81st International Scientific Conference of the University of Latvia 2023

Advanced Composites and Applications

Book of Abstracts

February 16, 2023

UNIVERSITY OF LATVIA

81st International Scientific Conference of the University of Latvia 2023

Tuesday, 16 February 2023
10:00-15:00, online

Programme

Chair: Assist. Prof. Tatjana Glaskova-Kuzmina		
10:00-10:05	**Tatjana Glaskova-Kuzmina** *University of Latvia, Riga, Latvia*	**Opening of the Conference special section**
10:05–10:20	***Andrejs Krauklis*** *University of Latvia, Riga, Latvia*	**Modelling material-environment interactions via modular and multiscale approach**
10:20–10:35	**Anish Niranjan Kulkarni and Andrejs Pupurs** *Riga Technical University, Riga, Latvia*	**Modeling high stress gradients and intralaminar crack growth in cross-ply composites**
10:35–10:50	**Małgorzata Szymiczek, Monika Chomiak, and Sara Sarraj** *Silesian University of Technology, Gliwice, Poland*	**Prediction of polypropylene properties modified with organic fillers based on selected mechanical characteristics**
10:50–11:05	***Liva Pupure, Leonids Pakrastins, and Janis Varna*** *Riga Technical University, Riga, Latvia, Luleå University of Technology, Riga, Latvia*	**Nonlinear 3D material modeling for advanced composite applications**
11:05-11:20	**Leons Stankevics, Tatjana Glaskova-Kuzmina, Sergejs Tarasovs, Jevgenijs Sevcenko, Vladimir Špaček, Andrey Aniskevich** *University of Latvia, Riga, Latvia, SYNPO, Pardubice, Czech Republic*	**Mechanical properties of epoxy and CFRP with core-shell rubber particles**
11:20-11:35	**Prasad Shimpi and Daiva Zeleniakiene** *Kaunas University of Technology, Kaunas, Lithuania*	**Improved method of manufacturing multiaxis woven composites**
11:35-11:50	**Aldobenedetto Zotti, Simona Zuppolini, Anna Borriello, Valeria Vinti, Luigi Trinchillo, Domenico Borrelli, Antonio Caraviello, Mauro Zarrelli** *Institute for Polymers, Composites and Biomaterials, Portici, Italy, Avio S.p.A, Rome, Italy, Sophia High Tech srl, Naples, Italy*	**Hyperbranched polyesters as tougheners of carbon fiber reinforced polymers**

11:50-12:05	**Łukasz Suchecki and Krzysztof Piernik** *Częstochowa University of Technology, Częstochowa, Poland,* *Kielce University of Technology, Kielce, Poland*	**Investigation of the influence of temperature on the cross-linking time of the polyester resin by the DSC method**
12:05-12:20	**Andrejs Pupurs and Alens Šņepsts** *Riga Technical University, Riga, Latvia*	**Self-heating effect in hybrid thin-ply laminates subjected to cyclic mechanical loading**
12:20-12:50	**Coffee break**	
12:50-13:05	**Rochele Pinto, Vladimir Spaček, and Daiva Zeleniakienė** *Kaunas University of Technology, Kaunas, Lithuania,* *SYNPO, Pardubice, Czech Republic*	**Characterisation and investigation of mechanical properties of basalt fibre reinforced star-like polymers composites**
13:05-13:20	**Stanislav Stankevich, Jevgenij Sevcenko, Olga Bulderberga, Maksims Piskunovs, Valerijs Ivanovs, Victor Ivanov, and Andrey Aniskevich** *University of Latvia, Riga, Latvia,* *ZRF Ritec SIA, Riga, Latvia*	**Electrical conductivity of nanomodified polymer based 3D printed structures**
13:20-13:35	**Urte Cigane and Arvydas Palevicius** *Kaunas University of Technology, Kaunas, Lithuania*	**Effects of the voltage and temperature of anodization on pore geometry of anodic aluminum oxide (AAO) membranes**
13:35–13:50	**Krzysztof Podosek, Piotr Zagulski** *Kielce University of Technology, Kielce, Poland*	**Use of composite materials in the construction of motorbike and bicycle handles in accordance with current standards**
13:50-14:05	**Justas Ciganas and Giedrius Janušas** *Kaunas Univerity of Technology, Kaunas, Lithuania*	**Hot embossing process for microstructures formation in PETG plastic**
14:05-14:20	**Gabriele Jovarauskaite, Gediminas Monastyreckis, and Daiva Zeleniakiene** *Kaunas Univerity of Technology, Kaunas, Lithuania*	**Self-sensing sandwich composites with embedded multiscale carbon-based materials**
14:20-14:35	**Tatjana Glaskova-Kuzmina, Didzis Dejus, Jānis Jātnieks, Andrey Aniskevich, Aleksejs Zolotarjovs, and Krishjanis Shmits** *Baltic3D.eu, Riga, Latvia,* *University of Latvia, Riga, Latvia, Riga, Latvia,* *Institute of Solid State Physics, Riga, Latvia*	**Effect of post-printing cooling conditions on the tensile properties of Ultem printed parts**
14:35-15:00	**Concluding remarks**	

Contents

MODELLING MATERIAL-ENVIRONMENT INTERACTIONS VIA MODULAR AND MULTISCALE APPROACH

Andrejs Krauklis[1]

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Materials are impacted by environmental ageing. The uncertainty of the material-environment interaction (MEI) compromises their integrity and physical and mechanical properties. For sorbents and biomaterials, a desired service lifetime and adsorption rates and levels can be modelled. Validation of new materials often involves costly testing programs. Therefore, modelling is an affordable alternative that can partly replace extensive testing and thus reduce validation costs [1]. Various approaches have been proposed to predict the long-term properties based on short-term measurements (in order to reduce time and involved costs) [2].

In light of the increasing interest in biopolymers, a “two-edged sword” nature of the ageing phenomena is discussed. Applications, where degradation is favourable (biodegradable plastics) and those for which it is unfavourable (structural polymers and composites) exist. In conventional degradation, the objective is to retain the material within the useful lifetime, whereas, in biodegradation, the end of life is simulated. Therefore, the same ageing phenomena and modelling approaches would be applicable if the “decomposition” criteria replace the “safety” criteria [3].

A systematised presentation of the state-of-the-art MEI models and accelerated testing methodologies is discussed.

Acknowledgements

This project has received funding from the European Regional Development Fund within the Activity 1.1.1.2 “Post-doctoral Research Aid” of the Specific Aid Objective 1.1.1 of the Operational Programme “Growth and Employment” (Nr.1.1.1.2/VIAA/4/20/606).

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MODELING HIGH STRESS GRADIENTS AND INTRALAMINAR CRACK GROWTH IN CROSS-PLY COMPOSITES

Anish Niranjan Kulkarni and Andrejs Pupurs

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Intralaminar cracking in 90-layer is the most common damage mechanism in cross-ply composites loaded in uniaxial tension. Intralaminar cracks (transverse cracks), generate stress perturbations in their vicinity which can be calculated using shear lag-type and variational-type [1] analytical models. These models calculate stress state in damaged 90-layers assuming uniform stress distribution through the thickness direction. With increase in applied tensile load, density of transverse cracks in 90-layers increases and stress perturbations generated by adjacent transverse cracks start to interact. Thus, a gradient in longitudinal stress is generated through the thickness direction in 90-layers. In the present work, longitudinal stress state in highly damaged 90-layers in cross-ply composites is studied using finite element modeling.

A 2D FE-model for cross-ply composite $[0/90]_S$ with uniaxially applied strain is developed. Longitudinal stress is calculated along the axial direction and through the thickness direction. Transverse crack density, normalized with respect to half-thickness of 90-layer, is varied from low (0.1) to very high (2.0). Presence of high stress gradients through the thickness direction is observed for cases with high (1.0) and very high (2.0) normalized crack densities. To study effects of these stress gradients on intralaminar crack growth, a new intralaminar crack is modelled at 0-90 interface in a region between two existing transverse cracks in 90-layer (refer Fig. 1). Length of the new crack (l_c) is incremented in steps, and fracture mechanics parameter ERR (available energy release rate) is calculated using J-integral. Variation in ERR is plotted against the crack length l_c for cases with different normalized crack densities. In regions with high stress gradient, ERR reaches zero for certain values of l_c due to presence of local compressive stresses. ERR trends are also affected by presence of delaminations in addition to transverse cracks.

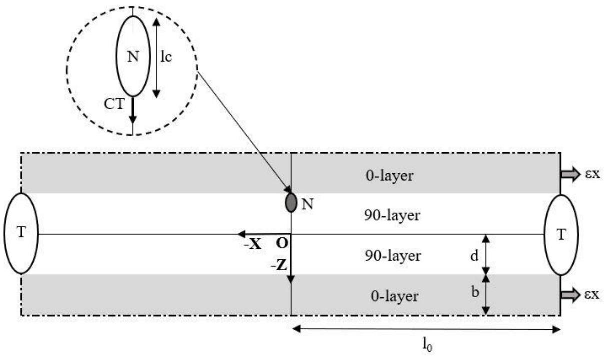

Fig. 1. RVE of cross-ply composite laminate for ERR analysis.

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PREDICTION OF POLYPROPYLENE PROPERTIES MODIFIED WITH ORGANIC FILLERS BASED ON SELECTED MECHANICAL CHARACTERISTICS

Małgorzata Szymiczek[1], Monika Chomiak[1], and Sara Sarraj[1]

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The work aimed to evaluate changes in the polypropylene properties modified with organic fillers subjected to accelerated aging in an aqueous environment. Evaluation of properties' changes was based on mechanical and physicochemical characteristic measurements. Polypropylene copolymer with increased stiffness MOPLEN EP340M used for elements requiring minimal deformation under load was selected. The fillers were corn starch, peanut shells, hemp shives, and a mixture of oak, birch and maple leaves.

In November, leaves of varying colors were obtained from forests in Silesia (Poland). The change in leaf color results from photochemical processes in which chlorophyll is converted into carotenoids and anthocyanins [1]. Hemp shive is produced using the decortication method, which allows for obtaining about 70% of shives and 30% of hemp fibres. Peanut shells contain cellulose, hemicelluloses, lignin, protein, carbohydrate, and ash content [2]. Corn starch is composed of two homopolysaccharides, amylopectin and amylase [3]. The fillers were dried at 60 °C for two hours in thermal chambers and milled before being introduced into the polypropylene. Composites containing 5, 10, 15, and 20% were prepared using an extruder. Test samples were prepared using an injection molding machine and then conditioned at 60 °C for two hours in thermal chambers, which allowed the elimination of residual stresses after production.

In order to determine changes in material characteristics, the obtained samples were subjected to accelerated aging tests in an aqueous environment at a temperature of 100 °C. According to Raw's correlation, 2 hours in aging conditions equals 3 months in real conditions. The evaluation of the influence of aging conditions on the composite properties was carried out based on tensile strength, strain at break, impact strength, and Shore D hardness. On the basis of mechanical properties, models were developed that allow the prediction of useful properties in the long term. The curves show a slow decline, and after 4 years show an inflection and a significant decrease in properties. Only the hemp shive-modified composites an increase in the values of the tested characteristics is visible after 3 years, after 4 years of the extreme, and then show a sharp decrease. The tests showed significant changes after 4 years of aging. For all materials, swelling of the samples was observed, as well as surface flaking in the case of corn starch-filled composites. Particle size, which affects the porosity of the structure, is of significant importance for the tested characteristics.

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NONLINEAR 3D MATERIAL MODELING FOR ADVANCED COMPOSITE APPLICATIONS

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Bio-based composites, conventional composites in demanding environments (high temperature, moisture etc.) and composites with different material states (degree of cure, thermal treatment etc.) can exhibit highly nonlinear behavior. In addition, most real-life applications demand 3D material models, not only due to complex loading cases or structures but even in relatively simple cases where 1D models show inaccurate internal stresses. It was demonstrated [1] that rectangular shape plates during the curing process show significantly higher stresses using a 3D material model than 1D. This is due to the false assumption that the plate in the lateral direction can freely move when in reality it will be constrained by the mould and thus create additional stresses due to limited contraction.

All of the above mentioned reasons have created the need to develop accurate nonlinear viscoelastic material models and tools that could capture this complex 3D nonlinear behavior of composite material systems. This study aims to develop such a model and implement it in finite element code. This can be done by performing several tasks: developing the 3D nonlinear material model, creating a clear methodology for parameter identification and implementing the developed model in finite element code.

Within the model, different mechanisms have to be analyzed separately – viscoplasticity, viscoelasticity and damage. It was demonstrated that viscoplasticity for isotropic materials has the same time and stress dependence in the axial and lateral directions. The difference is only within the total amount of viscoplasticity. This can significantly simplify the rather complex 3D material model. Similarly, viscoelasticity can be analyzed to see if further simplification can be done to the developed material model. At the current stage, the damage has not been studied separately since there are already existing damage models than can be adapted and added to the developed material model.

Acknowledgments

Livas Pupures work within this study has been supported by the European Regional Development Fund within the activity 1.1.1.2 "Post-doctoral Research Aid" of the Specific Aid Objective 1.1.1 "To increase the research and innovative capacity of scientific institutions of Latvia and the ability to attract external financing, investing in human resources and infrastructure" of the Operational Programme "Growth and Employment" (No.1.1.1.2/VIAA/4/20/646).

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MECHANICAL PROPERTIES OF EPOXY AND CFRP WITH CORE-SHELL RUBBER PARTICLES

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Nowadays epoxy resins are widely used as binders for fibre-reinforced composites in high-tech applications like aerospace and wind energy. To improve their crack resistance, epoxy resins are mixed with additives, such as core-shell rubber (CSR) particles. The aim of this research was to determine how CSR particles addition influence the mechanical properties of the epoxy resin and carbon fibre-reinforced polymer (CFRP).

Epoxy resin CHS-582 and hardener Telalit 0420 (Spolchemie, Czech Republic) were mixed with different CSR-containing three additives ACE MX 125, 156, 960 (Kaneka, Belgium) at filler content 0-6 wt. %. For the manufacturing of CFRP laminates, woven carbon fibre fabric (0/90, Havel Composites, Czech Republic) was used. As previous research showed, the highest fracture toughness of the epoxy was observed at CSR content of 4 wt.%. Taking this into account, double cantilever beam (DCB) CFRP samples were produced with epoxy matrix at 4 wt.% of CSR.

The Mode I interlaminar fracture toughness tests were performed by using Zwick 2.5 testing machine with and Canon EOS40D to record photos for the analysis of the crack propagation until a failure. The Modified Beam Theory method was used for the calculation of interlaminar fracture toughness. Hansen model considering spherical particles embedded in spherical shells of the matrix was used to describe the elastic modulus of the epoxy filled with CSR particles and pores. The porosity was derived from the density measurements for epoxy filled with CSR particles by using hydrostatic weighting with Mettler Toledo XS205DU balance. The glass transition temperature of the pure epoxy and epoxy modified with CSR particles was estimated by conducting thermomechanical analysis tests by using Mettler Toledo TMA/SDTA841e. The morphology of the fracture surfaces for CFRP samples was examined by using a high-resolution SEM-FIB electron microscope Helios 5 UX (Thermo Scientific).

It was experimentally found that for all CFRP samples the addition of CSR particles resulted in the increase of fracture toughness with the highest increase by 53% for ACE MX 960. It was observed that sample density followed modified mixture rule. The prediction by Hansen model for this pore volume fraction was in good agreement with the experimental results at high CSR contents. The glass transition temperature of the epoxy was gradually improved by 10-20 °C with the increase of CSR particles for all additives which could be attributed to the high crosslink density and toughening effect of rubber modifiers.

Acknowledgements:

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IMPROVED METHOD OF MANUFACTURING MULTIAXIS WOVEN COMPOSITES

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Multiaxis composites are useful in majority area of composite applications where conventional fibres in 2 directions are not sufficient to bear the structural load, for example in wing structures of aircraft and wind turbine blade [1]. The conventional method to distribute load evenly in composite is by orienting woven ply/fibres in various angles [2]. However, studies show that the difference in ply and fibre orientation causes decrease in the strength of the composites [3].

This research aims to develop a new method of manufacturing multiaxis composite by incorporating fibres in multiple directions other than 0°/90°. Carbon fibres of 200 tex were woven on a 24 heald shaft dobby loom with multiple shuttles to produce multiaxis preform with fibre directions in 0°, 90° and ±45° angle relative to fabric length, in a single preform. The preform was used as single and double ply together with plain woven carbon fabric, infused with bisphenol epoxy F in hand layup technique to manufacture carbon composite. To compare the efficiency of this method, conventional multiaxis composites with plain woven single and double ply oriented at 45° angle was also manufactured. The composites were subjected to impact loading in impact tower with 5.186 kg impactor mass having 20 mm diameter and at 0.4 m height.

The impact testing results show that as compared to plain woven composites, the multiaxis composite have higher impact strength. The fibres in ±45° reinforce the composite while the 0°/90° fibres prevent difference in the bending stiffness due to ply orientation mismatch. The conventional multiaxis composites showed decrease in the impact strength due to difference in mechanical properties of different oriented plies. It can be concluded that the newly developed multiaxis composites increase the impact strength of the composites and are cost effective and easy to manufacture since conventional weaving loom was used.

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HYPERBRANCHED POLYESTERS AS TOUGHENERS OF CARBON FIBER REINFORCED POLYMERS

Aldobenedetto Zotti[1], Simona Zuppolini[1], Anna Borriello[1], Valeria Vinti[2], Luigi Trinchillo[2], Domenico Borrelli[3], Antonio Caraviello[3], and Mauro Zarrelli[1]

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Carbon Fibers Reinforced Polymer (CFRP) have been extensively employed in many applicative fields due to their outstanding properties. Despite their exceptional in-plane performances, CFRPs are characterized by poor out-of-plane mechanical properties, limiting their usage in applications where high resistance to delamination are required. To overcome that issue, it is common practice to load CFRP with micro/nano fillers, e.g. hyperbranched polymers (HBPs), which improve the composite fracture toughness introducing additional energy dissipation mechanisms during crack propagation.

In our work, an aromatic HBPs, identified as G_HBP, was synthesized and employed as filler in a patented epoxy matrix (HXE75). Filler and matrix were mixed using a mechanical mixing technique, while during the prepreg fabrication process an unidirectional carbon fiber layer was continuously impregnated on both sides with the epoxy film and wrapped in coils. Before carbon fiber impregnation, epoxy nanocomposites have undergone a optimization process, and three different filler content (0.1, 1 and 3 wt. %) were analysed in order to maximize the fracture toughness properties (Critical Stress Intensity Factor – K_C and Critical Strain Energy Release Rate – G_C) withouth affecting the matrix thermomechanical properties: results have shown an optimized concentration of 3wt%, with a K_{IC} and G_{IC} increase of 16% and 40%, respectively.

The unidirectional CFRPs prepared using the 3wt% G_HBP loaded epoxy resin were tested in term of mode I (G_{IC}) and mode II (G_{IIC}) Interlaminar Fracture Toughness, as well as Compression After Impact (CAI) tests. Mechanical tests have revealed a remarkable increase of G_{IC} (53%) and a more modest improvement of G_{IIC} (6%) compared to the unmodified CFRP, and that behaviour can be attributable to the improvement of the fiber/matrix interaction due to the G_HBP presence. Although the improvement Interlaminar Fracture Toughness properties, CAI have not undergone an analogous increase due to the HBPs: according literature, that behavior was predictable because CAI properties are significantly affected by G_{IIC} variations (very low in our work), but are almost insensible to G_{IC} variations.

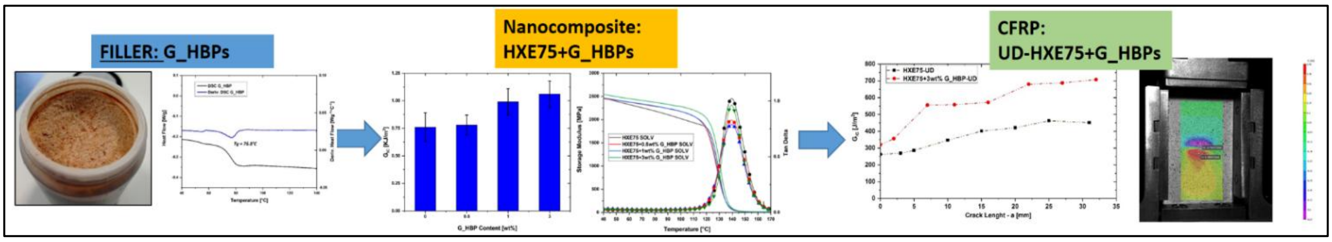

Figure 1. CFRP manufacturing process and characterization

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INVESTIGATION OF THE INFLUENCE OF TEMPERATURE ON THE CROSS-LINKING TIME OF THE POLYESTER RESIN BY THE DSC METHOD

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In this work, a study of the cross-linking time of polyester resin was carried out using a DSC Netzsch phox 204 measuring apparatus. The crosslinking reaction time of Havelpol1 polyester resin mixed with Butanox hardener at 2% by weight was measured under constant temperature conditions, i.e. 25˚C, 19˚C, 15˚C in an air atmosphere for 180 minutes. As a result of the test, the resin temperature was found to rise to about 28˚C in all tests. The test results were presented in the form of thermograms. It was also found that as the ambient temperature increased, the crosslinking time of the resin decreased significantly. In addition, before proceeding to the main tests, a scanning calorimetry test was performed at a heating rate of 10 K/min for comparison purposes with the available database, and the identification of the test sample was carried out.

SELF-HEATING EFFECT IN HYBRID THIN-PLY LAMINATES SUBJECTED TO CYCLIC MECHANICAL LOADING

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In the last decades the use of thin-ply composites has signinficanlty incresed in different high-performance applications owing to their increased damage resistance [1]. In addition to excellent mechanical properties, there is also high potential for using thin-ply composites as multifunctional materials, for example, in structural electronics, where composite laminate layers can perform mechanical load bearing and heat dissipation functions. In the present study carbon/glass thin-ply hybrid laminates with various combinations of layer thicknesses were analyzed experimentally to evaluate their mechanical and thermal behavior. Material specimens were subjected to cyclic tensile mechanical loading with frequency up to 30 Hz. A detailed investigation of self-heating within the laminate during mechanical loading was performed using high-resolution thermal imaging camera equipped with microscope lens.

It was found that higher applied maximum strain level leads to significantly larger self-heating temperatures recorded during the test, see Fig.1a. The effect of loading frequency (20-30 Hz) on self-heating for carbon fiber reference laminates was found to be relatively small, see Fig.1b. Compared to carbon fiber laminates, higher self-heating was found for glass fiber laminates when subjected to equal loading. Self-heating of various carbon/glass hybrid laminates was measured and a clear dependency of self-heating on laminate lay-up and maximum strain level was observed. For the same applied loading, the hybrid laminates with the most distributed layers and with carbon/epoxy external layers had the highest self-heating temperature compared to other studied hybrid laminate lay-ups.

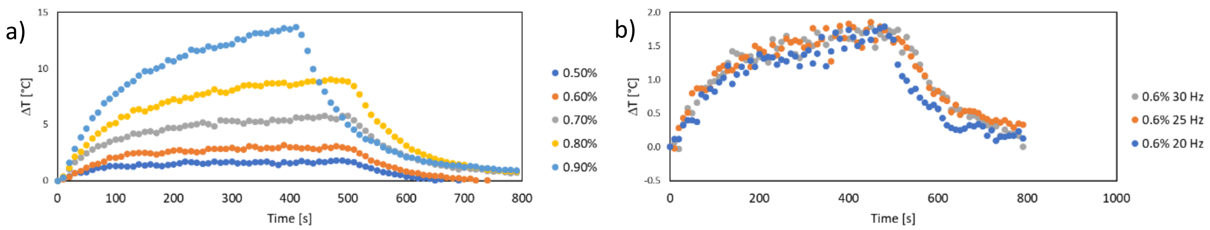

Fig.1. Effect of maximum strain level (a) and loading frequency (b) on self-heating temperature

Acknowledgements

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CHARACTERISATION AND INVESTIGATION OF MECHANICAL PROPERTIES OF BASALT FIBRE REINFORCED STAR-LIKE POLYMERS COMPOSITES

Rochele Pinto[1], Vladimir Spaček[2], and Daiva Zeleniakienė[1]

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In recent times, research on basalt fibre reinforced polymer composites has increased exponentially owing to its excellent thermal stability, corrosion resistance and far better mechanical properties as compared to glass fibers. However, the hurdle in application of these composites is due to their poor interfacial adhesion. Basalt fibers are produced by the melting of volcanic basalt rocks and as a result the surface of these fibers lack the surface roughness that is necessary for good interfacial adhesion.

The purpose of this investigation is to characterize and investigate the effects of novel star-like *n*-butyl methacrylate (P*n*-BMA) block polymer on the properties of BFRP. These type of polymers have shown to have bridging effects and an almost ‘stickiness’ to carbon fibers [1]. The polymers were characterized by using gel permeation chromatography. To configure the optimum loading of these polymers on the matrix, three different wt.% (0.2, 0.5 and 1.0) were used to create epoxy specimens and tested for tensile strength. The resulting optimum wt.% was reinforced with BF. Tensile, low-velocity impact and flexural tests were performed to investigate mechanical properties.

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ELECTRICAL CONDUCTIVITY OF NANOMODIFIED POLYMER BASED 3D PRINTED STRUCTURES

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Fused deposition modelling with multi-nozzle 3D printers allows the creation of special-purpose products with embedded electrically conductive elements. In this way, printed objects can provide electromagnetic shielding, de-icing, and damage detection.

The aim of this work was to study the behaviour of the electrical, thermoelectrical, and tensoresistive properties of printed conductive elements.

The resistance of the conductive printed elements at different structural levels was evaluated: filament as produced, extruded mono-fibre, traxel (printed single track), monolayer, and multilayer structure. Conductive printed elements were prepared using commercial conductive PLA supplied by Protopasta. Resistance increase of 5-7 times was noticed during molten material deposition by a printer nozzle forming a traxel.

Electrical resistance was obtained experimentally for printed specimens of different geometries and printing directions. Noticeable electrical anisotropy (up to two times) was observed for unidirectional specimens with different printing angles due to the orientation of printed tracks.

The effect of Joule heating (ohmic heating) was studied for printed specimens with embedded conductive tracks. Non-conductive base and conductive tracks were printed with regular ABS and commercial filament *Koltron G1 Graphene* respectively. The power of 1 W and temperature of 70 °C were obtained by the conductive tracks at 20 V. The resistivity of the tracks decreased up to 3-4 % when heated. Results showed good possibility of using printed conductive structures as a heating element.

Tensoresistive properties of printed conductive structures using *Koltron G1 Graphene* filament were investigated. Two specimen groups were tested: with conductive tracks in the outermost layers with one uncovered side; with conductive tracks fully embedded inside the specimen. During tensile tests, yield strain of 1.5 - 2 % was obtained with resistance increase up to 50 %. A gauge factor of 25 was obtained for embedded conductive tracks, which makes them suitable for use as strain sensors.

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EFFECTS OF THE VOLTAGE AND TEMPERATURE OF ANODIZATION ON PORE GEOMETRY OF ANODIC ALUMINUM OXIDE (AAO) MEMBRANES

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Recently, scientists have been developing effective methods for the production of different porous nanostructures [1]. Aluminum anodization has become one of the most popular processing methods that allow the formation of porous structures. The porous anodic aluminum oxide (AAO) fabrication process is usually carried out in electrolytes containing sulfuric, oxalic, or phosphoric acid. The structural properties of the porous AAO membrane include pore diameter, interpore distance, and porosity. The geometry of the pores is highly dependent on the chosen electrolyte and other anodization parameters such as anodization potential, current, temperature, time, etc.

The ability to control the specific geometry of the membrane pores allows AAO membranes to be widely used in different application areas, for example, for the production of various nanostructures and nanodevices (the deposition of various polymers in the pores has produced many materials, including nanowires, nanotubes, and nanodot arrays), optoelectronic devices, sensors, etc [2,3].

Due to the versatility and applicability of AAO membranes in different fields, research related to the production of AAO is valuable. Thus, AAO nanoporous membranes were synthesised in this study. The effect of important parameters, such as voltage and temperature, on the morphology of the AAO membrane was investigated. The two-step anodization process was carried out in an innovatively designed electrochemical reactor. Further, membrane morphology was examined using scanning electron microscopy and characterized using ImageJ software.

The results showed that AAO membranes with pore diameters ranging from 28 to 61 nm were obtained (when the anodization potential was between 40 V and 60 V, and the temperature was between 5 ºC and 15 ºC). Moreover, the dependences of the pore geometry on the applied voltage and temperature were determined.

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USE OF COMPOSITE MATERIALS IN THE CONSTRUCTION OF MOTORBIKE AND BICYCLE HANDLES IN ACCORDANCE WITH CURRENT STANDARDS

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This work presents part of a study to determine the material and strength properties of composites [1] for their possible use in the construction of motorbike and bicycle handles [2]. In addition, an analysis was made of possible technological defects such as inaccurate material placement and lack of filling in the mould. For this purpose, drying speed and temperature were analysed and compared with experimental results. Strength tests were carried out on samples in accordance with the standard. These are important for use in bicycles and motorbikes. The obtained test results indicate the possibility of using silicones in the production of bicycle and motorbike handles. Tests on actual structures have met the mechanical vibration requirements found in motorbikes [3].

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HOT EMBOSSING PROCESS FOR MICROSTRUCTURES FORMATION IN PETG PLASTIC

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In this work, the microstructures formed in the plastic are used in the application of the diffraction effect. The diffraction effect is widely used in creating holograms, X-ray diffraction, CD or other equipment [1]. The formation of structures with diffraction gratings is a difficult process, since an improperly designed grating can reduce the relative diffraction efficiency. One of the most widely used methods for forming diffractive microstructures is the hot embossing process. For better quality, vibrations are included in the forming process

The forming equipment consisted of a heating element, a vibrating pad and a tensile testing machine, which was used to generate and control the forming force. Polyethylene terephthalate glycol (PETG) plastic sheet was selected for this study. The molding process took place when the master matrix was heated to a set temperature and a set force was pressed into the plastic for a certain period of time. The vibrating pad worked throughout the molding process. After changing the parameters, the embossing process was repeated. During the hot embossing process, a pressure force of 3000 N was used, which pressed the structure for 10 seconds with an excitation frequency of 10 kHz. The resulting gratings were analyzed to find the best formation parameters using the calculated relative diffraction efficiency (RDE). The results are presented in Fig. 1.

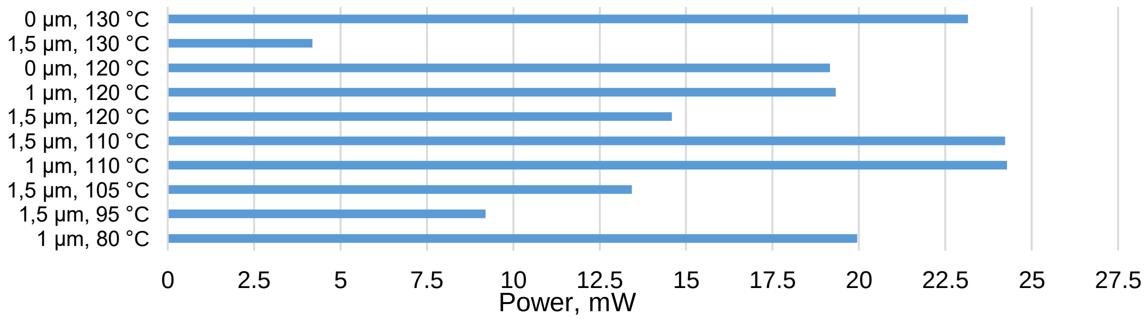

Fig. 1. Measurements of relative diffraction efficiency.

The results showed that the best quality of the microstructure was when the forming force was 3000 N, the structure pressure duration was 10 seconds, the excitation frequency was 10 kHz, the temperature was 110 ^{o}C, and the vibration amplitude was 1 μm. It was observed that RDE decreased as the plastic reached a higher molding temperature. RDE decrease could be explained by the non-optimal height of the grid.

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SELF-SENSING SANDWICH COMPOSITES WITH EMBEDDED MULTISCALE CARBON-BASED MATERIALS

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Numerous types of sensors, such as strain gauges, optical fibres, and piezo-electric transducers, are used to detect composite structure defects. However, they come with various disadvantages like additional installation procedures, maintenance costs and other limitations [1]. In addition, damage detection in composite materials is challenging since the material is a complex structure of different angle laminates with variable thicknesses of cores and adhesives. Therefore, the composite's inner structure may already be damaged, even if the surface laminates condition and the composite's rigidity are unchanged [2]. An excellent technological solution which can predict an early-stage micromechanical damage is based on self-sensing composites. They can be considered for structural health monitoring systems due to the piezo-resistive effect caused by electrical resistance diversity from damaged electrically conductive additives such as carbon nanotubes (CNT) [3].

This study aimed to develop a self-sensing sandwich-structured composite with an embedded carbon fibre chess-type grid, non-woven carbon fabric, and a 0.1–1 wt% CNT-modified epoxy matrix. In this work, the position of fibre cracking and the indentation size of the core material were estimated by local electrical resistance variations. Furthermore, damage detection using this technology was also monitored under in-situ mechanical testing, thus making it practically appealing for aircraft condition diagnostics during the flight.

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EFFECT OF POST-PRINTING COOLING CONDITIONS ON THE TENSILE PROPERTIES OF ULTEM PRINTED PARTS

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Fused deposition modelling (FDM) is one of the additive manufacturing technologies that has been extensively applied to efficiently produce complex structures saving production time and resources. One of the main features of FDM-processed polymeric parts is their highly anisotropic nature due to the intrinsic properties of the extruded filament, oriented build process, and limited degree of fusion between the layers. Additionally, 3D-printed polymer parts exhibit high sensitivity to thermal processing conditions. Fast removal from the printer and cooling in an oven with a similar thermal cooling profile as the printer could allow printing of more samples, thus improving the productivity of the 3D printing process.

The aim of the work was to estimate the effect of post-printing cooling conditions on the tensile properties of ULTEM® 9085 printed parts processed by FDM. Three different cooling conditions were applied after printing Ultem samples: from 180 °C to room temperature (RT) for 4 h in the printer, rapid removal from the printer and cooling from 200 °C to RT for 4 h in the oven, and cooling at RT. Tensile tests were carried out on dogbone samples printed in three orthogonal planes (X, Y, and Z) to investigate the effect of the post-printing cooling conditions on their mechanical properties. Optical and scanning electrone microscopy (SEM) were employed to relate the corresponding macrostructure to the mechanical performance of the material.

Based on the results obtained it was confirmed that the effect of post-printing cooling conditions on the tensile properties of ULTEM 9085 printed parts was almost the same when cooled in the printer or oven but more notable when cooled at room temperature. The cooling of the specimens at RT resulted in a more significant reduction in the tensile strength (by 10%) and elastic modulus (by 12–15%) for all printing directions, while the results could be regarded as very close for cooling in the printer or oven, considering the observed data scattering. The lowest mechanical performance and sensitivity to the thermal cooling conditions were defined for the Z printing direction due to anisotropic nature of FDM and debonding among the layers.

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