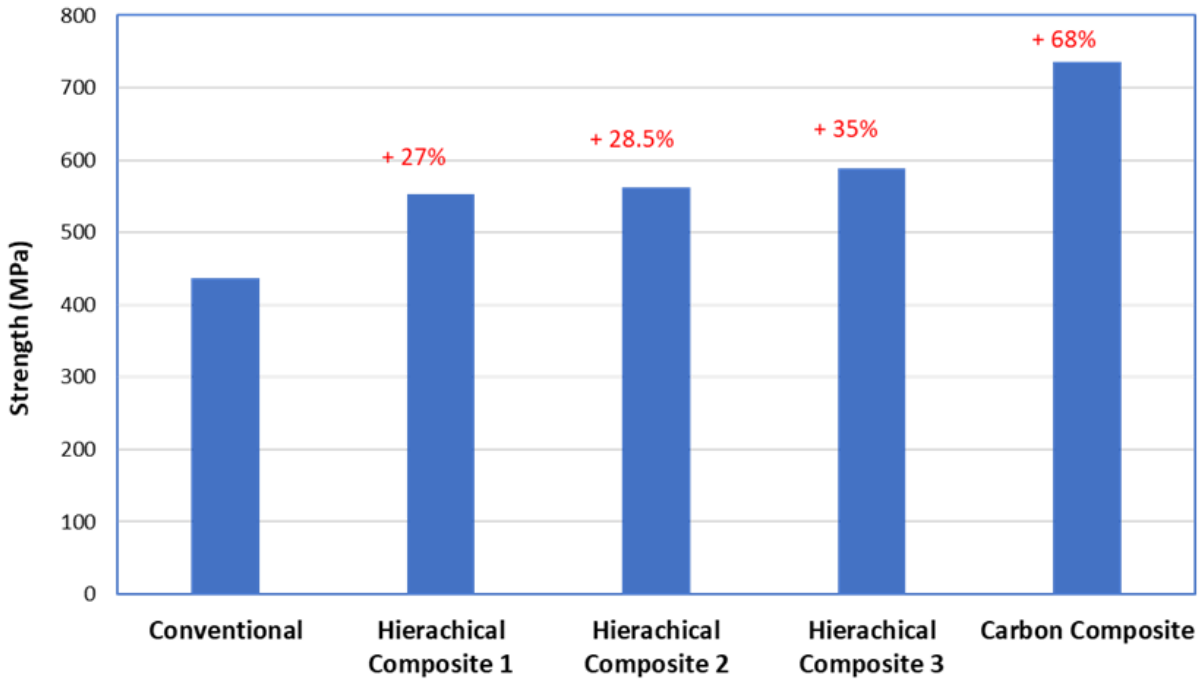

Fig.1 Flexural strength of conventional, hierarchical and carbon fibre composites

This experimental study confirmed that the developed novel hierarchical composites had superior mechanical properties over conventional composites as well better ductility and fracture behaviour as compared to carbon fibre composites. Further studies are underway to evaluate the application potential of these novel composites in different industrial sectors including defense.

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ID237
MODERN DESIGN PROCESS OF CBRN PROTECTIVE GARMENT

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ABSTRACT
This research work comprehends the development of technical and scientific expertise in functional coatings for the creation of innovative solutions that meet market needs in the personal protective equipment (PPE) sector, namely for military applications. The main objective is to create multilayer solutions with active protection capabilities against chemical and biological (CB) harmful agents, which will then be integrated in an innovative army suit design towards the achievement of highly comfortable, functional and versatile clothing designs coupled with active and passive protective technology against CB threats.

INTRODUCTION
The textile sector has been adapting to all the ongoing transformation in the technical textile's scenario, trying to respond to new challenges with new design, technology, quality, innovation, and business models [1, 2]. Currently available products are quite uncomfortable for the user due to their high weight and poor maintenance of thermo-physiological balance of the human body/protective clothing interface [2]. There are also considerable limitations in terms of the user's movements caused by poorly adjusted fitting. The ideal is to create a functional protection suit with a high CB protection factor [3]; a suitable thermal and physiological comfort index following exposure to different ambient conditions [4]; and ease of use, allowing its use during extended active missions in dangerous environments.

RESULTS AND CONCLUSIONS
The new design results in a modern CB protection suit consisting of 2 body pieces: the jacket and the pants (Figure 1).

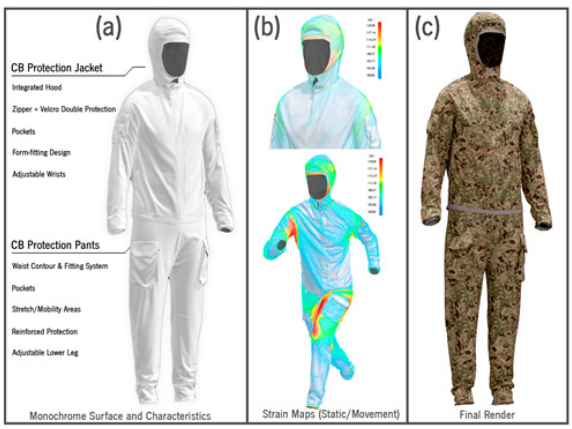

Figure 1 - (a) Monochrome surface of the CB suit design and (b) strain map simulations for static and movement-related situations. (c) Final render of the suit.

With a focus on ergonomics, it was possible to design a modern suit with a close fit to the body, resulting in a reduced silhouette and lower weight compared to commercial models, allowing the user to move freely and comfortably. The design also incorporates several attachment points for the addition of field equipment and accessories such as gloves, helmets, ballistic vests, etc. The integrated hood was designed to be compatible with certain mask models as to completely remove any peripheral vision loss caused by the suit itself, a negative factor also seen in older suits. Several fastening straps were included to protect every part of the user's body, including the zipper + Velcro combination, which creates a tight seal against contaminants while allowing an easy way to open and close the various suit elements. This also means that the act of getting dressed and undressed is unhindered by cumbersome fastening solutions such as suspenders and excessive amounts of tape. Another solution for this was the development of a lower leg adjustment system also using a zipper + Velcro combination, which allows the user to easily remove the pants, even with the boots on, or to adjust the pants more accurately to the desired width. To justify the removal of suspenders, a modern waist contour & fitting solution was designed with the use of an integrated belt and additional lumbar support to ensure a perfect waist contour and fit. Additional material panels were added to certain areas of the body for enhanced protection and textile durability (Figure 1a). The real-time form-fitting simulation and rendering provided by the software CLO 3D was essential to identify problematic areas [5], enabling quick adjustments (Figure 1b), and to showcase the product design in a realistic manner (Figure 1c). Overall, CLO 3D ensures a fast and efficient design stage, so that the prototyping stages, especially in regard to fitting and pattern dimensions, can be optimized.

ACKNOWLEDGMENTS

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BALLISTIC IMPACT OF UHMWPE-GLASS-AUXETIC MULTI-LAYER SANDWICH PANELS, TO THE LEVEL III OF NIJ 0108.01

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ABSTRACT

The aim of this work was to compare the ballistic performance of developed multi-layer composites, using several combinations of woven fabrics arranged in different orientations (angle-ply effect), and with the addition of an auxetic structure, in order to create a functionally graded materials. The ballistic multi-layer composites panels were developed using E-glass fibers impregnated with thermosetting epoxy resin, prepregs of Ultra High Molecular Weight Polyethylene (UHMWPE), and an auxetic structure impregnated with polyurethane resin as a core, which were developed in autoclave. All the samples were tested according to the level III of NIJ 0108.01, and the objective was to verify the ballistic impact resistance and understand the functional gradient of the multi-layer panel by analyzing the impact cavity.

INTRODUCTION

Protective structures are designed to resist when exposed to ballistic threats, but it was known that the failure modes experienced by the panel's solutions changes with the increasing of the kinetic energy of the threat. During a ballistic impact, it is verified an association of several mechanisms that happens during the impact, namely fibers subject to phenomena such tensile, flexural, compressing and shear forces, caused by the interaction of the projectile/fragment with the composite laminate, as shown in Fig. 1 [1].

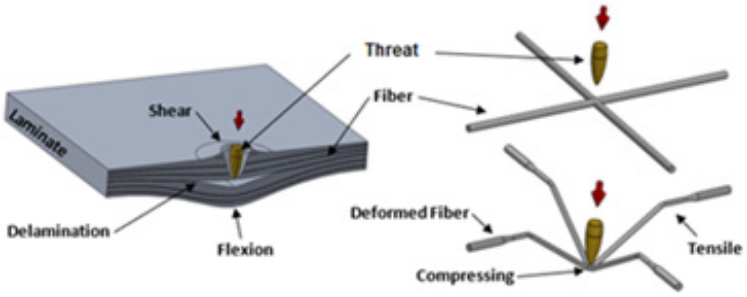

Fig. 1. Some mechanisms associated to a ballistic impact.

A feasible way to enhance the ballistic resistance is to create solutions with higher thicknesses (which implies mass increasing) or create multi material combinations like sandwich structures to obtain functional gradient properties [2].

Ultra High Molecular Weight Polyethylene (UHMWPE) are fibers capable of high energy dissipation, and auxetic materials, due to its negative Poisson's coefficient, are a good ones for energy absorption. Then, the main goal of this work is to create ballistic panels with the high capacity of energy dispersion, through high modulus materials use in the first layers, and high absorption capacity by using high elongation material in order to absorb the impact energy, as it possible to verify in Fig.2 [3].

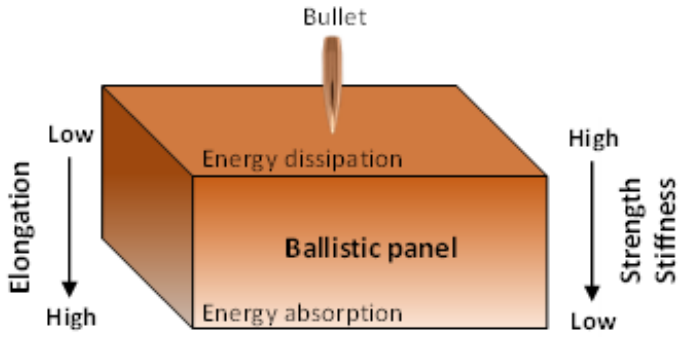

Fig. 2. Ballistic panel with functional gradient.

RESULTS AND CONCLUSIONS

Different multi-layer panels were developed using different thicknesses of each type of layer, and different positions of the auxetic structure. For that, it were produced five different ballistic panels combinations that were tested according to level III of NIJ 0108.01 (projectile with 838 m/s). The panels configuration and ballistic results are presented in Table 1, and the damage inside the impact zone of the panels with total penetration, are show in Fig. 3.

Table 1: Internal composition of each sample produced.

	Market reference	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Composition	UHMWPE	E-Glass UHMWPE Auxetic E-Glass	E-Glass UHMWPE Auxetic E-Glass	E-Glass UHMWPE Auxetic UHMWPE E-Glass	E-Glass UHMWPE Auxetic UHMWPE E-Glass
Ballistic result	Partial penetration	Total penetration	Total penetration	Total penetration	Partial penetration

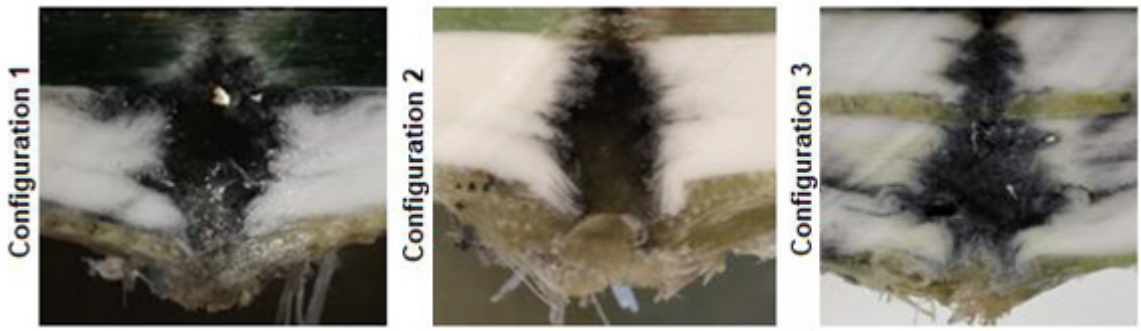

Fig. 3. Sectional cuts in the impact zones, of the panels with total penetration.

According to study of the impact zone, it was detected the total penetration by the projectile. But, the presence of copper and lead particles, resulting from the defragmentation of the projectile during impact, in panels 1 and 3, showing a greater resistance to the projectile comparing to the sample 2. In these two panels it is still possible to verify the presence of delamination in the final layers of the panel, showing that the projectile had a greater loss of kinetic energy than in panel 3, according to ballistic mechanisms. Analysing the areal damage of each impact zone (using Image J software), and taking the damage of the configuration 2 as the reference, configurations 1 and 3 presented about 13% and 14% more damage. This means that these two combinations made it difficult for the projectile to penetrate.

Including auxetic structure in the middle of the UHMWPE layer, allowed to increase the energy absorption, for forcing the projectile to cross more border zones (different materials), and due to this, the projectile loses more kinetic energy, so the laminate resists better to its penetration, increasing its delamination, one of the common mechanisms associated in ballistics.

Finally, comparing the market reference and configuration 4 panels, it was verified that to the same level protection, using a multi-material using an auxetic structure, was possible to reach functional gradient properties, and can get a mass reduction up to 20%.

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