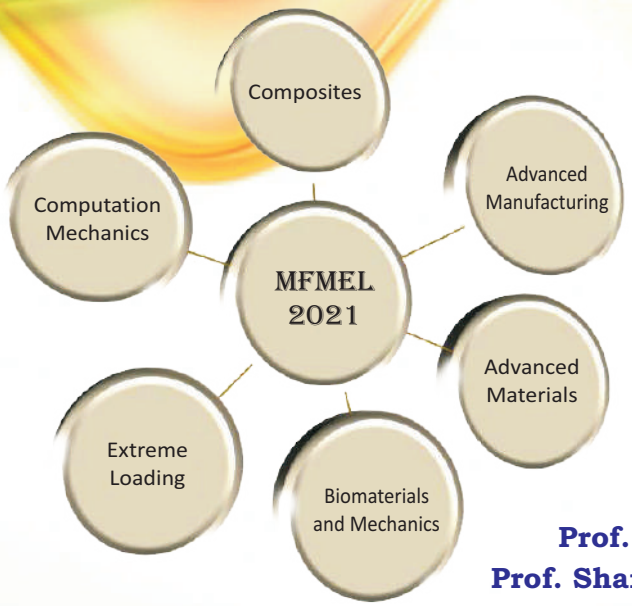
Multi-Functional Materials for Extreme Loading

22 – 24 February, 2021

MFMEL 2021

Book of Abstracts



Editors

Prof. Sung Kyu Ha

Prof. Shankar Krishnapillai

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Organized by

Indian Institute of Technology Madras, Chennai, India

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SPARC Project: Multiscale Studies of Compression-After-Impact in Fiber Reinforced Composites

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PATRONS

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Dr. Sung Kyu Ha has a Ph.D. in department of mechanical engineering (1988) from Stanford University and joined Hanyang University since 1991. Dr. Ha has been actively collaborating with global composites industry in the areas of aerospace, automotive, wind turbine and oil & gas application. Dr. Ha developed innovative multiscale approach and tools for industry to predict static and fatigue failure behavior and to simulate virtual manufacturing process of composite materials. In 2016, Dr. Ha was awarded the Life Time Achievement in JEC Group for his life-long unmatched contribution to composite industry. In 2019, the HSCL was selected as the Top Prestige Global Industrial University Collaboration Center of Hanyang University.

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Dr. Shankar Krishnapillai, Professor in the Department of Mechanical Engineering, IIT Madras. He obtained DPhil from The University of Oxford (UK) in 1996 from the Department of Engineering Science. Thereafter he worked at the NASA Johnson Space Center and as faculty in National University of Singapore. He joined IIT Madras in 2003. His areas of interest are Machine Design, Materials, Structural Dynamics with a special interest in optimization methods in design. He has 190 research publications and completed 25 Phd and MS research students. He has numerous research and consultancy projects from the Government as well as private industry in mechanical design. He is a member of design review committee for the Indian defence research agency.

Dr. R Velmurugan

Dr. R Velmurugan, Senior Professor of Aerospace Engineering, IIT Madras. His areas of research include, Composite materials, Nano Materials, Finite Element Analysis, Structural Crashworthiness and Impact Mechanics. He has completed many consultancy and sponsored projects from many DRDO Labs, ISRO Centers, Government agencies, and Many Private Industries. He has more than 350 research articles and guided many students for PhD, MS and M Tech Degrees. He has delivered many invited lectures in many international and national conferences. He is fellow of AeSI, FIE and member, Editorial Board, Journal of Aerospace Sciences and Technologies.

PREFACE

Indo-Korean workshop on 'Multi-Functional Materials for Extreme Loading (MFMEL 2021) is organized when the state of the art materials are being developed to satisfy the needs of the 21st century. The challenges are to develop strong, light-weight, sustainable and eco-friendly materials capable of handling extreme loading conditions. The necessity of extreme loading material application ranges from civil engineering to aerospace technology, where it has effects on safety and reliability. There is a new emphasis on Multifunctional materials for defence, medicine, structures and space science. MFMEL 2021 virtual workshop is being jointly organized by the Indian Institute of Technology Madras, India, and Hanyang University, Seoul, South Korea. The main objective of the workshop is to bring together researchers from academia, laboratories, and industries. The workshop encouraged discussion, dissemination of information, exchange of ideas, and collaboration among the participants.

This workshop's proceeding includes a list of abstracts of all presentations, including key lectures from the invited speakers in the field of multifunctional materials and paper presented by distinguished researchers and practitioners working in institutions and industrial/business organizations worldwide. The abstracts are categorized under Advanced Materials, Advanced Manufacturing, Composites, Armour and Ballistics, and Biomaterials as in the workshop schedule provided. The abstracts reflect the current experience, challenges, concerns, methodologies, and solution approach in multifunctional materials for extreme loading.

Our sincere thanks to everyone who involved in our SPARC Project "Multi scale Studies of Compression-after-impact in fiber Reinforced Composites", Project No: "SPARC/2018-19/P1019/SL", and also to the sponsor of the project MHRD (Ministry of Education) Govt. of India. We also express gratitude towards the competent authorities of the Indian Institute of Technology Madras, India, and Hanyang University, Seoul, South Korea, for supporting the SPARC program. Finally, we thank all those who have involved directly or indirectly in the workshop's successful organization.

Prof. Sung Kyu Ha
Prof. Shankar Krishnapillai
Prof. Velmurugan R

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SPARC Project:
Multiscale Studies of Compression-After-Impact in Fiber Reinforced Composites

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ABSTRACTS

Development of Automotive Hybrid CFRP/Steel Composite B-Pillar with High Crashworthiness

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Abstract: A carbon-fiber-reinforced plastic (CFRP) have been used for automotive components due to its superior mechanical characteristics. In this study, an automotive hybrid B-pillar was designed by finite-element-method (FEM) with steel and CFRP for both weight reduction and improving crashworthiness. The hybrid B-pillar composed of CFRP reinforcement component between the outer and inner panel which is made of steel. LS-DYNA was used for impact simulation and Genesis was used for optimization. To simulate the crash of B-pillar, appropriate boundary conditions, tie condition, mesh, and material properties were investigated. In addition, for reliability of simulation, the static properties such as tensile, compression and shear properties of CFRP were measured and used for simulation. To maximize the impact performance under dynamic impact loading condition by FEM, the equivalent static load method (ESLM) was applied, which combined impact simulation and linear optimization method for computational efficiency. To optimize the deflection profile while meet the impact energy requirement, shape, stacking sequence, and thickness of the CFRP reinforcement was optimized. Based on the design result, the CFRP reinforcement was manufactured by resin transfer moulding (RTM) process and combined with outer and inner steel panel. In sequence, the impact performance of automotive hybrid B-pillar was tested by drop weight test and compared with simulation result. And then, an improved crashworthiness and reduced weight was shown compared with conventional steel B-pillar. As a result, the impact energy, deflection profile and failure surfaces shows good agreement with simulation result. The optimal design shows 25% reduction of deflection and 60% reduction of weight compared to conventional steel component

Keywords: *Deep-learning, finite-element-method (FEM), stress fields*

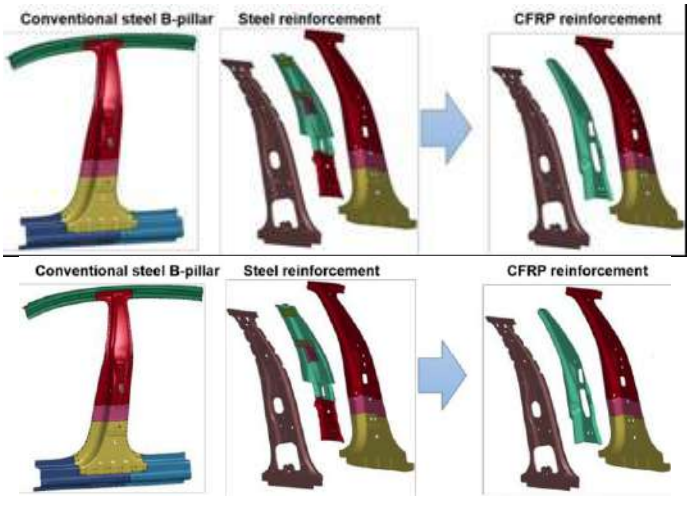

Fig. 1 hybrid steel/CFRP B-pillar

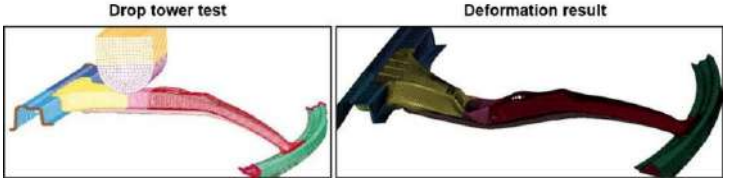

Fig. 2 Drop tower test

* * * * *

Study of Different Materials to Mitigate Blast Energy for the Tunnel Subjected to Buried Explosion

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Abstract: In the present study, performance of different materials for mitigating the energy imparted on tunnel subjected to buried explosion is investigated. Explosive is located laterally to a box-shaped tunnel and blast damage is measured in terms of lateral

deflection of tunnel wall facing the explosion. Three different energy absorbing materials have been considered herein, namely, porous concrete, polymeric syntactic foam and closed cell aluminium foam (ACCF). A series of numerical simulation is conducted to carry out the comparative study adopting Multi-Material Arbitrary Lagrangian Eulerian (MM-ALE) method using commercially available computer program LS-DYNA®. Explosive and soil are modelled using Eulerian formulation while concrete and reinforcement bars of tunnel are modeled using Lagrangian element formulation. Jones-Wilkins-Lee (JWL) equation of state has been used to simulate the detonation of explosive. Soil has been modeled as two parts with different element formulation techniques. The part surrounding explosive is modeled using Arbitrary Lagrangian Eulerian (ALE) formulation and the other part surrounding structure is modeled using Lagrangian formulation. Nodes of adjacent elements at ALE-Lagrangian interface of soil are merged together to maintain continuum in soil domain as illustrated in Fig. 1. The material perform effectively in reducing the effect of blast loading on the structure. The blast response of bare tunnel is finally compared with tunnels fitted with different energy absorbing materials considered herein.

Keywords: *Blast loading, Tunnel, Mitigation*

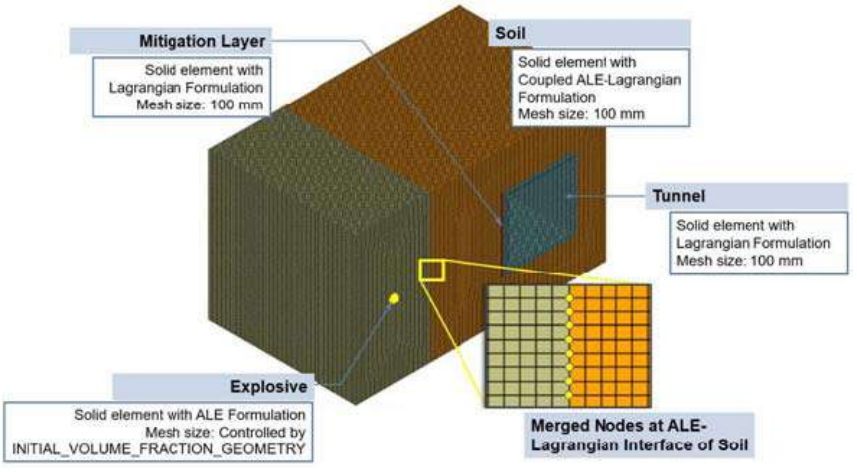

Fig. 1 FE model of soil domain encapsulating the structure with mitigation system

* * * * *

Investigation of Machine-Learning Based Damage Detection Method of Carbon Fiber/Polypropylene Composite via Electrical Resistance Change Method

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.**Abstract:** Carbon-fiber-reinforced-plastic (CFRP) has received a lot of spotlights as an alternative material for metal because of their excellent mechanical property such as high strength and stiffness with lightweight. For this reason, CFRP are used in wide area such as wind blade, auto mobile, satellite, and robot arm. However, CFRP easily occur to matrix cracking or delamination in a direction perpendicular to the fiber. These failures can be resulted in fatal accident. It is essential to develop a damage detection technique to prevent them. To solve this problem, Electrical resistance change method (ERCM) was used. This method utilizes multiple metallic lines on upper- and bottom-surfaces of composite. Each metallic lines are parallel, and bottom and top electrodes are perpendicular to each other. Using these electrodes, the resistance change in the thickness direction is measured and the damage is detected. Moreover, to improve the accuracy of damage detection, machine learning technology was applied. The system was established for learning resistance change data and using the training data to identify the location of damage. To generate learning data, Kirchhoff's electrical resistance model was used. The developed model was compared with ABAQUS simulation and experimental result. The generated resistance change data were utilized for deep learning using the Artificial Neural Network (ANN) algorithm. As a result, it was successfully performed deep learning algorithm based on ERCM exhibited high accuracy damage detection resolution under compressive test.

Keywords: *Addressable conducting network, damage detection, deep learning and artificial neural network*

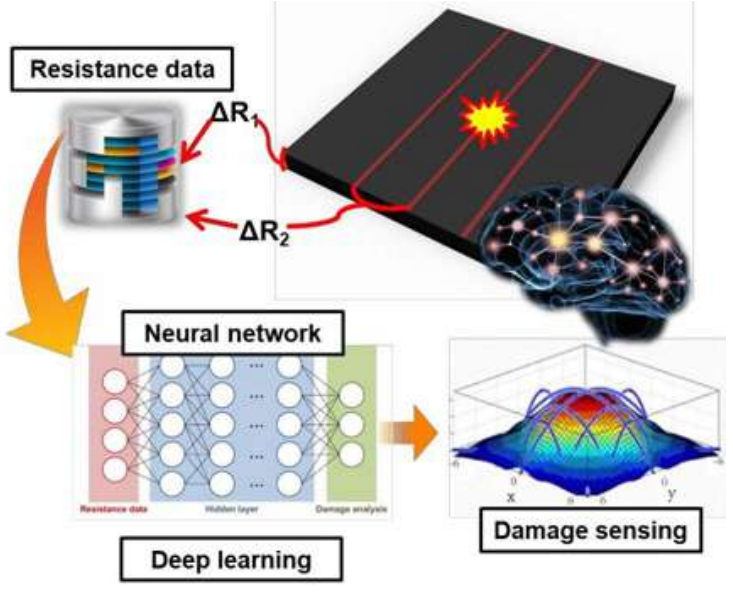

Figure1.Schematic of damage detection process with machine-learning

* * * * *

Numerical Study of Ballistic Impact Performance of Perforated Metallic Armour

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Abstract: Monolithic armour is the basic structural design developed to defeat (armour piercing bullet) threat in hostile environment without any metallurgical problems. However, weight is the most prominent factor at designed velocity whether operated for applique or structural applications in combat vehicles. To address the issue, perforated steel plates as additional or complementary armour is targeted with piercing projectiles. This paper investigates two different designs of perforated armour system of same material that can act as passive armour to deflect projectiles or to get fragmentate before hitting the main armour. Ballistic performance of Secure 500 armour is investigated by adding perforated armour using two different types of hole cross-section. Regular

arrangement of circular and slotted type hole pattern were used in perforated plate. In order to ensure diversion of projectile from its trajectory resulting in reduction of penetration capability, size of the hole is kept smaller compared to the diameter of bullet. Methodology involves formulation of 3-D nonlinear finite element method of impact sequence in commercial software ANSYS Explicit Dynamics. To understand metal under high strain-rate, Johnson-Cook (JC) material model is used to describes strain hardening parameter, adiabatic temperature rise and dislocation sensitivity. Accounting ductile facture due to stress triaxiality sensitivity with temperature softening effect, JC facture criteria is used for all materials. The finite element model of perforated Secure 500 steel target is validated by comparing results from experimental source. Subsequently, developed validated numerical model was used for understanding penetration mechanism and material ballistic properties when perforated add-on armour is used. Comparison of circular and slotted armour is also discussed under different impact configuration point (Fig. 1). Proposed non-linear finite element method used in this paper demonstrates good agreement with experimental results of projectile impact on perforated add-on armour plates

Keywords: *Perforated Armour, Armour piercing bullet, Numerical Simulation*

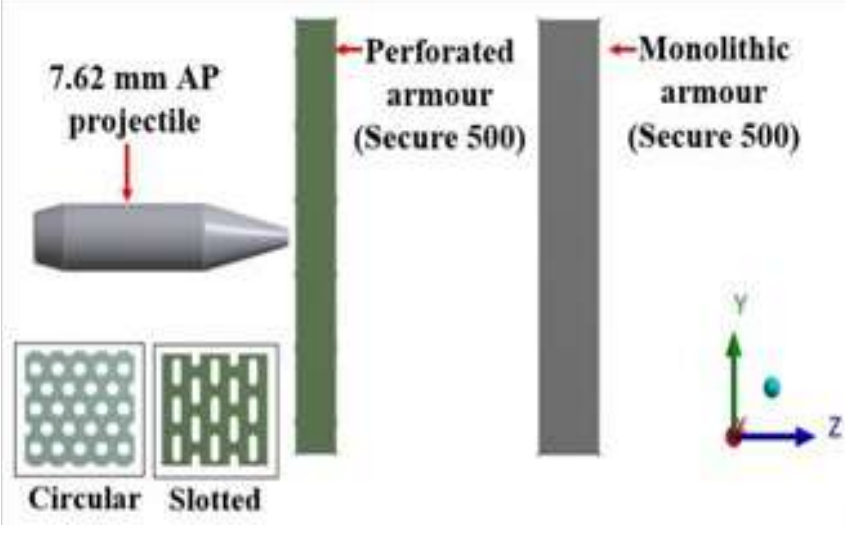

Fig. 1 Ballistic impact setup with different configuration of perforated armour

* * * * *

A Numerical Study of Ballistic Resistance of a Single Layer Ceramic Target

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Abstract: The ballistic resistance of a single layer alumina target has beenexplored numerically against eccentric ballistic impact. The alumina 99.5 was used as a single layer target that has been impacted by a steel 4340 ogival nosed projectile. The ogival projectile has a shank diameter of 10.9 mm, total length of 52.6 mm and 30 gram mass. The thickness of ceramic layer is taken as 5 mm; with 100 x 100 mm, planar dimension. The Johnson–Holmquist–2 (JH-2) constitutive model has been employed for ceramic and Johnson–Cook (JC) elasto–viscoplastic model was used predicting the behaviour of metallic projectile. A comparison was made between residual velocities obtained for different level of eccentricity with impact velocities in a range, 100 – 300 m/s . The numerical simulation model was developed using ABAQUS/ explicit finite element and validated with the experimental data available. The energy absorption by the ceramic target was found to be minimum when the impacting projectile hits the target with no eccentricity. The optimum size of the ceramic tiles in case of mosaic armour system for efficient ballistic resistance has also been discussed in the present study.

Keywords: *Ballistic, Ceramic Target, Finite Element Modelling.*

* * * * *

Simulation of Ballistic Impact Analysis on Composite Laminated Armor

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Abstract: Nowadays, the composite materials are widely used in many engineering applications because of their various physical and mechanical properties such as high

strength and stiffness, lightweight and toughness. In defense sector the composite materials are used to develop ballistic resistance armor. To enhance the ballistic resistance of armors various laminate combinations have been developed. However, the developed armor causes major injury and not completely withstands high velocity impacts due to insufficient strength. Hence, in this paper, new composite laminate has been developed and studied by conducting numerical studies. The studies are carried out by using finite element software ANSYS. The accuracy of the finite element results is validated with the available results in the literature. The behavior of laminate composite armor has been discussed with the help of developed graphs.

***Keywords**: Finite element model, Fiber cement layer, Graphene, Kevlar 29 fiber.*

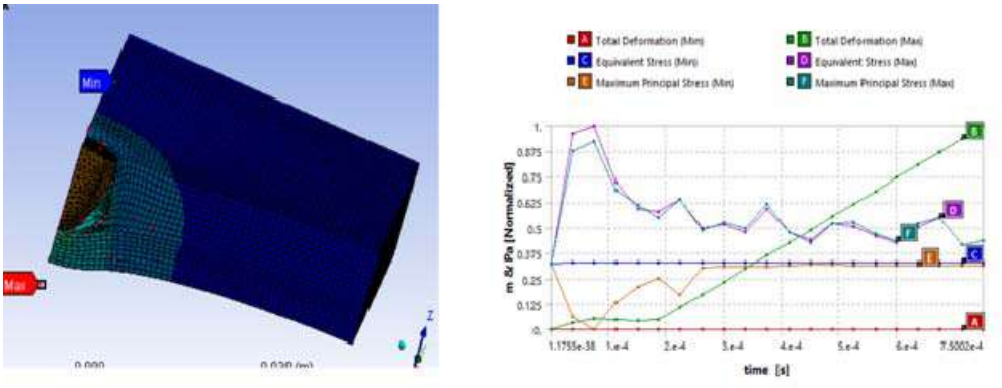

Fig. 1 Total deformation of sample and Plot of Total Deformation (m), Maximum principal Stress (Pa) and Equivalent Stress (Pa) versus Time(s)

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Design and Analysis of Bullet Proof Jacket under Impact Loading

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Abstract: Bullet Proof Jacket is a protective wear that can withstand high velocity bullet impact, thereby protecting the wearer from injuries. Increasing weight of the jacket is a

common issue faced, which reduces the mobility. Nowadays composite materials turns out to be one of the leading material used in jacket due to its lightweight, high strength and ability to withstand impact loading. Kevlar, Graphene, Dyneema, UHMWPE (Ultra High Molecular Weight Polyethelene) are some of the composite materials which suit to be used as bullet proof jacket material. This paper aims to design and analysis of bullet proof jacket that can withstand impact loading. In this study Kevlar fibers and Dyneema fibers are used as the composite material. Kevlar is a composite made up of glass and carbon fibers and Dyneema is a synthetic fiber, which is effective in low weight applications. Jacket is designed as 3 types, Kevlar, Dyneema and by stacking layers of both. The bullet (impactor) modelled as cylindrical which is made up of copper. Modelling and analysis of the system is carried out using FEM software ANSYS. Full body jacket is modelled, and analyzed for high velocity bullet impact. Energy absorption and deformation of each material during impact is determined. From the post impact results the jacket material with highest energy absorption and least deformation which resist perforation (complete penetration) is recommended for practical applications.

Keywords: *Bulletproof jacket, Kevlar, Dyneema, Perforation*

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Finite Element Analysis of Ceramic/Dyneema Composite Armour against Multiple Impacts

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Abstract: The performance of a ceramic/dyneema composite flat panel against multiple impacts has been assessed using Finite Element Analysis. The panel consisting of 6mm thick Boron Carbide facing the bullet and 10 mm of UHMWPE with polyurethane or epoxy adhesive between the two. The thickness of the adhesive is varied. The geometry of the bullets is similar to NIJ surrogate bullet of 7.62x39 mm but with Hardened Steel Core (HSC). The ceramic, UHMWPE and steel core are modelled using Johnson-Holmquist model, Orthotropic Model and Johnson-Cook model. The panel was impacted with six bullets in accordance with the test criteria mentioned in BIS and the damage in ceramic and composite and back-face signature of the panel were studied. The effect of geometry of ceramic tiles, whether hexagonal or rectangular, thickness of adhesive,

distance between impacting bullets is also investigated. The back face signature for a sinlge and six bullet impact has been observed to be approx. 23 mm and 38 mm respectively. A preliminary comparison with experimental results is also performed.

Keywords: *Composite Armour, Multiple Impact Analysis, Dyneema*

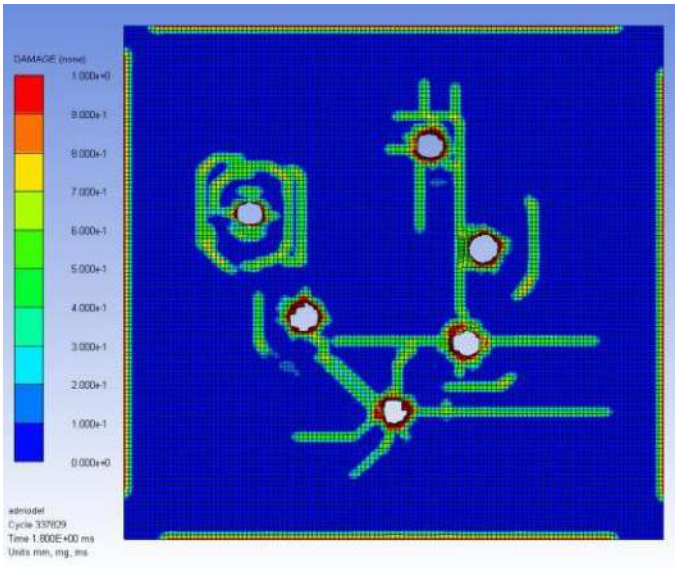

Fig. 1 Damage Contour of Ceramic

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High Velocity Impact Studies of Dyneema Fabric with and without STF Experimental and Analytical using LS-DYNA

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Abstract: High strength synthetic fibres are being used in the defense sector in impact-resistant structures, mainly bullet-proof jackets. The ultra-high molecular weight polyethylene (UHMWPE) fabric is high strength against the high speed impact. Woven

Dyneema fibres are impregnated with a shear thickening fluid (STF) fabricated with nano-silica powder and polyethylene glycol-400 (PEG). The samples are subject to impact by a steel projectile using an air gun and the ballistic limits are obtained. For the conduct of impact test, we have used impact testing air gun operated by compressed air along with the high speed camera PCC 2.8v software for the calculation of residual velocity by capturing the high speed imagery over the different scenario of velocities ranging from 20 m/s to 400 m/s. The addition of STF is found to improve the ballistic limit of the samples. The ballistic limits velocities and energy absorption with and without STF are obtained for 8, 10, 12, 20, 30, and 40 layers of Dyneema fabric layers. It's observed that STF impregnated Dyneema fabric has better ballistic limit and energy absorption than neat Dyneema fabric. LS-Dyna is used for modeling and simulating the impact event and to validate the experiments. The experimental and numerical results are found to be comparable to each other.

Keywords: *High-velocity impact, STF, impact behaviour, LS-DYNA, residual velocity, ballistic limits.*

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Study on the Design and Manufacturing Method of Hydrogen Tank using Thermoplastic Resin

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Keywords: Hydrogen pressure vessels, thermoplastic resin, filament winding

Abstract: This research aims to ensure stable quality, performance, and recyclable eco-friendly products when developing composite pressure vessels through finite element structural analysis and filament winding technology. There is a huge need to ensure the price competitiveness of hydrogen pressure vessels. This article introduces research on ensuring competitiveness through the rational design of recyclable thermoplastic hydrogen pressure vessels, with a view to achieving eco-friendly and explosive growth in the hydrogen vehicle market. The filament winding method is a composite molding method in which a continuous fiber impregnated with resin is wound in a cylindrical

rotating mold and then cured to produce a rotationally symmetric structure. In this article, we reduced the material consumption of composite pressure vessels through appropriate design and improved the reliability of the analysis by comparing and analyzing theoretical and structural analysis values. Based on this titration design, UV curing and thermal curing can be performed at the same time to produce a Type4 thermoplastic composite hydrogen tank that can be recycled with the thermoplastic resin Elium. By confirming that the curing process of the long filament winding takes only one hour, the excellence of the process is also verified.

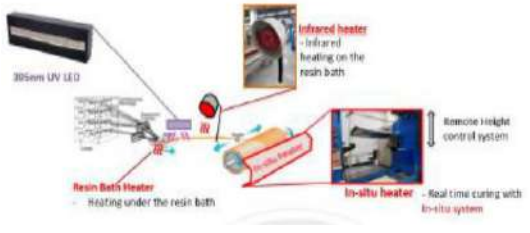

Fig. 1 Diagram of the entire filament winding process

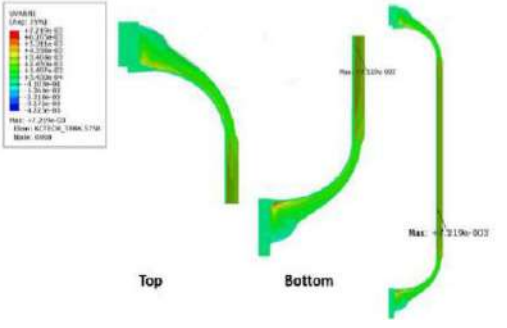

Fig. 2 Fiber direction strain in Abaqus

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Analysis of Multiwall Carbon Nanotube asan Additive in Methanol Blending in Automobiles Fuels

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Abstract: Multi Walled Carbon Nanotubes are hollow, cylindrically shaped allotropes of carbon that have a high aspect ratio (length to diameter ratio). Their name is derived from their structure and the walls are formed by multiple one-atom-thick sheets of carbon. Addition of multiwall carbon nanotubes in the methanol blends with petrol enhances the advantages of methanol as an alternative. If proper blending percentage is done, MWCNTS can increase the torque, power and BTE up to a range of 10-15% effectively and thus boosts up the advantages of methanol. Methanol is a cleansing agent.

When used in engine, it cleans the dirt and filth is formed in the engine. This may damage some parts of the engine and make them useless. Taking into account these properties of methanol, certain modifications are required in engine. The modifications vary depending on the maker of engine; technologies used percentage of fuel to be used, etc.

Keywords: *Fuel for spark ignition engine operation, Greenhouse effect, Methanol economy, Renewable methanol by capturing CO2, Air/alcohol mixture, Multiwall carbon nanotubes, Ultrasonicator.*

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Thermal Stability of Mechanically Milled Silicon

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Abstract: Silicon, the second most abundant element in the earth's crust. Besides the semiconductor industry, it is used as as a deoxidizer in steel industries, as an alloying element for castable aluminium alloys for automotive applications and also as a precursor for synthesis of abrasives for cutting and grinding applications. In this work, we report results from our investigations on thermal stability of mechanically milled silicon. Mechanical milling was carried out on silicon powders and the powder was found to exhibit a grain size of 11 nm and 7 nm after 7 and 40 h of milling. Differential scanning calorimetry experiments were conducted on the 7 h and 40 h powders and the obtained data was analyzed using the Kissinger's approach to obtain an activation energy of 233 kJ/mol and 436 kJ/mol for the 7 h and 40 h powders respectively. The difference in activation energy was attributed to the amount of amorphous phase present in the milled silicon with higher activation energy values corresponding to higher amount of amorphous phase fraction.

Keywords: *Thermal Stability, Mechanical Milling, Silicon, Differential Scanning Calorimetry, Kissinger Analysis, Activation Energy, Amorphous*

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Coating Material Design for Traction Motor Bearings of Electric Vehicles under Electrical Loads

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Abstract: Bearings in the motors of electric vehicles irrespective of the type experience stray currents and voltages which leads to significant damage in them. Many pathways for these stray currents through the bearings have been proposed in the literature. A method suggested to prevent these types of failures is to use an insulated coating, typically made of alumina on either the inner race or outer race. An ideal insulated coating can protect the bearings from damage due to extreme currents. However, the poor quality of the alumina coatings due to non-uniformities during the manufacturing process, wear, and environmental conditions such as humidity lead to a reduction in the electrical conductivity which in turn allows significant electric currents and voltages in certain situations to pass through the bearings. These in turn cause degradation of the lubricant whose properties on the influence of current flow are beyond the scope of this study. Preliminary investigations using a simplified model in COMSOL® showed that coatings with a thickness of 100 microns with ideal electrical conductivity were able to reduce the current flow through the coating to nA range. The results from the simplified model were validated with the analytical expression available in the literature and found to be in good agreement. This will in turn help to determine an optimized coating thickness which will prevent premature failure of drive motor bearings due to electrical loads.

Keywords: *Bearings, electric vehicles, insulation coatings, numerical simulation*

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Effect of Additives on A DLC Coated Surface Textured Piston Ring–Cylinder Liner System

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Abstract: Diamond like carbon (DLC) provides exceptional mechanical and tribological properties. They offer ultra-low friction and good resistance to wear. Recently, research

on DLC has centered on the application of these coating to the components that operates under boundary lubrication regime. Further, conventional lubricant additives were formulated for metal surfaces; hence their interaction with DLC surfaces is not completely explored. In this study, individual andsynergistic contributions of friction modifier and anti-wear additives tothe tribological performance of DLC coated textured PRCL (piston ring-cylinder liner) system under boundary lubrication contact condition will be evaluated. Texturing will be done on DLC coated piston ring using Ytterbium fiber laser.Experiments will be carried out in a Bruker's universal tribometer with contact condition as –Load 75N, frequency 0.1 Hz, and Temperature 80°C. Molybdenum dithio-carbamates (MoDTC) & Glycerol Mono oleate, (GMO) will be used as friction modifier and Zinc dialkyldithiophosphate (ZDDP) as antiwear additive. The post-testanalyses were done using SEM, EDX, Raman spectroscopy and profilometer

Keywords: *Diamond like carbon, boundary lubrication, piston ring-cylinder liner*

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Analysis of drill tool wear using acoustic emission signals based on IBS technique for CFRP laminates

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Abstract: Carbon fiber reinforced polymer (CFRP) based structures are widely used in aerospace and automobile application due to its excellent strength to weight ratio. For making a product using this CFRP component along with other components requires a hole to be drilled for assembly requirements. The holes drilled in CFRP leads to delamination at entry and the exit. These delaminations occur due to improper selection of cutting conditions, drill tool geometry and wear. For delamination free drilling without compromising on the productivity requires monitoring the process. In this work acoustic emission signals collected during the drilling process used to evaluate the extent of delamination and tool wear. The time, frequency domain and information based similarity approaches were used to evaluate the information content of the AE signals. The evaluated parameters clearly distinguish the delamination and the tool wear occurred during the process. This approach can be easily adapted for online continuous monitoring

of the process to assess the extent of damages for defect-free drilling of composites for various applications.

Keywords: *CFRP, Acoustic Emission, Information-Based Similarity, Drill tool wear, Damages analysis*.

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Debonding Effects and Shock Propagation in a Layered System Subjected to High Velocity Impact

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Abstract: When a system undergoes high velocity impact, shock waves are generated at the point of impact. The propagation of a shock through a layered system is studied numerically using LS Dyna, a finite element simulation software. Earlier, Vinamra Agrawal performed a study of shock wave propagation through a one dimensional heterogeneous medium and obtained an analytical solution for simplified material models without considering debonding effects. An idealized bilinear stress-strain relationship and different compressibility conditions were considered for layers. The present study focuses on shock propagation in layered medium by considering debonding effects and using a nonlinear stress strain relationship which is linear in the elastic region and nonlinear in the plastic region. In the present study, an elastic impactor is hit on a target multi-material layered system of similar dimensions with high velocity. The materials in the target layered system are modelled in such a way that they have similar elastic properties, but differ in plastic properties. This is achieved by varying equation of state parameters for the materials. In the target system, shock impedance decreases from the start to end of the system. This study is carried out using uniaxial strain conditions. Three cases are simulated with different interfacial conditions i.e., (1) bonded system, (2) fully debonded system and (3) partially debonded system. Stress variations at various locations in the material, specially at the interfaces, are studied. Failure map in the material is obtained from different shock wave interactions. A schematic diagram of the three cases is shown in Fig. 1. A stress variation plot for a system in which the layers are debonded is shown in Fig. 2.

Keywords: *Shock waves, Debonding effects, Impact, Layered system*

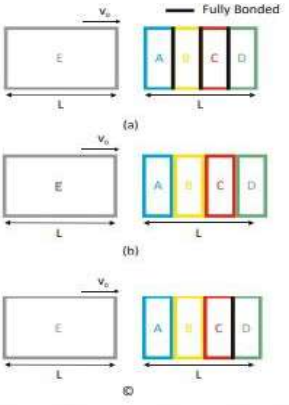

Fig. 1 Three cases (a) bonded system (b) fully debonded system and (c) partially debonded system

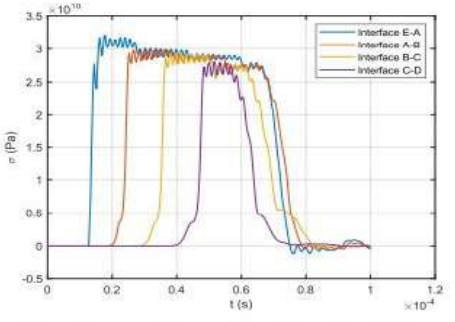

Fig. 2 Stress variation plot for a fully debonded layered system

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Energy Absorption of Foams with Non-Linear Variation in Cross-Sectional Area under Stationary Impact

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Abstract: The dynamic compressive behaviour of foams with a non-linear variation in the cross-sectional area profiles is studied. A theoretical model has been developed based on the one-dimensional shock theory and the rigid, perfectly-plastic, and locking (RPPL) material model, to establish the governing equations of motion of an initially stationary foam struck by a rigid projectile. Both decreasing and increasing cross-sectional area profiles with various power-law exponents are considered. The proximal end of the cellular solid with cross-sectional area A_p is struck by the projectile, whereas, the distal end with cross-sectional area A_d, is fixed. The area-gradient is defined as $\theta_A = A_d / A_p$. The cross-sectional area at any distance z from the proximal end in the undeformed configuration is given by $(z) = A_p + (A_d - A_p)\ (z\ /L_0)\ ^{\wedge}N$. N is the power-law exponent that dictates the variation in the cross-sectional area and $L0$ is the undeformed length of the foam. The foam is modelled as a solid with a circular cross-section and a relative density of 0.2. The geometry of a convergent foam used for the finite element model is shown in Fig. 1. Due to the symmetry of the circular cross-sectional profile, only a

quarter model is simulated. The numerical simulations suggest that the decreasing area profiles, referred to as the convergent foams, exhibit a double-shock mode and the foams with an increasing area-profile, referred to as the divergent foams, exhibit a single-shock mode. The theoretical predictions of both the double-shock and the single-shock cases are validated against the finite element simulations. An expression for the plastic energy dissipated by convergent foams has been derived, and we observe that the convergent foams dissipate less energy than the divergent foams. The plastic energy dissipated is not affected significantly by the gradient for the divergentfoams, whereas for the convergent foams, it increases with the area-gradient as shown in Fig. 2

Keywords: *Area-graded foams, stationary impact, double-shock, energy absorption*

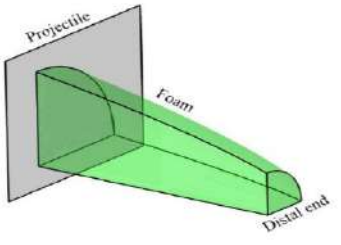

Fig. 1 Geometry of the convergent foam used for finite element simulations.

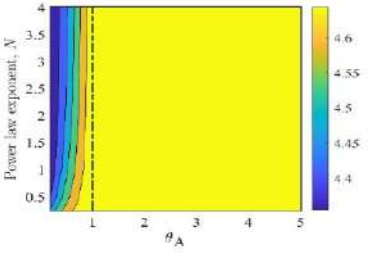

Fig. 2 Contour plots of the plastic energy dissipated at the end of crushing, as a function of area-gradient θ_A and exponent N, at a non-dimensional impact velocity $v_0 = 5$, corresponding to mass-ratio $\Gamma = 0.5$. For convergent foams $\theta_A < 1$, and for divergent foams, $\theta_A > 1$.

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Comparison of Experimental and Operational Modal Analysis on a Flexible Silicone Tube Conveying Fluid

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Abstract: The flexible tubes are light in weight, corrosion-resistant and chemically inert to fluids. Also, as it offers low bending stiffness compared to the axial tensile stiffness, it

can be rolled into a single tube and can be fabricated without any joints for making long pipes. The above properties make flexible tubes a good replacement for metal tubes in many fluid conveyance applications. Flexible tubes conveying fluids can show intense vibration due to the fluid-structure interactions resulting from the frequent transfer of energy between the fluid and structure. But compared to the metal tubes, flexible tubes need only very minimal energy to get excited. Hence small undulations in fluid flow through the flexible tube can induce severe internal excitation, which results in the flow-induced vibrations of such tubes. If the flow induced vibrations frequency matches with any of the fundamental frequencies of the fluid conveying tube, resonance will occur. Hence the design of flexible tubes and its supports rely on the accurate identification of the fundamental frequencies as well as on the understanding of the influence of flow induced vibration on the fundamental frequencies of the flexible tubes conveying fluid.

This paper compares the two modal analysis techniques, Experimental modal analysis and Operational modal analysis, on identifying the fundamental frequencies of the flexible silicone tubes conveying fluid. Experimental modal analysis includes the identification of fundamental frequencies and mode shapes using external excitation techniques, while the Operational modal analysis deals with the identification of frequencies and mode shapes of structures when it runs in its operating conditions. For the present study, an experimental setup was designed to create a steady flow as well as a pulsatile flow of fluid with the head over the tube as 1.92 m. Both Experimental modal analysis as well as Operational modal analysis is conducted on a pre-stretched tube. For conducting Experimental modal analysis, the tube is excited using an electromagnetic shaker and the responses are acquired using Laser Doppler vibrometer. A rotary disc valve was employed to provide a flow pulsation to conduct Operational modal analysis. The identification of fundamental frequencies and plotting of mode shapes were done using ME scope VES software.

Inorder to find the fundamental frequencies and mode shapes the fluid conveying using Experimental modal analysis, pipe lines are normally excited using some external exciters such as electromagnetic shakers or impact hammers. This constrained external excitation mostly restricts the structural vibrations to act along the direction of excitation. But the flexible structures generally experience out of plane oscillation when it is excited in a single direction using constrained vibration techniques. Even though the tube is excited in the X-Z plane, it experiences vibration in different planes due to the influence

of sagging. The vibration amplitude of the tube along X-Z and X-Y plane is shown in Figure 1(a). As the tube is pre-stretched, the amplitude of vibration measured along X-Z and X-Y plane decreases.But in the Operational modal analysis the tube vibrates due to the fluid pulsations happened due to the flow undulations. When the flexible tube is excited using internal pulsations, the tube vibrations is not restricted either in horizontal or vertical plane rather, it will vibrate along an inclined plane (along the direction of its mode of vibration). Figure 1 (b) represents the variation of tube vibration along X-Y and X-Z plane for different pre-stretching.

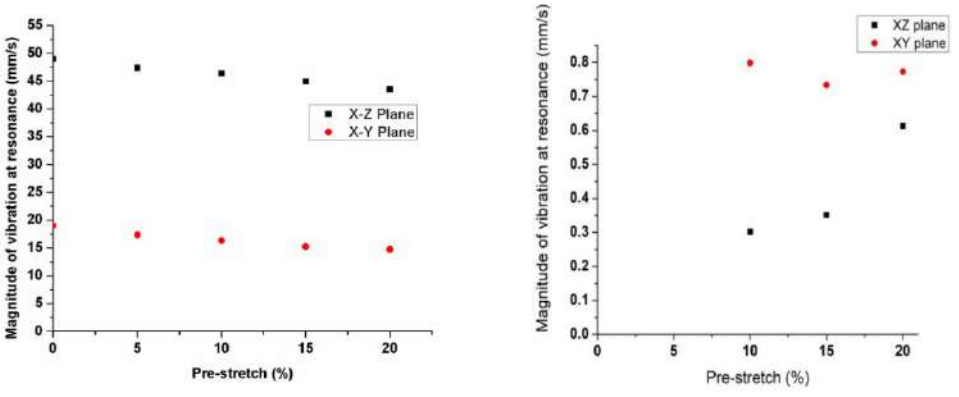

Figure 1:- Variation in Magnitude of Vibration along X-Z and X-Y plane for EMA and OMA

The results reveal that the constrained external excitation of flexible tubes conveying fluid results in the oscillations of the tube in an arbitrary plane even if the tube excitation is in horizontal direction. This out of plane oscillations results in the beat phenomenon of flexible structures. Hence the constrained external excitation will not give any reliable data to plot the modes shapes and to get the fundamental frequencies of the flexible tubes conveying fluid. Meanwhile the Operational modal analysis shows that the tube vibration always stabilizes in a particular arbitrary plane under excitation due to pulsation. Hence the influence of multiple plane vibration and the resulting the beat can be avoided if the study is done when the tube is excited due to internal flow.

Keywords: *Operational modal analysis, Experimental modal analysis, Beat Phenomenon, Silicone rubber tube, Natural frequency*

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Numerical Simulation of Strain Rate Effect of Al Circular Tube for Dynamic Loading Applications

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Abstract: The strain rate effect is the most important mechanical property dealing with the responds of impact material under dynamic applications in engineering material aspects. The Split Hopkinson Pressure Bar (SHPB), namely as Kolsky bar is a widely used setup for a high strain rate ranging from 10^2 to 10^4 s^{-1}. Numerical impact mechanics of SHPB is simulated by using Finite Element (FE) analysis in ABAQUS 6.14. The design assessment of structural material requires accurate knowledge of deformable and strength properties of materials involved under dynamic loading conditions. These properties can vary with temperature and time. The strain rates of Al circular tube are determined by using FE simulation at room temperature and at elevated temperature. These results will be useful to study the dynamical properties and related dynamic respond of materials for future engineering applications.

Keywords: *Split Hopkinson Pressure Bar, Strain-Rate, Inverse problem, Quality Control*

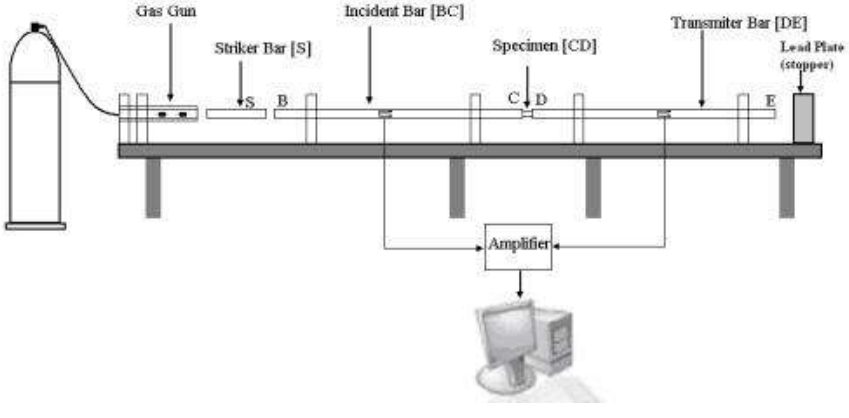

Fig. 1 Schematic of split-Hopkinson pressure bar

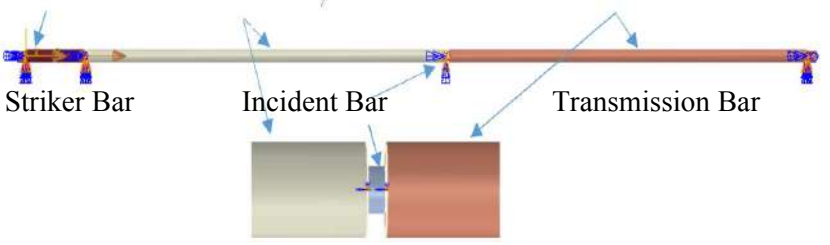

Fig. 2 Simulation of split-Hopkinson pressure bar

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Nonlinear Structural Response of an Offshore Platform under Jetfire

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Abstract: This paper presents a methodology for analysing the behavior of offshore structures under jet fire conditions. Jet fires are one of the most dangerous types of fires in this sector causing numerous accidents resulting from weakening of structural steel and leading eventually to the collapse of a platform.High heat flux from combustion of gaseous fuel in jet fires can cause thermal insult of a critical structural member. The mode of thermal insult can be by direct impingement or by radiative heat transfer. A typical scenario of that of an accidental rupture of a pressurized line leading to efflux of flammable gas causing a jet fire is considered here. This study focuses on thethermo mechanical behavior of the model under such extreme jet fireconditions. The study results that modeling the fire for compartmental effects will have a significant effect on the structural response. Most of the previous studies have focused on transfer of heat to the structural member and finding the structural response due to the high temperature without considering compartmental effect. Numerical experiments were run with three - dimensional finite element models on ABAQUS software the heat transfer and non-linear structural response have been considered here. The transient heat transfer was calculated using a refined finite element mesh, whereas fire simulation was done using FDS, a popular open source in fire research community. Here we took the Piper Alpha Platform for Comparison.

Keywords: *Jet-fire, Nonlinear analysis, Finite element, FDS*

Fig. 1. The Piper Alpha (left) and Deepwater Horizon (right) accidents.

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Free Vibration and Blast Load Analysis of Porous Functionally Graded Plates

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Abstract: Functionally graded plates with metals and ceramic constituents distributed across the thickness and length directions are now used in different applications like aircraft, biomedical, automotive engineering etc due to their high thermal resistance and mechanical strength. In comparison with laminated composites, the problems of interlayer stresses, delamination and cracking are not seen, but there is a considerable effect of porosity on the overall dynamic behaviour. A multitude of works on the dynamic analysis of functionally graded porous plates is noticed in literature. Most of the works focussed on buckling and free vibration behaviour using finite element modelling, approximate techniques using Rayleigh-Ritz, Galerkin and Gauss differential quadrature methods. The analytical modelling of materials and dynamic model of the plate are straight forward. However, the solution scheme of complex resultant equations for different boundary conditions of the plate is an involved procedure and is not unique. In present work, aluminium-zirconia functionally graded porous rectangular plate subjected to central blast (triangular) load is studied using analytical approach based on Navier's method. The power law index is used to calculate volume fraction of ceramic constituent.

Fig.1 shows the ceramic volume fraction variation as a function of power law index n along the depth.

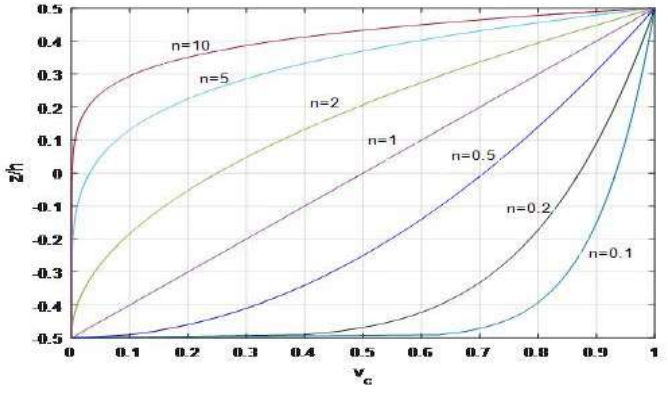

Fig.1 Power law distribution of ceramic volume fraction considered

The effects of aspect ratio, power law index and porosity factor on the first few natural frequencies are first studied and further, the dynamic response of the structure is obtained from modal superposition method. Finally radial basis function neural network model is implemented to generalize the effect of various parameters on the fundamental frequency and amplitude of impulse response from the structure. The studies are very useful for the design of first wall material of fusion reactor vessel

Keywords: *Free vibration analysis, Analytical solution, Transient response, Neural network modelling, Porosity distribution*

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Effect of Eccentricity of Load on Buckling Behaviour of FRP Columns

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Abstract: The applications of FRP columns are increased in various engineering fields due to their high strength and stiffness, lightweight and corrosion resistance. Being a

thin-walled structure, their designs are often governed by buckling criterion. Buckling strength depends on state of stress of elements which is greatly influenced by fiber orientations. Further, real structures may have different kinds of various inaccuracies such as geometric imperfections, production inaccuracy and non-uniform boundary conditions that may cause load eccentricity of a thin-walled profile, particularly when it is subjected to compression. Hence, in the present work, influence of fiber orientation and load eccentricity on the buckling behaviour of FRP lipped channel columns (both inward and outward lipped) subjected to static compression is investigated. Extensive parametric study is carried out by using finite element software 'ANSYS'. The whole section is modelled by using shell elements. The effect of imperfections and the dependency of finite element mesh are carefully treated. Based on the generated database effect of eccentricity of load on buckling behaviour is discussed with the developed graphs. It is observed that when the eccentric load is applied towards the higher rigidity of the column's section, this has an insignificant effect on the buckling load. In contrast, when the eccentric load was applied parallel to the web of the top-hat profile considerable effect has been observed.

Keywords: *Buckling, Critical load, Eccentric load, Thin-walled structure, FEA*

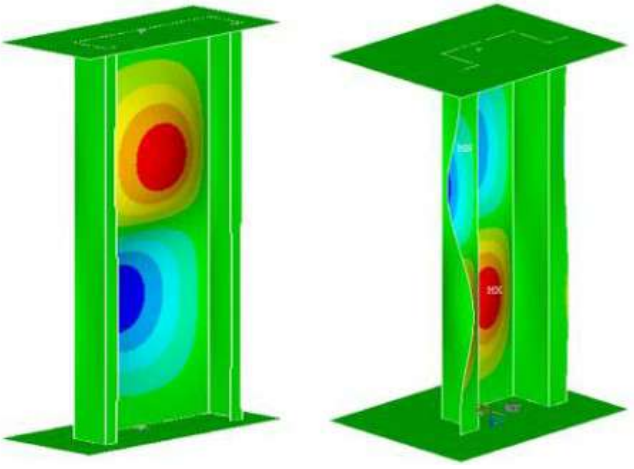

Fig. 1 Buckling mode shapes

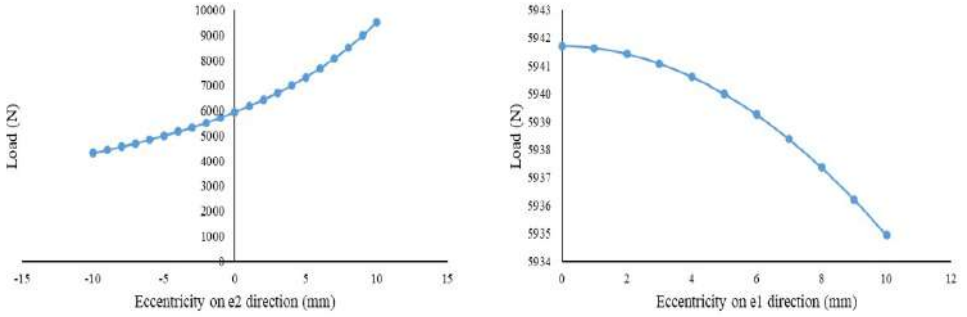

Fig. 2 Load eccentricity versus buckling load

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Effect on Mechanical Properties of Jute/Glass Hybrid Polymer Composites Due To Moisture Absorption

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Abstract: In the recent years, cellulosic natural fibers have been used widely in the reinforcement of composites mainly due to their lower cost, abundant, renewable, eco-friendly and biodegradable. Partial replacements of synthetic fibers with natural fibers are an interesting subject for engineers considering the environmental awareness and cost reduction. In this paper, the moisture absorption behaviour and its effect on the mechanical properties of woven jute and jute/glass fibers were investigated. Hybrid and non-hybrid composites consisting of woven jute/glass fibers were prepared by a hand lay-up process that used epoxy as the polymer matrix. The water absorption characteristics of the fibers were obtained by immersing the composite samples in normal water at room temperature, at different intervals of time. The dry and wet hybrid and non-hybrid composite samples were subjected to tensile, flexural and impact tests. The study shows that the mechanical and water-resistant properties of the jute/glass fibers were improved through hybridization. However, as a result of water penetrating the fiber/matrix interface, longer water- immersion times reduced the tensile, flexural and impact strength of the composites. The incorporation of glass fibre in jute fibre

composites enhances the mechanical properties and leads to increase in the utilization of natural fibres in various applications.

Keywords: *Water absorption, Hybrid composites, Mechanical Properties, Natural Fiber*

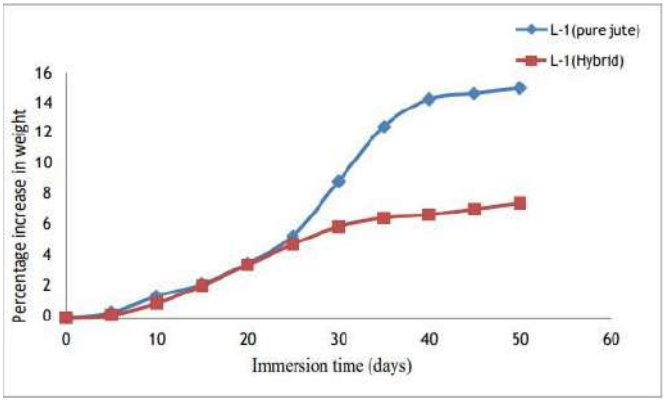

Fig.1 Percentage increase in weight (vs) Immersion time of the composites

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An Analytical Approach to Predict the Stress Variation of Single Lap Adhesive Bonded Joints

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Abstract: In this modern world use of composite has evolved to commonly incorporate a structural fiber and plastic known as fiber reinforcement polymer [FRP]. Generally rivet and bolt are used to make joints which may lead to initiation or propagation of crack. In order to overcome this issue adhesive joints can be used. Adhesive bonding joints play a vital role in many industrial and practical applications such as marine, aerospace technologies. Strength and failure modes of joints are based on the types of adhesives used such as ductile or brittle. In present paper analytical model has been proposed to predict stress variation at adhesive interface as well as load carrying capacity of single lap composite joint. For this purpose the stress function variational method is used for calculating the stresses in single lap joint where two stress functions considered are interfacial stress and normal (peeling) stress. The axial normal stresses in the upper and lower adherends

are following the Euler's Bernoulli beam theory which is also known as Classic Beam theory. The stress equilibrium equations used to determine the lateral normal stress and shear stress. The fourth Order Differential Equations is used to minimize the strain energy of the joints and solved by using the Eigen functions. The analytical method has been validated with the experimental results from literature. Present mathematical modelling can be used to predict the interfacial stresses of single lap joints with different types of adhesives and can be used to predict the combinations of ductile and brittle adhesives to get optimum joints.

Keywords: *Single lap joint, Adhesives bonded joints, Interfacial stresses, Energy method, Elasticity*

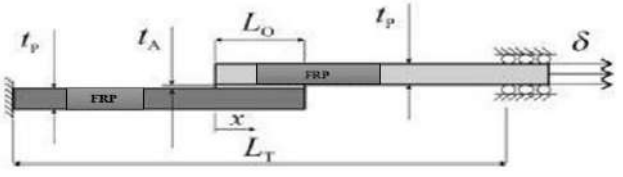

Fig. 1 Adhesive bonded single lap joint.

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Generative Pseudo Penalization Based Topological Optimization of Automotive Bracket with Efficient Additive Manufacturing Constraints

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Abstract: Decades-Long the Automotive Industry showed the harmful vehicle emission to cause a direct impact on Human Health and Environmental Conditions, in this scenario of increasing pollution, the statutory government bodies strengthen the laws on Automakers to curb the harmful emission under permissible limit. Such example suggests EU Commission regulation (EU), They set a mandatory reduction in emission target on a fleet average car by 2021 where 95 Grams of CO2/ KM is appreciable to cut down fuel consumption rate to 4.1 Liter/100 KM for Petrol and 3.6 Liter/100 Km for

diesel. This Strict laws by government bodies cause Automakers immense pressure to vanguard different strategic product development methods to curb the emission of vehicles.

A powerful strategic product development adopted by Automakers to curb fuel consumption is achieved by structural weight reduction technique since a lighter car consumes less power to come up with inertia, A flat 6 to 8 % of mileage boosting can be achieved by weight reduction technique. In the structural weight reduction method, an engineering fundamental question comes where to place right material in constraint designed space limit? For this, Topological Optimization FEA based techniques provide an adequate solution to place the material in the correct layout. In the present paper Generative design based regressive Topological optimization technique has been developed for an Automotive calliper mounting bracket, the work aims to investigate Structural characteristics of the bracket before and after Topological optimization operation whereas in post-process operation bracket has been developed as per the Additive manufacturing constraints in ANSYS SPACE CLAIM. The comparative contours on validation are proposed between Computational modelling and actual developed 3-D printed prototype as shown in Figures 1 and 2.

Keywords: *Topological optimization, Design of machine, Weight Optimization, Weight reduction*

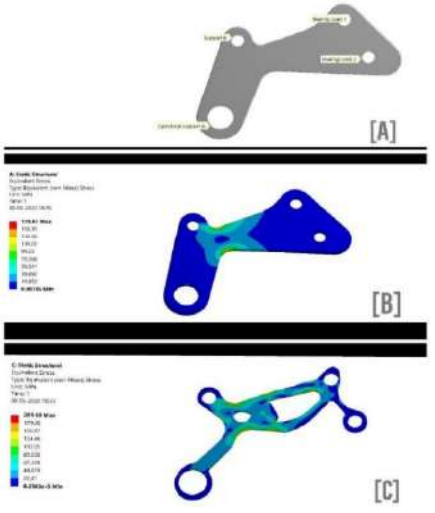

Figure 1. A) Boundary condition on Bracket, B) Structural Validation over Bracket & C) Structural Validation of Optimized Bracket.

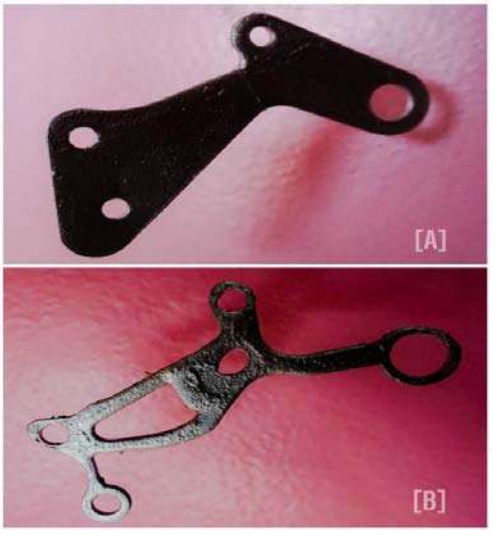

Figure 2. A) Developed Prototype of Non-Optimize Design & B) Practical Developed Topological Feature of Optimized Part.

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Behaviour of Nickel Foam as Flow Distributor in PEM Fuel Cell under Mechanical Loads

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Abstract: The Proton Exchange Membrane (PEM) fuel cells are clean and affordable alternative energy sources for next-generation mobility. The PEM fuel cell provides energy with a pair of redox reactions by using hydrogen as fuel, and each cell comprises bipolar plates, gas distribution plate, membrane, gasket and endplates. The reliability of PEM fuel cells depends on many factors like design and geometry of flow fields, properties of materials used, and stack clamping method followed. A fuel cell stack attached to the mainframe of the vehicle experiences extreme vehicular vibrations due to

road unevenness and road humps or accelerating and braking of vehicles. The vehicular vibrations will result in small relative displacements within the stack. The newer designs employ metal foams, as a flow distributor in the fuel cell, and the low amplitude displacements in the assembly may lead to fretting damage. This study is directed towards understanding the possible relative displacements between components due to vehicular vibrations through numerical simulation. A 3-D finite element model of PEM unit fuel cell having the metal foam as flow distributors (active area of 3 cm by 3 cm) assembled using eight bolts was created and analyzed using the commercial software. The vehicular vibrations are mimicked by giving a displacement boundary condition perpendicular to bolt pre-tension load at one end of the fuel cell while the nut surface at another end is fixed, as shown in Fig 1. The relative displacements, equivalent stress and total deformations of each component were obtained and the results are compared with conventional PEM fuel cell with graphite bipolar plates. The relative displacement between components varied from 2-50 µm and depends upon applied end displacements. The analysis will assist the designers to suitably select the clamping and damping systems.

Keywords: *PEM fuel cell, Nickel foam, Vehicular vibrations, Relative displacements, Fretting*

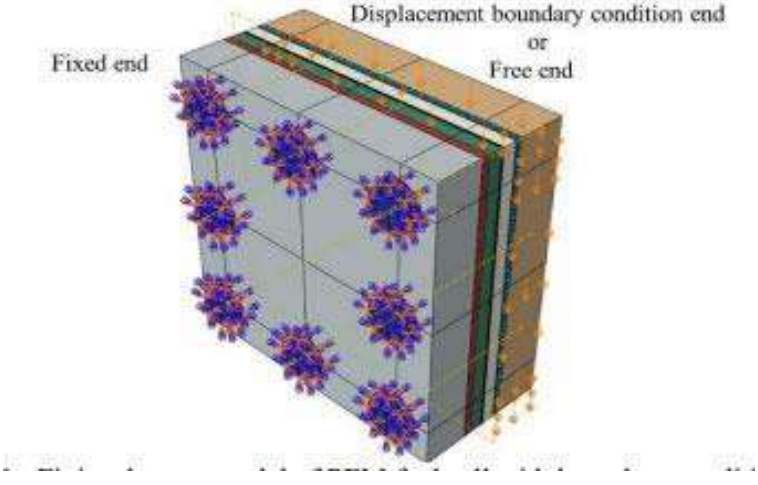

Fig. 1: Finite element model of PEM fuel cell with boundary conditions

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Hybrid Phase Field Modelling of Dynamic Brittle Fracture and Implementation in Fenics

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Abstract: Fracture is one of the most common mechanisms of failure in engineering brittle materials. Numerical methods provide efficient tools to both predict the crack propagation path and also understand the fracture process. The phase-field method is shown to be an efficient numerical method due to its ability to simulate crack initiation and propagation without any ad-hoc criteria. It uses a scalar dam age variable to model the discrete crack as a diffuse crack phase field. A hybrid phase field model has earlier been proposed to simulate th e quasi-static elastic brittle fracture which enabled a significant reduction in the computational cost. In the present work, a hybrid phase field model has been adopted to study the process of dynamic brittle fracture. Numerical examples involving dynamic crack propagation and crack branching cases have been simulated. The crack propagation path showing the dynamic crack branching has been shown in Figure 1. The present model consists of two coupled partial differential equations – the mechanical equilibrium equation and the phase-field evolution equation. A Newmark-β method using the implicit time discretization has been used to update the acceleration and velocity. The solution to this system of equations drives the crack propagation path and the displacement fields in our problems. Throughout this study, a staggered solution scheme is used to solve the system of PDEs using open-source finite element software FEniCS.

Keywords: *Dynamic brittle fracture, Phase field method, FEniCS, Staggered scheme*

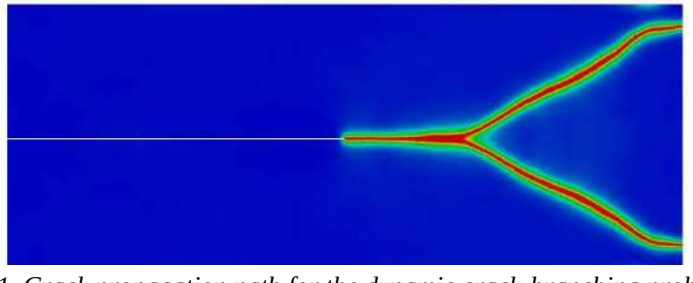

Fig. 1. Crack propagation path for the dynamic crack-branching problem.

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Energy Storage Potential of Functionalized Reduced Graphene Oxide for Solar Desalination Application

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Abstract: The demand of water is increasing rapidly with increasing population and industrialization. Solar still (SS) utilized abundantly available solar energy for generating clean water from brackish water resources using different energy storage medium, but low water productivity of SS is major concern. Considering the above, present experimental investigation deals with improving performance of SS using functionalized reduced graphene oxide (rGO) nanosheet mixed in black paint coating. rGO was prepared from graphene oxide through hydrothermal treatment. In this typical procedure at first 1g of graphene oxide (GO) was dispersed in 100 ml double distilled water and sonication for 15 min until the solution is mixed. Then 5 ml ammonium hydroxide and 5 ml hydrazine hydrate were added to the GO solution, stirring the mixture for 30 min at room temperature. Subsequently, the mixture was heated to 90 °C in water bath for 45 mins under constant stirring. Eventually, solution mixture turned to dark indicating reduction was completed. The final sample was collected and the specific area and mean pore diameter were found to be 167 m^2/g and 22 nm, respectively. SEM and TEM image of the rGO shows the porous and wrinkled structure (Fig. 1 a, b). Three different solar still namely conventional SS with only black paint coated absorber and two SS with rGO mixed in black paint coated absorber (2 wt.% and 4 wt.%) were used in the present study and tested under Indian climatic conditions. Experimental results showed that the utilization of 4 wt. % of rGO in black paint coated absorber of the SS enhanced the water and absorber temperature by 6% and 7% respectively than that of absorber without Nano sheet. The accumulated water yield of SS was augmented by 25% (4 wt. %) with rGO coating, compared to conventional SS.

Keywords: *Solar desalination, Reduced graphene oxide, Nanocoating, Water Yield*

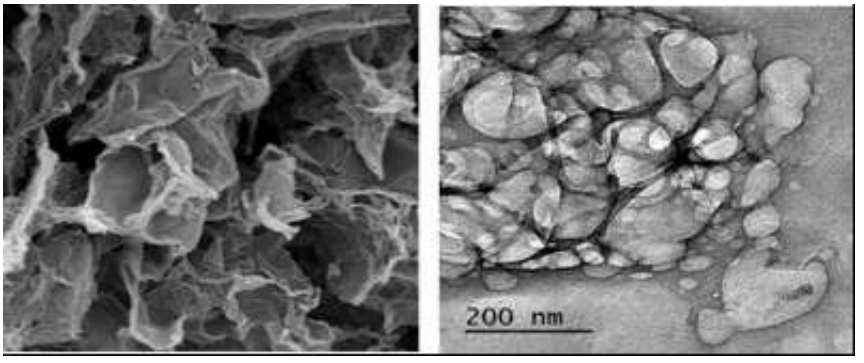

Fig. 1 (a,b) SEM and TEM image of the functionalized rGO

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Assessment of Relative Displacements in Proton Exchange Membrane Fuel Cell Stack Materials due to Severe Service Loads

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Abstract: The next generation of modern mobility systems will use fuel cells as the prime energy source and Proton Exchange Membrane (PEM) fuel cells are among the many types widely researched. Each PEM comprises of multiple parts comprising of the solid polymer electrolyte membrane, two gas diffusion layers GDLs, two gaskets, two flow-field plates as shown in Fig.1. Depending upon the power requirements multiple fuel cells, even up to a few hundred are assembled and stacked in a vehicle. Many such unit cells are assembled between two end plates to form a fuel cell stack. These fuel cell stacks during service in automotive applications experience vibrations resulting in frequent impact loads. Such extreme loads lead to relative displacements between components in the stack which affects the performance and durability of the fuel cell system. In the present work, the deformation behaviour and the relative displacements at various locations of fuel stack having about 140 unit cells is evaluated using finite element analysis. The effect of vibrations of the fuel cell system located adjacent to the ends plates and at the central region is observed. A through-bolted assembly is considered to maintain uniform pressure. However, performing numerical simulations on

the complete fuel cell system is computationally expensive. Therefore, two solids blocks (representing 70-unit cells each) are modelled and positioned next to two end plates as shown in Fig.2. The equivalent modulus and thickness of 70 cells are evaluated and given as input properties to two blocks. The centre region of assembly consists of all the components of the unit cell with realistic dimensions. In this way, the rigidity of the system is not compromised and made computationally effective. The load and boundary conditions are given as shown in Fig.2. The relative displacement for each component of the fuel cell in the stack varies based on its location from the endplate. The bipolar plates and the gaskets experience relatively higher stresses than the MEA.

Keywords: *PEM, MEA, Fuel cell, Stack, Deformation*

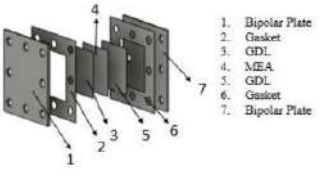

Fig. 1 Components of a single PEMFC

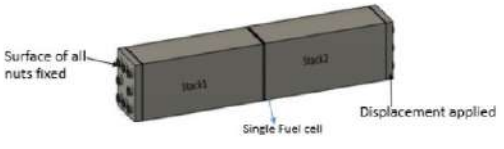

Fig. 2 Boundary conditions applied on a PEMFC stack

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A Coupled Photo-Mechanical Model for Light Actuated Locomotion of Soft Materials.

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Abstract: Stimuli driven soft-robots have created a significant impact in the field of robotics by allowing unconventional manoeuvres due to their high compliance compared to rigid robots. Soft robots are advanced bio-inspired systems capable of mimicking complex motions from natural beings that extend their use in practical engineering

applications. The interaction of Soft-Robots aka Stimuli-Responsive Materials with the environment due to their sensitivity to external stimuli results in a coordinated response, thus giving rise to novel actuators. Liquid crystal polymers (LCP's) are considered to be an exclusive class of soft materials due to their ability to generate large deformation by responding to external stimuli such as light, temperature and chemicals. The flexibility in designing actuators from liquid crystal thin films has helped the engineers to generate user-defined self-sustained motion. The lack of numerical simulations in this field has limited the fundamental understanding of the dynamics of soft robots, and our goal is to perform computational analysis on the simple rolling motion of the liquid crystal actuator modelled as a wheel. In this work, a coupled photo-mechanical numerical model incorporating the light attenuation and mechanical characteristics of LCP is presented. The splayed-nematic and planar alignment of directors through the thickness of the wheel results in asymmetric deformation about its central axis when irradiated by light on one side. This asymmetry in shape helps in manoeuvring the wheel to and fro depending on the light intensity, wavelength and illumination direction. This developed numerical model allows for exploring possible actuation mechanisms for various geometries that will lead us to design and build novel soft actuators. The results of the numerical model provide necessary insights for developing a light-actuated cart in the laboratory.

Keywords: *Soft robots, Stimuli-Responsive Materials, liquid crystal elastomers, photo-mechanics, Finite Element Method, rolling, rocking, soft actuators*

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Mechanical Response of Unidirectional CFRP in the Presence of in-Plane Fiber Waviness

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Abstract: The use of fiber reinforced composite materials has experienced a significant boom in recent years, with its applications wide spreading across multiple branches of industry. Manufacturing processes are rapidly improving and fabrication defects

occurrence is being significantly reduced, although it remains not feasible neither cost-wise effective to eliminate them completely. This work investigates the effects of fiber waviness, a commonly found manufacturing defect, in key structural properties of carbon fiber/epoxy reinforced composites. Finite element analyses using the commercial platform Abaqus® were performed to simulate unidirectional laminaecontaining in-plane graded undulations in the shape of sinusoidal waves, an attempt to resemble real encountered imperfections. The goal was to provide a computationally efficient analysis framework to support decisions for quality control guidelines. Automated model generation was performed through the use of parametric Python scripting. The peak misalignment angle was taken as sole influence parameter (□). Laminae were subjected to in-plane loading and boundary conditions, with analyses being divided into uniaxial normal longitudinal/transverse and biaxial normal loading. Results proved that fiber curvature affects local stresses distribution, leading to stress concentration/relaxation and inducing the occurrence of local stresses other than the original ones found in laminae with no defect. The influence on effective elastic modulus was less significant than on strength values. Initial failure was predicted by Hashin failure criterion, distinguishing between fiber and matrix failure modes. A significant strength knockdown effect was observed as misalignment angle increased, favouring a matrix dominated failure mode. Longitudinal load cases showed a higher strength reduction than observed on transverse loading. Regarding biaxial loading, the case of longitudinal tension + transverse compression was the most severely affected in terms of failure; the case of longitudinal compression + transverse tension was the least susceptible one

Keywords: *Fiber reinforced composites, Defect, Fiber waviness, Finite element analysis*

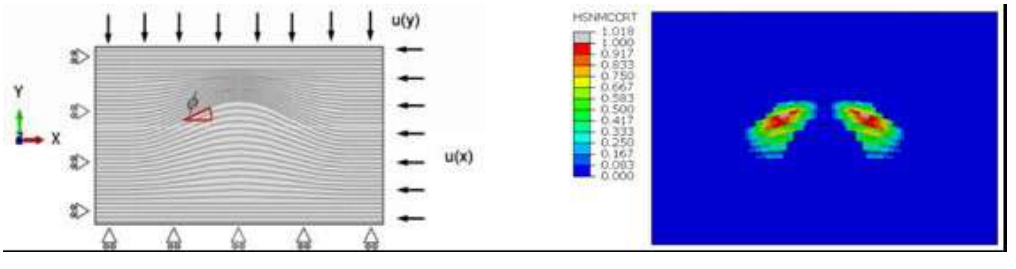

Fig. 1: Sketch of plate geometry, waviness distribution, load and boundary conditions. Fig. 2: Hashin failure matrix compression index for a plate with ϕ = 20° in-plane central waviness under compressive loading

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Bending Properties Analysis for Sandwich Structure Fabricated by 3D Printing Method

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Abstract: The sandwich structure consisting of a core and face-sheets onboth sides shows increased the bending stiffness by increasing the moment of inertia about the natural axis. In such a light-weight sandwich structure, the core material serves as a load transmission, and the characteristics vary according to the three-dimensional shape of the core. In this study, the core was 3D printed by using short and continuous carbon fiber filament through fused deposition modeling (FDM) method. And the geometrical parameters of corrugated core were angle of inclined lattice strut, and length of inclined and horizontal lattice strut. The core was designed by using split number, so the conventional corrugated core was split and arranged symmetrically in width direction. The face-sheet was also 3D printed with stacking angle of [0/90]3s. The fabricated core and face-sheet was bonded by using epoxy adhesive. The curing was performed during 4 hours at 80 ℃. The three-point bending test was conducted to investigate the bending properties of sandwich structure. The loading was applied by displacement control with speed of 2mm/min. Also, the simulation was performed to further analyze the bending behavior of sandwich structure. The bending characteristics according to the split number were compared for 3D printed sandwich structure. In both the experimental and analysis results, the bending stiffness tended to increase as the number of splits increased. In case of core fabricated with short carbon fiber filament, this tendency decreased when the number of splits was higher than three. Also, the failure mode was different according to the split number. In the case of N1 core which was not split, the fiber breakage occurred in the face-sheet.But, as the split number increased, the unstable face-sheet failure was not occurred.

Keywords: *Fused deposition modeling (FDM), 3D printing, CFRP composites.*

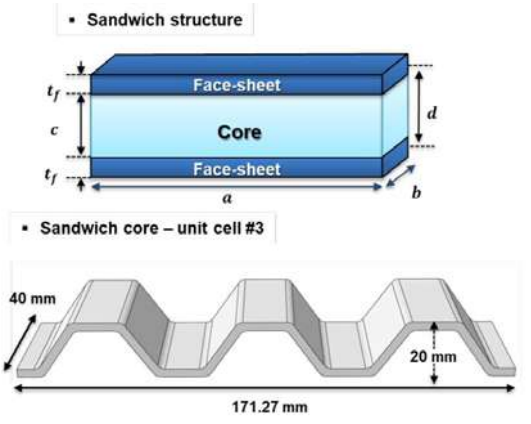

Fig 1.Schematic of sandwich structure and core

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Effect of Annealing Time and Temperature on Dynamic Mechanical Properties of FDM Printed PLA

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Abstract: Additive Manufacturing (AM) is a layer-wise manufacturing process and considered as one of the recent times' best innovations. Fused Deposition Modeling (FDM) is a type of additive manufacturing, where thermoplastic polymer filaments are melted and deposited layer-wise one over the other to obtain complex 3D geometry. FDM is a widely used AM process due to simple operation, relatively low cost and wide range of available material options. Commonly used feedstock materials in FDM are petroleum-based polymers. Petroleum-based polymers significantly influence the environment in terms of CO_2 and plastic waste addition. To minimise these effects, understanding and application of bio-based and biodegradable polymers for engineering applications are essential. Poly Lactic Acid (PLA) is a bio-based, biodegradable, biocompatible and recyclable thermoplastic polymer used in engineering and medical application. Dynamic Mechanical Analysis (DMA) is an experimental technique used to

analyse the polymers' viscoelastic behaviour with varied temperature, frequency, and stress/strain. Post-processing heat treatment processes, including annealing, can influence mechanical properties of the processed polymer parts. Improved crystallinity, Heat Deflection Temperature (HDT) and increased glass transition temperature (T_g) are a few advantages of annealing thermoplastic polymers. Annealing process parameters temperature, time, and cooling rates can significantly affect the various mechanical properties gained through the annealing process. The dynamic mechanical properties such as storage modulus, loss modulus, anddamping factor are also affected by annealing. The effect of annealing parameters on dynamic mechanical properties of FDM printed polymers are rarely studied, and this knowledge gap needs to be fulfilled. In this study, the effect of annealing parameters such as time and temperature on dynamic mechanical properties of FDM printed PLA is considered and reported

Keywords: *FDM, 3D printing, DMA, Annealing, PLA*

* * * * *

Study on Drilling of Additively Manufactured Inconel 718

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Abstract: Inconel 718 Ni-based super alloy was fabricated through selective laser melting (SLM) technique. Drilling operation was performed on the cylindrical component produced through SLM technique. During drilling process the thrust force was measured by varying the process parameters like drilling speed and feed rate. Near net shape component can be produced through SLM process and in case a need for additional machining operation like drilling is required for assembly purpose, this report will help to understand the behavior of the material and selection of optimum cutting parameters.

A case study is presented, with a view to understand the drilling operation on a Metal Additive Manufactured part analyzing the thrust force with respect to varying two

process parameters, i.e. feed rate and revolution of drilling bit, is studied and presented with the experimental results. A component with a hole of a particular diameter manufactured in an SLM process, the exact dimension of the hole is difficult to obtain because of the down skin/up skin melting zone which is inherent in this manufacturing process. Hence drilling operation needs to be carried out to get the hole with exact dimension and surface finish. This paper presents the optimum revolution and feed rate for desired dimensional accuracy and finish.

***Keywords**: SLM, Inconel 718, drilling of Inconel 718*

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Effect of Van Der Waals Force on the Powder Spreading in Powder Bed-Based Additive Manufacturing Process

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Abstract: The powder bed-based additive manufacturing techniques are used to manufacture intricate shapes with high mechanical strength. In these techniques, the components are fabricated through layer by layer spreading of powders, followed by sintering/melting of particles using a laser beam. The structural and thermo-mechanical properties of the finished components depend on the generation of the powder bed, heating sources, melting, and solidification rates of the particles. Therefore, the investigation of the above-mentioned aspects is crucial in producing high-quality parts. The present work analyzes the powder flow dynamics of the cohesive particles. At the microscopic scale, in addition to forces like elastic, gravitational, and frictional, particles also experience cohesive forces like van der Waals force. Therefore, the generation of powder bed needs to incorporate such cohesive forces to study the realistic behavior of the powder flow during the spreading process. The van der Waals force of attraction, along with the Hertzian contact force, has been incorporated in the contact model of the open-source DEM software LIGGGHTS to study the powder bed's dynamic behavior. The influence of van der Waals force is assessed using the ratio of net force (Hertzian contact force and van der Waals force) to the particle weight. The van der Waals force

increases with a decrease in the size of the particle, as shown in Figure 1. Therefore, smaller particles tend to form agglomerates due to higher van der Waals force. The powder agglomerations affect the uniform spreading of the powder leading to voids, thereby reducing the quality of the powder bed.

Keywords: *Cohesive particles, Discrete element method, Powder spreading, van der Waals forces*

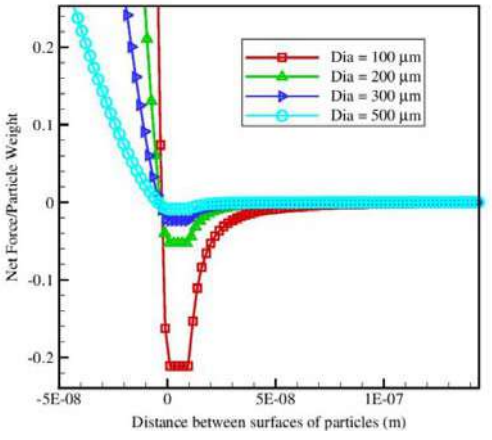

Fig 1: Net force/Particle weight vs distance between the surfaces of particles (for two particles collision)

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Extrusion Based 3D-Printing of Bioceramic Structures-A Review

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Abstract: Additive manufacturing (AM) is a recent efficient manufacturing technology for printing complex bioceramic parts with high dimensional stability, less time and low cost. Many research works have been carried out to unveil the printing mechanism of bio ceramic materials manufactured by AM processes. Among the different AM processes, direct ink writing (DIW) has gained attention among academia and industry because of its easiness and flexibility. Also there is no need of complex and expensive systems like laser source and powder bed. In the recent decade only limited articles have been

published on processing of bioceramics using DIW method. This article aims to review the development of bioceramic parts and effect of printing parameters on mechanical and biological properties. As such this survey provides delightful essence for the future researchers about the current status and printing challenges involved in DIW for biomedical applications

Keywords: *Bioceramics, Additive Manufacturing, Direct Ink writing*

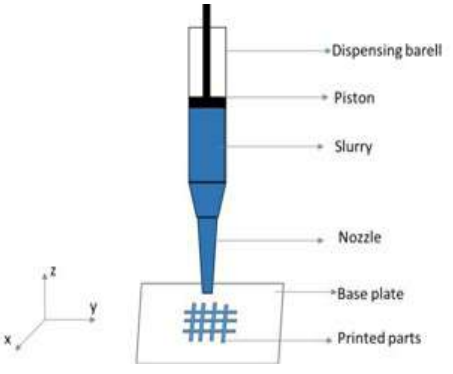

Fig.1 Schematic of DIW extrusion process

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Review on Performance of Various Materials for Energy Storage Device

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Abstract: Additive Manufacturing (AM) is the technique of fabricating three-dimensional products by depositing the material layer by layer process. It is a fascinating method to fabricate material directly which effectively differs from another manufacturing process. In this review article development of materials for EES devices was discussed. Carbon-based materials were commonly used in the energy storage device as an electrode material that has necessary characteristics, namely high conductivity, high discharge rate, and energy storage density. However, the development of carbon- and carbon-based material is highly challenging, and extended research is

required to find alternate materials for better performance in storing energy. The main aim of this article to explore different types available material which can be fabricated with additive manufacturing technique to achieve the required property like high performance, conductivity, high density & high discharge rate.

Keywords: *Additive Manufacturing, Energy Storage Device, Carbon Materials.*

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Multiscale Based Fatigue Life Prediction of Composite Wind Turbine Blade

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Abstract: Industrial applications on wind turbine blade involve cyclic-loading conditions which degrade the effectiveness of the structural components over the period due to the occurrence of fatigue failures. Thus, the understanding of fatigue life estimation is one of the critical design requirements which in turn improve the safety and reliability of the structure. This work aims at predicting the fatigue life performance of a large-scale, 10 MW, composite wind turbine blade on the application of extreme load conditions. The use of numerical multi scale approach for fatigue life prediction helps in reducing the number of experiments and thus able to acquire faster results. The blade is subject to unsteady aerodynamic forces due to the wind shear and the gravitational cyclic moment at the root. TurbSim generates a full-field stochastic wind simulation to be used for fatigue load prediction. The FAST program is used for predicting both the extreme and fatigue loads of the blade according to the wind status. FAST uses the Aero Dyn subroutine generate aerodynamic forces along the blade. The fatigue damage of fiber, matrix, and interface is calculated separately, and the blade fatigue life is estimated based on the most critical constituent fatigue damage. The effects of fiber angles, resin types on the 10MW wind turbine blade fatigue for Design Load Case DLC 1.2 and DLC 6.2 of IEC 61400-1 are studied in detail. Bi-axial composite laminates with thermoset (Epoxy) and thermoplastic (Elium) resins are considered for thorough comparative study. The effect of ply orientation and material symmetry of the wind turbine blade skin and spar cap is also analyzed. Reduced resin and interface damage

occur while using Elium as resin. The use of Elium resin is shown to be an effective way of enhancing the fatigue life of wind turbine blades

Keywords: *Fatigue Life prediction, Large-scale wind turbine blade, Micromechanics of Fatigue*

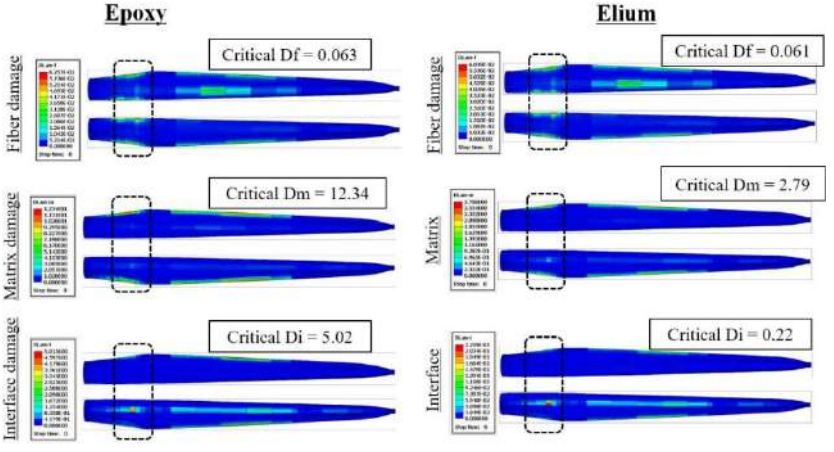

Fig 1: Damage contour of the wind turbine blade

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Numerical Investigation of Strain Localisation Effects on Additively Manufactured AlSi 10 mg under Tension with CPFEM Studies

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Abstract: Additive Manufacturing (AM) is rapidly taking over conventional manufacturing processes due to the ease of producing net shaped components. However,

its application to high end products is still limited owing to the relatively lessened properties of the end products. Detailed investigations have shown that the microstructural features such as grain size, morphology, secondary phases, etc. formed during AM have dominant influence on the deterioration of expected properties. This degradation can be partially eliminated by choosing optimal process parameters. Experimentally validated numerical models of AM processes and microstructural deformation can provide an amicable solution in optimizing AM processes to achieve desired design targets. The present work focusses on the development of a combined experimental and numerical approach to attain this objective. Specifically, the laser scanning strategy in Powder Bed Fusion (PBF) type of AM has been investigated in this work. It is well understood that the scanning strategy is an important parameter in this method and has profound effect on the microstructure leading to property variations. In this work, AlSi10Mg specimens fabricated with two different scanning strategies, X0 and X67, were investigated. EBSD analyses were performed to quantify the respective microstructures. The analyses showed that X0 has a heterogeneous grain size and shape distribution, while X67 has more homogeneous and equiaxed-shaped grains. Subsequently, tensile tests were carried out and X0 demonstrated a higher tensile strength while the elongation of X67 was found to be greater. Voronoi tessellated statistically equivalent microstructures based on EBSD analyses were then developed for X0 and X67.These microstructures were then used to perform Crystal Plasticity Finite Element Method (CPFEM) simulations to understand the role of microstructure on localization. At first the CP model parameters were evaluated for X0 and X67 specimens using genetic algorithm based optimization where the L_2norm of error between the experimental and simulated stress vs strain curves was used as the objective function.The calibration process showed that certain variations in the model parameters, irrespective of grain morphology, exists. Subsequently, the microstructural distribution of maximum principal stress, effective plastic strain and plastic work were compared to understand the early failure of X0 specimens. The analyses revealed that X0 specimen has more severe localized response than X67 specimen which may explain this behaviour.

Keywords: *Additive Manufacturing, Crystal Plasticity, AlSi10Mg, Scanning Strategy, Strain localization*

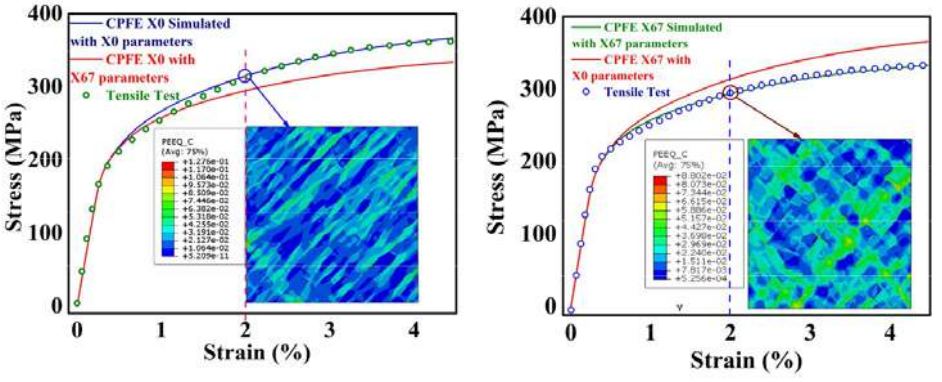

Fig. 1 Plastic Strain distribution analysis of X0 with CPFE with CP parameter sensitivity Fig. 2Plastic Strain distribution analysis of X67 with CP parameter sensitivity

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Pressure-Impulse Diagrams for Paper Honey Comb Core Sandwich Panel using Numerical Method

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Abstract: The threat of increased industrial accidents and terrorist activities demands protection of structure against blast loading. The pressure-impulse (P-I) diagrams, also called iso-damage curves, indicates damage level in a structure. P-I diagrams are divided into three loading region i.e. impulsive zone, dynamic zone and quasi-static zone. These diagrams are useful in the initial assessment of the structure to find the damage. In the present investigation, P-I diagrams for sandwich panel with steel face- and back-sheets and paper honeycomb core are developed. The sandwich panel are made of face- and back-sheets and paper honeycomb core of size 400 mm × 400 mm. Thickness of face- and back-sheets is 2 mm and depth of honeycomb core is 57 mm. The numerical approach is used to get series of pressure and impulse points for a particular damage level. The damage criteria considered, in the present study, is the maximum back-sheet deflection, wherein core crushing is limited to 5 mm. Sandwich panel with paper honeycomb core is modelled in ABAQUS/Explicit® and blast load is applied for range of loading using CONWEP formulation. The common types of failures observed in honey

comb sandwich panel are face-sheet bending, core crushing and face-sheet de-bonding. The de-bonding of face-sheet from core is not considered herein. However, core crushing and face-sheet bending failure modes are considered in this investigation. Based on the analysis, P-I diagrams are developed for da mage levels of 1%, 1.5%, 2%, 2.5% and 3%. It is observed that as the damage level increases, P-I diagrams shifts upwards. Hence, based on the P-I diagrams obtained and available values of pressure and impulse acting on sandwich panel, the damage level of sandwich panel can be evaluated.

Keywords: *Blast, Sandwich Panel, P-I Diagram, Paper Honeycomb*

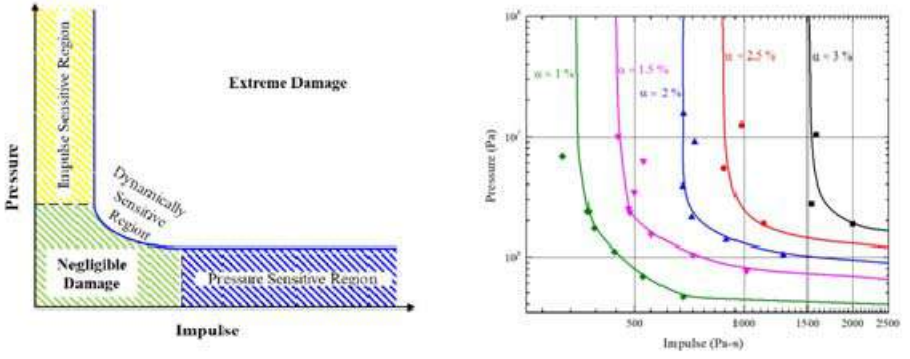

Fig. 1 Pressure-Impulse Diagram with Damage Regions and Developed Pressure-Impulse (P-I) Diagrams for Paper Honeycomb Core Sandwich Panel

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Mechanical Behaviour of Biomaterial with Special Reference to Finite Element Method

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Abstract: There is an ever increasing demand of novel biomaterial used as implants and equipment due to the continuous advancement of technology in the medical field. Biocompatibility is the prominent feature accompanied with the use of biomaterials in medical device. In addition, investigation of mechanical behavior of biomaterials is

another very important parameter. Hence it is very important to analyze the mechanical property of the biomaterials before being utilized in the medical implants. The properties required to be estimated includes performance under the applied load, fatigue strength, fracture behavior and bending properties. Experimental methods are quite expensive and require more time to determine the mechanical properties as compared to the Finite Element Methods (FEM). Finite Element Method is a computational analysis method that extends its usage from medical device to biomaterials and to estimate designs in sequestration of tissues. Finite element simulation enables to identify the fracture through deformation in biomaterials. In recent years, various modelling and simulation of biomaterials has been investigated through FEM in the field of biomechanics. FEM has been extensively used to recognize a high stress zone area which facilitates implant design and to imitate the micro structure of substance. The present paper reviews the application of FEM for simulating and determining the mechanical properties of biomaterials (Fig.1). It also present the state of art on FEM application in fields related of mechanics of biomaterials including stress and deformation analysis, elastic modulus, fracture analysis and determination of micromechanical properties. Finally the future scope of the study based on the extensive review is reported for the researchers working in the field of biomaterial.

Keywords: *Biomaterials, Mechanical Properties, Finite Element Method*

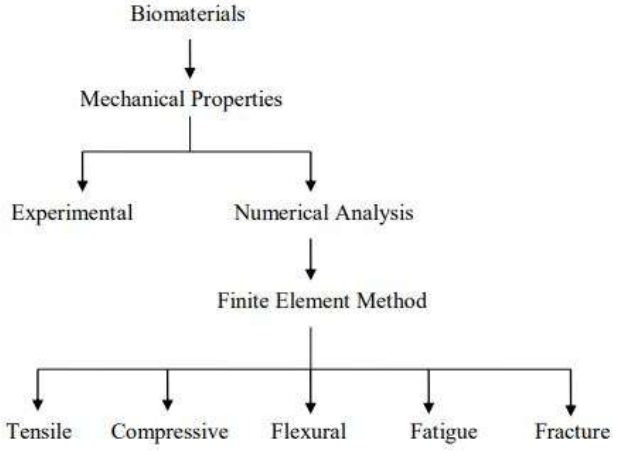

Fig. 1. Methodology adopted for review of biomaterials using FEM.

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Effect of Cell Geometry on the out of Plane Response of Aluminium Honeycomb using Finite Element Method

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Abstract: Two-dimensional cellular structures - honeycombs are known to exhibit high compressive strength and energy absorption in out of plane compressive loading. The energy absorption capability of impact crushing of these structures is affected not only by the mechanical properties of the honeycomb but by the geometric structure of the honeycomb cell as well. In the present study, a finite element (FE) framework is utilized for the comparison of the peak collapse stress, mean plateau stress, and densification strain for different cell shapes of aluminum honeycomb core under impact loading. In addition, the results are related with the deformation mechanism involved with the change in cell shape. Non-linear dynamics software LS-Dyna is used to develop an explicit code framework for the simulation which is validated using compression test results on a thin-walled hexagonal honeycomb of aluminum. The thin-walled core of the honeycomb is modeled as a deformable body with shell elements, while the crosshead is modeled as rigid bodies, which strikes the honeycomb core with a velocity ranging from 5 m/s to 10 m/s. The cell shapes which are commonly used in sandwich panels like the regular hexagonal honeycomb-square, triangular, and square are studied for similar relative densities. It is observed that the triangular cell shapes are the stiffest while the hexagonal honeycomb has high energy absorption.

Keywords*: Aluminum honeycomb, Impact loading, Plateau stress, Finite element framework*

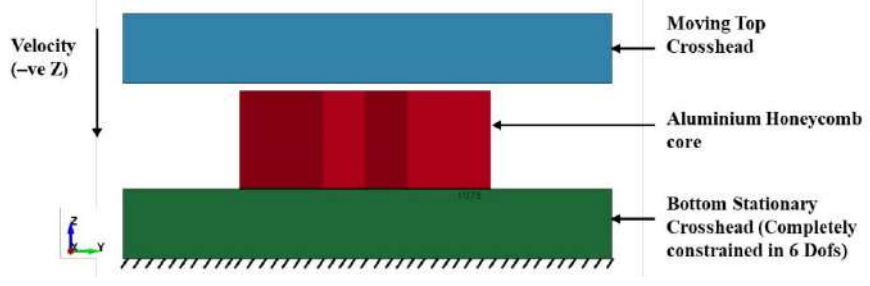

Figure 1. FE Setup and Boundary conditions

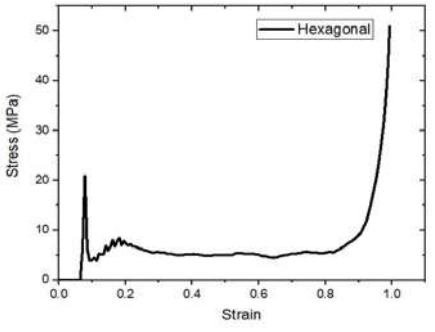

Fig 2. Stress Strain curve of Al honeycomb with hexagonal cells

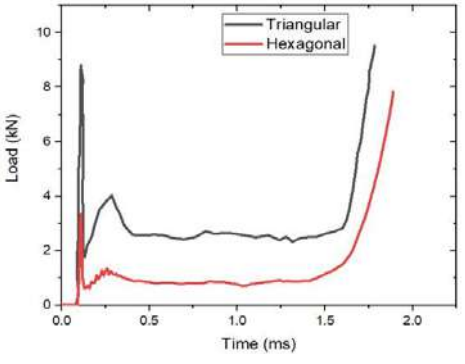

Figure 3. Comparison of impact response of Al honeycomb for hexagonal and triangular cells

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The Unprecedented Role of 3d Printing in Fighting the Covid-19 Pandemic: A Comprehensive Review

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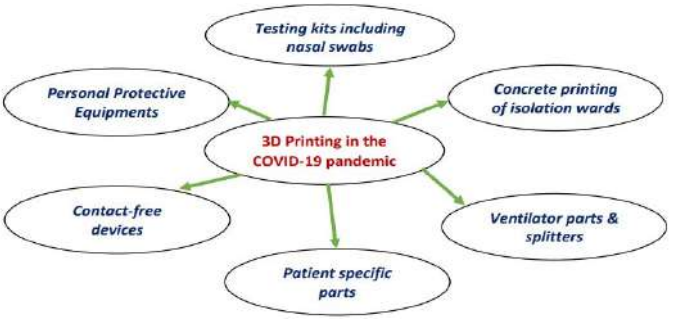
Abstract: The COVID-19 has spread to over 180 countries and has abruptly disrupted the production-rates and supply chains worldwide. Since then the 3D printing/additive manufacturing, known as a novel technique that uses layer by layer deposition of material to produce the complex 3D model, has been engaged in reducing the distress

caused by the outbreak. During the early stages of this pandemic, shortages of the Personal Protection Equipment (PPE), including face shields, face masks, respirators, and medical gears, were significantly answered by remotely 3D printing them. Amidst the growing testing requirements, 3D printing has emerged as a potential and fast solution manufacturing process due to its flexibility, reliability, and rapid response capability to meet the production requirements. In recent times, 3D printed ventilator parts, splitters, and patient-specific products are some of the other medical applications that have gained prominence in the scientific community. Regarding the non-medical applications, researchers have successfully developed contact-free devices by employing Fused Deposition Modelling and other techniques to address the sanitary crisis in public places. Few attempts have been made in the direction of 3D printing the isolation wards and quarantine shelters. This work aims to systematically review the applications of the additive manufacturing techniques involved in producing various critical products essential to limit this deadly pandemic's progression.

Keywords: *3D Printing, covid 19, Corona Virus, Pandemic*



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Micromechanical Analysis for Prediction of Failure in Calcified Abdominal Aortic Aneurysm (AAA)

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Abstract: The aorta is the largest artery in the human body. Abdominal Aortic Aneurysms (AAA) are an abnormal enlargement of weak sections in the aorta, which can lead to serious complications due to its rupture. Calcification of AAA is a known issue

and its effect on the rupture is not very well understood. The objective of the present work is to study the effect of calcification on the failure of AAA using micro-mechanical finite element analysis. A unit cell consisting of calcium particles embedded in arterial walls is considered. Calcium particles are modeled as stiff elastic inclusions that are randomly distributed with a certain volume fraction. The arterial wall is modelled as an anisotropic material and its failure is described by a phase-field model given by Gültekin et al. (2016). The unit cell is subjected to biaxial loading with different stretch ratios in two directions. The objective is to generate a failure envelope for calcified AAA. Effect of factors such as the extent of calcification and shape of inclusions on the failure envelope as well as failure behavior of arterial wall will be studied. This analysis will help with better prediction and understanding of rupture of calcified AAA.

Keywords: *Aneurysm, Anisotropic material, phase-field*

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Application of 3D Concrete Printing in Construction of Isolation Wards and Quarantine Shelters to Fight the Covid-19 Pandemic: An Explicit Review

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Abstract: The food, shelter, and medicine supply chains have been abruptly disrupted due to the COVID-19 outbreaks, which has spread to over 180 countries. According to evidence, coronavirus disease is primarily being transmitted between people through respiratory droplets and contact routes. As a safety measure, the health and civic authorities worldwide have worked towards the isolation of COVID-19 patients and prone health-care workers to contain the outbreaks. This has led to an unprecedented high demand for isolation wards and quarantine shelters in various parts of the world. 3D printing or additive manufacturing is the technique that uses layer by layer deposition of

materials to produce the desired 3D model. The recent trends in 3D printing include its advent in construction technology. The 3D printing using concert and cob (an earth-based material) has proved its superiority over conventional construction methods. The primary advantages include rapid response, on-demand manufacturing, and overall time required to construct shelters (A 350 sq. ft. shelter can be built in a week). Many attempts have been made in the direction of developing 3D printed isolation wards for coronavirus patients and medical staff. This work aims to systematically review the applications of 3D printing technology to construct sustainable isolation wards and shelters for tackling the COVID-19 pandemic. This study also compares and reveals the significant advantages and challenges in relying on 3D concrete printing to remotely construct isolation wards and quarantine shelters, over the conventional construction techniques.

Keywords: *3D Printing, Construction Technology, COVID-19 pandemic, Isolation ward, Quarantine Shelter*

Fig. 1 (a) Concrete 3D Priniting Nozzle (b) 3D printed isolation wards for COVID-19 using concrete [Courtesy: Winsun 3D Printing].

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Targeted Delivery of Insulin Loaded Solid Lipid Nanoparticles to the Lung for Diabetes Treatment via Inhalation

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Abstract: The traditional subcutaneous insulin administration is painful and discomforting as it requires multiple daily injections. This lead to the expanded research to develop different insulin administration route for better treatment options. The

pulmonary route of administration proves to have improved patient compliance and rapid absorption of drugs because of rich blood supply and a large surface of lungs. This study aims to evaluate the targeted pulmonary delivery of insulin nanoparticles via the inhalation method. Insulin loaded solid lipid nanoparticles (SLN) were prepared by double emulsion method using Witepsol (W) and Softisan (S) lipids. The lipid phase was prepared by dissolving the lipid in dichloromethane and the aqueous phase contains tween 80 and sodium deoxycholate solution. The lipid and aqueous phase homogenized together to prepare the insulin nanoparticles. The prepared particles were characterized for their size, zeta potential, uniformity of nanoparticles, encapsulation efficiency XRD, FTIR and release profile. The size distribution of inhalable particles was demonstrated by 8 stage Cascade impactor. The size of the insulin loaded nanoparticles was in the range of 282±4.74 to 330±3.15 nm with zeta potential of - 23±2.186 to -40±3.20 mV and PDI 0.134 to 0.259. The mass median aerodynamic diameter (MMAD) and Fine Particle Fraction (FPF) of W nanoparticle was 3.13±0.74, 64.86±9.13% and 3.09±0.76, 67.60±8.02 respectively. The encapsulation efficiency of insulin loaded into the nanoparticles was found in between 70±1.09 to 72±1.08 %. The XRD studies of W and WS nanoparticles showed average crystallite size of 29.21 and 26.81 nm respectively. In the release study, the W and WS nanoparticles showed about 10±3.46, 20±1.60 % burst release and 26± 3.87%, 45± 2.90% controlled release in 48 hours respectively. The aerodynamic properties of nanoparticles were found to be appropriate foe inhalation delivery. The future research includes evaluation of functional efficacy of insulin SLN in in vivo animal model.

Keywords: *Insulin, Diabetes, Inhalation, solid lipid nanoparticles*

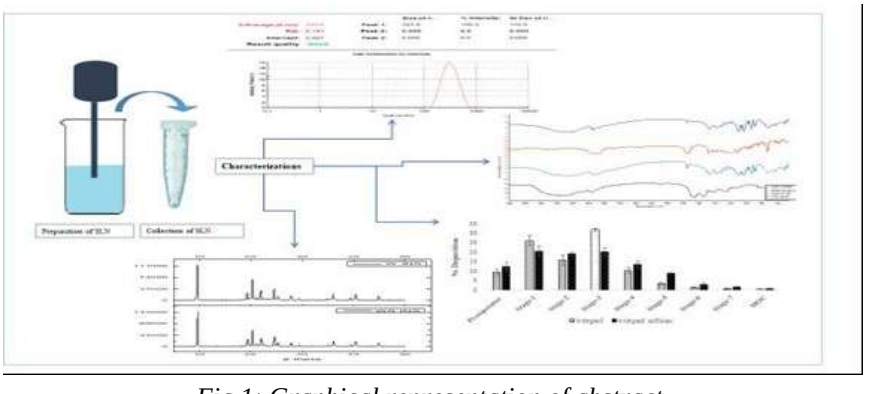

Fig 1: Graphical representation of abstract.

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Computational Study of Primary Orthopaedic Lateral Blast Injuries on Lower Extremity

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Abstract: The effect of a blast pressure wave interacting with tibia from a lateral side and its corresponding primary orthopaedic injuries were studied by Hull (Hull 1995). Hull demonstrated that the most common injury for a lateral blast is an oblique fracture on the tibia proximal end, which conforms well with the clinical lateral blast injury pattern reported in the field hospitals. In this research work, these studies have been used as a basis to characterize primary blast orthopaedic injury patterns on the tibia. The Multi-Material Arbitrary Eulerian-Lagrangian approach (MM-ALE) is used for near field cases where CONWEP yields inaccurate results. A coupled CONWEP and MM-ALE approach has been used for far-field studies where using the MM-ALE approach only increases analysis time due to the large air domain. Lateral blast scenarios are analyzed at various scaled distances (0.25 to 1.00 m/kg$^{1/3}$) by varying the charge mass and stand-off distance to study the response of tibia and associated injury patterns. Simulation results show that lateral blast causes a differential motion between the ankle and tibia femoral joint, causing micro-fractures and an oblique fracture at the tibia's proximal end. The predicted injury patterns agree well with the findings by Hull (Hull 1995). Tibia's maximum principal stresses, peak pressures are compared for various scaled distances from the lower extremity, and no failure zones are identified. Various computational studies are presented to identify different lateral blast parameters' impact on lower extremity skeletal injuries.

Keywords: *Lateral blast, Orthopaedic injuries, Tibia, LS Dyna*

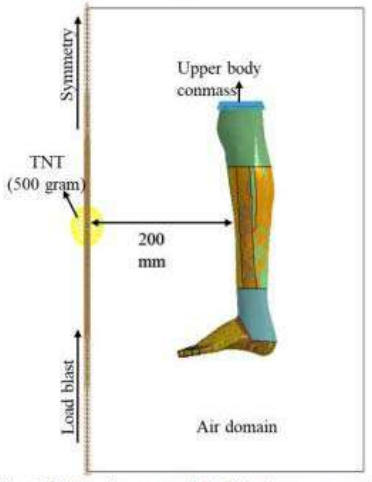

Fig. 1 Finite element model of the lower extremity for lateral blast scenario (MM-ALE approach)

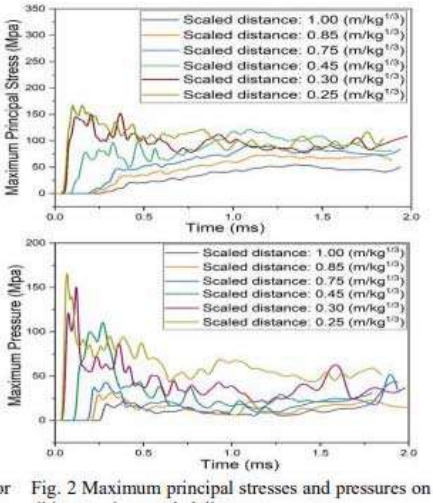

Fig. 2 Maximum principal stresses and pressures on tibia at various scaled distances

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Eco friendly Sisal Fiber /Poly Lactic Acid Composite Material for Thermal Insulation Applications

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Abstract: In India the share of residences electricity consumption rises from 46% in 2015 to 68% in 2040 of total energy consumption. Investigators are interested in the development of biodegradable thermal insulating materials to reduce energy consumption. The main objective of this study is development of eco-composites using biodegradable sisal fiber and polylactic acid (PLA) for thermal insulation applications to reduce energy consumption with significant ecological advantage. Composite samples of 50 mm in diameter and 10 mm in thickness were prepared using compression moulding technique. The thermal conductivity of samples was measured using guarded heat flow thermal conductivity meter as per ASTM E1530. The effect of fiber content and

temperature on thermal conductivity of composites was studied. The results revealed that as sisal fiber content increased from 0 % to 30 % (weight basis), thermal conductivity of composite decreased from 0.164 W/(m.K) to 0.148 W/(m.K). The insulation capability of composite at maximum fiber content was 9.75 % higher than plain PLA. As temperature of composites increased, the thermal insulation of composites decreased as shown in figure1.

Keywords: *Thermal insulation, Biodegradable materials, Poly latic acid, Sisal fiber*

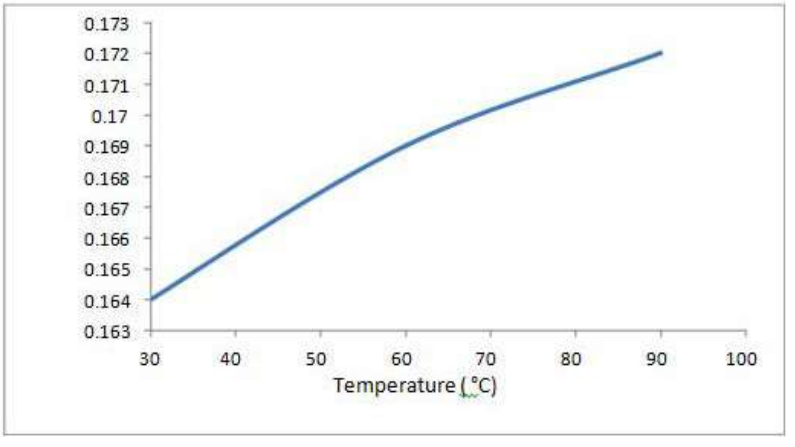

Fig.1. Effect of temperarture on thermal conductivity of sisal fiber/PLA composites

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Variability of Geometric Parameters and Their Effect on the Fibre Stresses in Unidirectional Composites

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Abstract: A limiting factor for unidirectional (UD) composites is often the response to transverse loadings. Due to the random spatial locations of the fibres, different fibres are stressed differently when subjected to loading in the transverse direction. The inter phase of the fibres with the highest stress are often the critical regions where damage initiates. While there are analytic means to estimate the average stresses over the entire fibre phase, models for predicting the stresses in individual fibres are not yet developed.

In this paper, three scanning electron microscope images of unidirectional composites are translated into finite element models and the average stresses in each individual fibre is determined. The immediate neighbourhood of each fibre is characterized by different parameters such as distance between the nearest neighbours, angle between the nearest neighbour, orientation of the line connecting the centre of two nearest neighbour and local fibre volume fraction. The average stress in each fibre is correlated with the different parameters. It is concluded that the average fibre stresses depend on the immediate neighbourhood in an average sense, but the influence of the individual parameters is not straight forward. There is mild dependence on the different parameters with significant outliers. Inspection of the location of the fibres with highest stress led to notable insights which can aid understanding of how UD composites fail under transverse loading.

Similarly, for the matrix, the region with the highest fibre content does not necessarily lead to the highest matrix stress. We conclude that the fibres with highest average stresses and the regions with highest matrix stresses are difficult to determine and cannot be simply correlated with parameters like nearest neighbour distance, or local fibre volume fraction. Future scope of work involves use of machine learning algorithms to correlate the fibre stresses with the different geometric parameters.

Keywords: *Stochasticity, Finite element modelling, Unidirectional composites, Geometric characterization*

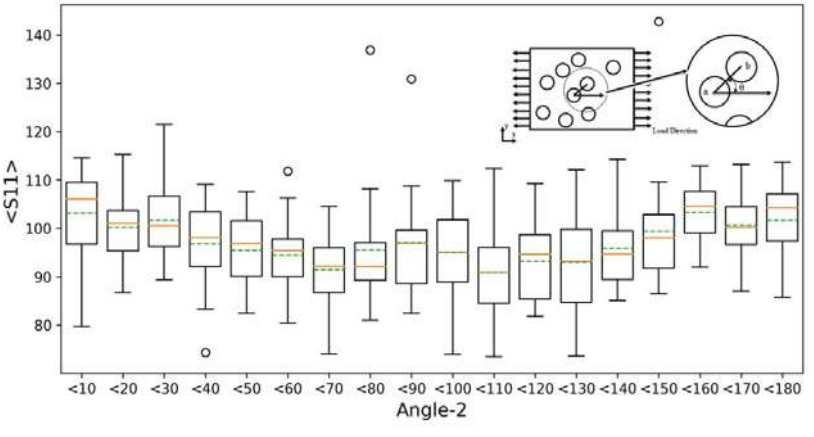

Fig 1:Variation of the average stress in a fibre and the angle between centre of two nearest neighbour andthe loading axis

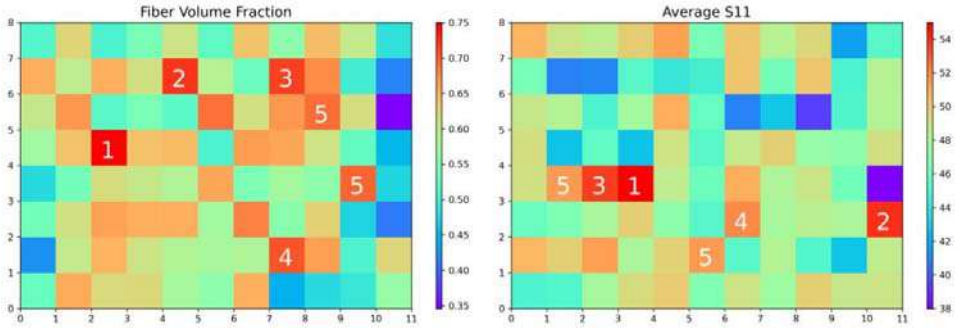

Fig 2:Comparison of the regions with highest fibre content and highest average matrix stresses, thenumbers in the box indicate the rank of the region with respect to the fibre volume fraction (left) and average matrix stress (right)

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Potential of Graphene Reinforced Geopolymer Composites towards Circular Economy and Sustainability

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Abstract: Many of today's most utilized structural materials have confinements, particularly concerning their impact on the environment due to which there is always a need for a more advanced eco-friendly material. These construction materials have to showcase enhanced durability and mechanical performance and have to integrate functionalities that would satisfy multiple needs to be suitable for emerging construction applications while supporting sustainable development. Geopolymers are one such novel eco-friendly construction materials which are made up of aluminosilicate industrial waste such as fly ash, ground granulated blast furnace slag (GGBFS), ferrochrome ash (FCA), rice husk ash (RHA), silica fume, etc. along with an alkaline solution composed of sodium hydroxide and silicates. Implementation of geopolymer composites (GC) can support achieving sustainable waste management leading to the accomplishment of a circular economy. The incorporation of nanomaterials in geopolymer composites has

been recognized as a feasible technique to enhance its properties. There is a wide consensus in the research community that geopolymer composites which are also called green composites are the next face of the construction material industry and have to be engineered at the nanoscale, where it's chemical and physio mechanical properties can be truly enhanced. Graphene, a nanomaterial derived from graphite has been proved to enhance various crucial properties when combined with geopolymer composites. This paper discusses the significant benefits of graphene reinforced geopolymer composites while promoting the circular economy. An exclusive review of graphene implementation on geopolymer composites concerning their enhanced properties is provided, which could lead a long way in creating a more smart and sustainable future.

Keywords: *Graphene, Geopolymer, Waste Management, Nanomaterial, Sustainability*

* * * * *

An Experimental Investigation on Adhesivity of Modified Epoxy at Different Curing Temperature

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Abstract: Experimental results have shown that there is a substantial change made by the addition of reinforcing materials. The significant variation of the reinforcing materials was also analysed and its effect on the strength of the aluminium lap joints was taken into consideration. For the aluminium lap joint, this study was carried out by applying many reinforcing materials to the epoxy, then testing the tensile strength. The reinforcement materials include at different concentration epoxy hardener, nano clay, pineapple leaf fibre. The clamping was carried out on standard samples of 250 mm long, 25 mm wide and 3 mm thick aluminium rectangular plate. The results obtained indicate that by adding the reinforcement materials at different curing temperatures where the bond strength was greatly increased. The optimum improvement obtained with the rough joint of specimen aluminium plates using epoxy mixtures. Using adhesive bonding methods, the samples of aluminium plates were joined by pouring the resin between the plates. The samples prepared have been characterized and the findings have been recorded. NE's adhesive intensity for "rough sample" has improved by up to 63.34 % over the normal sample, 60.25 % over the smooth sample, 7.2 % over the room

temperature of the normal sample. The surface roughness (i.e.: regular, smooth, rough) and curing temperatures (i.e.: room temperature and 100° C) differ between all specimens. Using the load-displacement diagrams, the results of lap adhesive strength measurements of tension on bonded joints prepared with epoxy containing different fillers in this experiment**.**

Keywords: *DGEBA, Nano clay, Pineapple fiber*

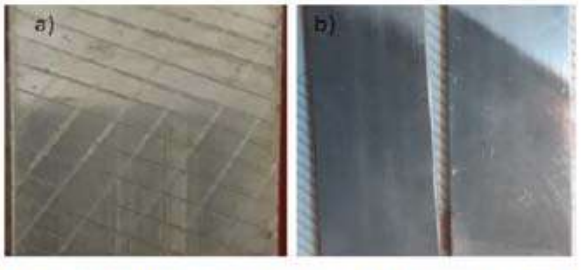

Fig -1: Aluminium plate a) Rough sample b) Smooth sample

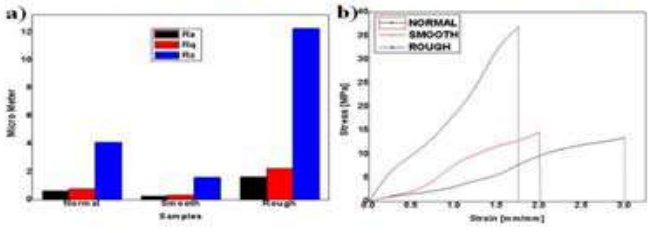

Fig.1 a) Bargraph representation of average roughness value for sample set-1, b) Stress Vs strain curve for NE

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A Study on Mechanical Properties of Aluminium Hybrid Nano Composites – A Brief Review

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Abstract: Work in the field of nanocomposites has been significantly increased over the last ten years. Researchers and scientists have discovered that at the most fundamental

level & at the nano scale, the tribological & mechanical properties can be modified. Aluminium hybrid nano composites are a latest era of MMC's with the ability to meet the current requirements of today's industrial applications. Such requirements are fulfilled because of enhanced properties, convenience of modern processing techniques and the possibility of the cost of producing hybrid composites. The output of such materials depends mainly on the selection of the appropriate mixture of the reinforcement particles, as most of the process variables are correlated with the reinforcement of the particles. Nano sized reinforcements improve the aluminium matrix properties compared with micro sized reinforcements. Hybrid reinforcement impregnates aluminium matrix composites with superior properties compared to aluminium composites with single reinforcement. This paper seeks to examine the various combination of reinforcement and the effect on the material tribological & mechanical properties and also focuses on summary of AMCs based on nano & hybrid aluminium. The aim of this work is to compile and link literatures on various fields of nano composites development and applications, with the goal of contributing to a broad perspective on various aspects of the processes and the theories of nano composites, thus helping to ease and lift nano composite development and study to a greater level

Keywords: *Nano composites, Aluminium matrix, MMCs*

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On the Advantages of Thermoplastic Composites for Impact Applications

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Abstract: Advanced composite materials are widely used in the aerospace industry due to its high stiffness and strength-to-weight ratios, and inherent anisotropy, which provides elastic and mass tailoring abilities for structural component design. However,

complex test programs are necessary to fully characterize the material and the failure modes. The use of Methyl Methacrylate (MMA) thermoplastic resin can reduce the component carbon footprint, while achieving better impact performance. This environmentally friendly thermoplastic matrix has become an attractive alternative for thermosetting matrices concerning its recyclability, high impact and damage tolerance properties, and ease and efficient processing and manufacturing. Thermoplastic resin systems can undergo more deformation thanks to their viscoelastic response, presenting less impact damage as compared to their thermoset counterparts. Composite impact properties can be obtained by means of a drop weight impact test (Fig 1) which consists in a concentrated load by dynamically applied to a specimen using an impactor drop device. Impact damage and mechanical properties can be then measured. Thus, the objective of this study is to evaluate the effects of low velocity impact damage in composite laminates and further after-impact loading schemes, focusing in the Compression After Impact (CAI) problem. Numerical analyses were performed using 3D finite elements models with inter-ply surfaces connected by cohesive elements (Fig.2). Predictions were compared to experimental test data results for each material application. Impact analysis, focusing in CAI was studied for thermoplastic and thermoset matrices, using carbon, glass and carbon-glass hybrid fibre reinforcements. Thermoplastic composite panels presented less impact damage when compared to thermoset composite panels, leading to smaller stiffness degradation and greater residual strength. In addition, glass-laminated specimens present less impact damage than carbon, while hybrid showed a trade-off between impact and loading carrying.

Keywords: *Methyl Methacrylate, Advanced composite materials, impact performance*

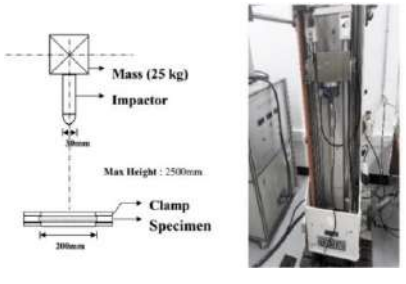

Fig. 1 Impact Drop Tester (ITOH SEIKI Co.Ltd.)

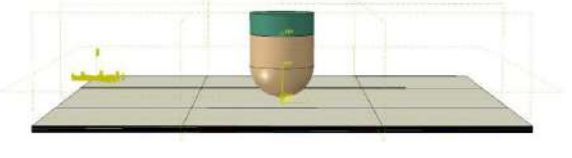

Fig. 2 Proposed numerical model

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Idiomatic Expression of Aluminium /Tin Electrode Materials Using Thermal Behavior of Battery Energy Storage System

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Abstract: The growing lithium-ion battery industry is constantly looking for new materials that meet the production and retail needs of the global renewable energy industry. In particular, a new novel electrodes material is needed for battery systems that can be used as renewable energy for the next decade without the emission of plug-in hybrid electric power cars. However, the historically used graphite anode material could meet the new energy and power density requirements. But new emphasis focuses on the metallic materials (anodes) such as silicone and tin. This study is one of the most exciting electrode materials of aluminium and tin, characterized by thermodynamic prosperity, such as electron current density distribution, actual resistance, specific heat, kinetic/potential energy conversion to build and discharge the proper thermal behaviour of the battery using the finite element method. Based analysis and simulation results show the surface rate of discharge curve at 1C has been changed at maximum and minimum temperature conditions respectively in the battery energy storage device.

Keywords: *lithium-ion battery, cathode, anode, aluminium, Tin, Multi-Scale Multi-Dimensional (MSMD), NTGK battery Module, discharge rate.*

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Numerical Simulation of an Impact Damper System by Finite Element Method

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Abstract: Impact dampers are passive devices used to attenuate vibrations by means of momentum transfer and dissipation of energy. This paper deals with investigations

carried out to evaluate the damping ratio of an impact damper system for case without and with impact ball of same size made of different materials. Finite element modelling of the system is carried out using ANSYS FEA (finite element analysis) software. Simulation studies are carried out using Augmented Lagrangian Multiplier (ALM) contact algorithm to obtain the transient response of the system. The transient response of the system is evaluated from the forces generated due to impact of ball on the primary system. Theoretical studies are carried out with impact mass placed at tip of cantilever beam by varying base excitation frequency in vicinity of systems fundamental frequency to obtain the frequency response curve. The response curves thus obtained with impact mass made of different materials show that damping achieved with higher impact mass is very effective in attenuating the vibration response. Results from simulation studies show good agreement with experimental data. The effect of damping with different mass ratio is also investigated.

Keywords: *Impact Damper, Magnification Factor, Damping Ratio.*

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Interaction of Structures with Near Field Detonation: Effect on Shock Wave Pattern and Overpressure Profile

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Abstract: During a detonation of high energetic material in the air, the spherical shock wave is generated with a peak overpressure corresponding to the Friedlander curve. The peak overpressure changes when the detonation of the charge is buried under the soil (e.g. land mine detonation). The differences in peak overpressure as well as in the distribution pattern are observed when both the situations (buried and not buried under the soil) are considered. The changes are more significant in the case of the near field scenario (scaled distance < 0.2 m/kg$^{1/3}$) when compared to the far-field scenario (scaled distance > 0.2 m/kg$^{1/3}$). The shock wave pressure distribution in the near field gets further affected when the target objects (a structure, a person, or both) are interacting with detonation. The structures could be protective equipment or standard equipment,

which on interacting with the detonation changes shock wave pattern and alter the overpressure experienced by one another. Also, based on the shape and size of the structure the value of overpressure and pattern exposed to the person could be different. The current numerical study summarizes the effect of introducing a structure in a near field scenario when the detonation of a charge is buried under the soil. The study is performed using a simulation technique called MM-ALE (multi-material arbitrary lagrangian eulerian) available in commercially available software, LS-DYNA. A numerical simulation of detonation event has been performed by introducing different objects into the near-field and variation of peak overpressure in the close range is plotted for comparison. It has been found out that the predicted pattern of the overpressure is agreeing with the Friedlander curve.

***Keywords**: Overpressure, Scaled distance, Friedlander curve, Near field, MM-ALE*

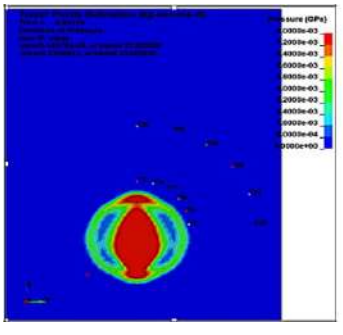

Fig. 1 Pressure profile at 0.03 ms free air detonation: Cut section at centre in 3D FE Simulation plot

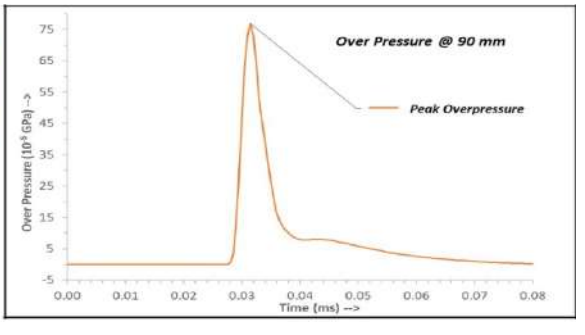

Fig. 2 Positive phase of over pressure observed at 90 mm from the detonation point in a free air detonation simulation

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Design and Analysis of a Hyperelastic Viscoelastic Vibration Isolator under Shock Load

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Abstract: Scientific and technological advancement in recent years have led to the opportunity to build a large and powerful machines, high precision manufacturing equipment and systems with fine-tuning. Despite the difference in size of these machines

and equipment they have the same problem - vibration. Machines are becoming more powerful and more compact, and this inevitably leads to increased equipment vibration. They could be beneficial or detrimental. Vibration isolation is a procedure by which the undesirable effects of vibration are reduced. Isolation mounts reduce the transmission of energy from one body to another by providing a resilient connection between them. Vibration isolators of marine engines have serious size requirements, and at the same time high vibration isolation parameters. Therefore researchers develop semi-active and active techniques for controlling low frequency vibrations. However these techniques are complex and costly. Achieving low natural frequency for the isolator is observed to be difficult, keeping the required load bearing capacity. A system with quasi-zero stiffness allows to obtain simultaneously high static load and low dynamic stiffness various elements leads to design complexity and high friction. So for to be economical, there arises the idea of single material vibration isolator. In this paper a single dome shaped vibration isolator made up of hyper elastic viscoelastic material (polyurethane) is subjected to shock loading. This is analyzed numerically using ANSYS software. Design based the stress limits are considered for the numerical study. Mesh convergence study is also carried out for the numerical analysis.

Keywords: *Vibration isolation, Hyperelastic, Viscoelastic*

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Investigation of Debris Impact on Reflector Tension Forces of Inflatablle Planar Membrane Antenna

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Abstract: The inflatable structures are the potential solution for the near term space missions due to their advantages such as higher packaging efficiency, low on-board volume requirement and ease of deployment. The planar membrane reflector is attached to the torus with the help of a connecting system. The connecting system gives the predefined amount of tension force to the reflector to maintain the predefined value of stresses. The tension force is the contributing factor for the shape accuracy of the membrane structure. The debris impact on the radio-frequency zone of the membrane

reflector will change the reaction forces on the supporting structure of the reflector. The present study investigates the effect of debris impact on the tension force at the anchor point of the reflector. Fig. 1 shows the geometry configuration of the planar membrane reflector. The numerical investigation of the impact loading is carried out in ABAQUS software. The rectangular membrane reflector is modelled using S4R5 thin shell elements. The Kapton is used as a torus and reflector material. The different sizes and shape of the debris particle are used for impact study. The numerical simulation result on the cylindrical shape debris particle is shown in Fig. 2. The study details the numerical approach for a debris impact study on inflatable planar membrane reflector. The allowable deformation of the supporting structure is also studied for different impact velocities. The findings of this investigation will serve as an input for designing the connecting system and support structure of the membrane reflector.

Keywords: *Planar membrane reflector, Impact, tension forces*

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Multi-Material System Response to an Impact-Induced Shock

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Abstract: High-velocity impacts, where strain rates is of the range of 10^3 /s or more, result in the generation of shock waves. The response of layered composites to shock is studied analytically through a periodically layered material system consisting of alternating isotropic material. Chen has found the analytical solution to the plate impact on the periodically layered material system. Chen has found the stress profile in the material by treating the impactor and target as semi-infinite. In this work, impact-induced shock wave propagation in a multi-material system has been considered, with finite impactor and target. Individual interactions of wave with material interface and wave with another wave have been considered. The material is in the state of uniaxial strain and behaves in the manner, as shown in Fig. 1(a). The real material behavior has been simplified in order to avoid rarefaction fan and to make it more feasible to track each wave and their interactions. Impactor has been considered as perfectly elastic, and the target is modeled behave as in Fig. 1(b). Governing equations have been considered

from Davison. A Matlab code has been written which tracks each wave and then finds the interaction which happens in minimum time and then update the waves in the system. Each wave has stress, strain, particle velocity associated with it. In Fig. 2, the material with a longer yielding part is more compressible. In the target shown in Fig. 2, A, B,C,D have increasing compressibility from A to D. The higher the material is compressible, the lower is the impedance to the shock wave. The X-t diagram in Fig. 2 shows the interaction of shock and elastic wave with material interfaces and with each other. Tracking each wave, the stress, strain, and particle velocity state in each material is determined.

Keywords: *High-velocity impact, Shock wave, Material Heterogeneity, Impedance Mismatch.*

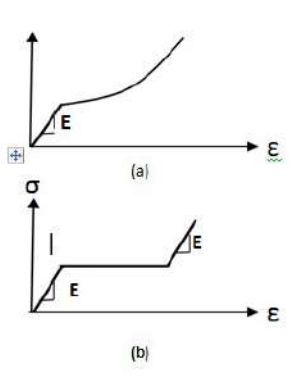

Fig. 1 Material Behavior (a) Real (b) Simplified

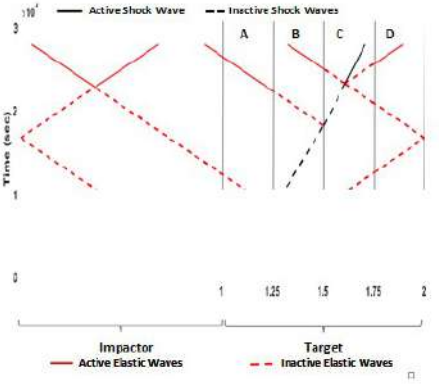

Fig. 2 X-t diagram

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Modelling of Close/Contact Range Blast on Aluminium Honeycomb Structure using Finite Element Method

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Abstract: The study on the finite element (FE) prediction of the peak overpressure under free air blast loading has been well established for the very far-field range (i.e. scaled

distance greater than 0.35 m/kg$^{1/3}$). However, it is very difficult to determine the peak overpressure for a very close-range to contact range (i.e. scaled distance from 0.06 to 0.30 m/kg$^{1/3}$), due to the experimental limitations. Also, the empirically determined peak overpressure for the close-range/contact range is not valid due to the complex physics involved in the blast. In this work, the FE methodology has been used in LS-DYNA and ANSYS/AUTODYN softwares to determine and understand the peak overpressure under free air blast loading for the scaled distance in the range of 0.06 to 0.30 m/kg$^{1/3}$. Also, we know that most of the structures are not designed for the close-range to contact range blast events because of highly non-linear, advanced, and complex loading scenario. That's why the structural response has also been studied under the blast loading for the close-range/contact range blast. The aluminium honeycomb structures have been subjected to close range blast load and the material response is computed in terms of the force transmission to the steel rod. The variation in the force transmission with the thickness of the aluminium honeycomb structure showed the energy absorbing behaviour of the material and hence predicted the proper material response in this range. It is recommended that the transmitted force could provide the basis for the design of the structural material under such extreme loading conditions.

Keywords: *High energetic material loading, Peak overpressure, Close to Contact blast, Aluminium honeycomb, LS-Dyna.*

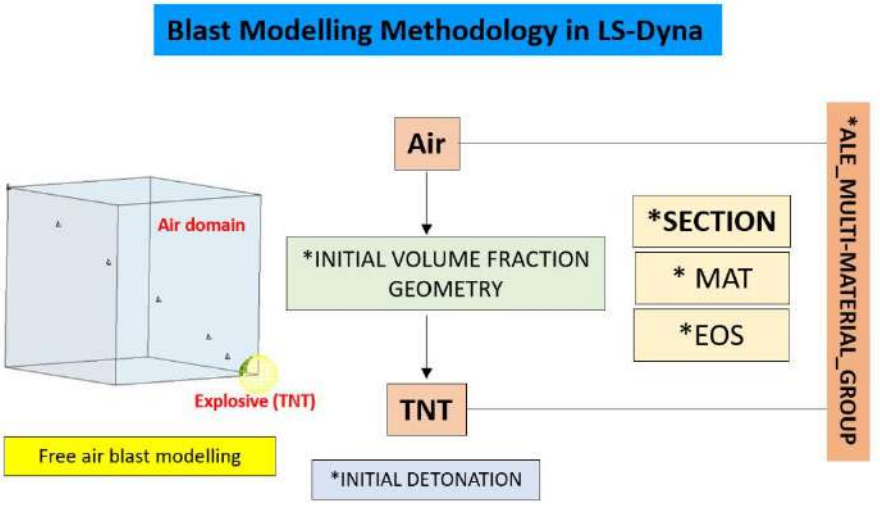

Fig. 1 Blast modelling methodology used in LS-Dyna

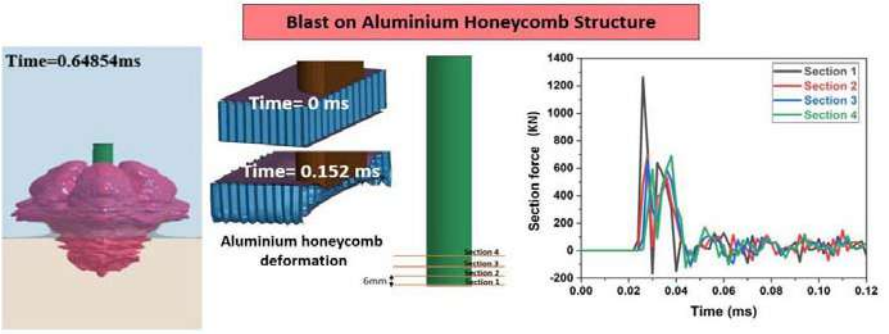

Fig. 2 Aluminium honeycomb blast loading response in terms of transmitted force for scaled distance of 0.08 m/kg$^{1/3,}$

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Numerical Simulation of V-Shaped Composite Plate Subjected to Blast Loading

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Abstract: Improvised explosive device buried under the soil has become a new threat to the armour personal carrier (APC) and it has made engineers to rethink about the design or the material of the V-shaped plate placed under the APC. Dyneema composite could be one of the potential materials which could be thought off. It is an ultra-high molecular weight polyethylene (UHMWPE) fibre, has a strength of 3600 MPa, low density (0.97 g/cc), 15 times stronger than steel, and 40% stronger than aramids fibre on an equal weight basis as per DSM (Manufacture Company for Dyneema Composite). Numerically and experimentally determined deformation of the centre point of the V-shaped plate made of steel has been well reported in the earlier literature. However, in this work, an effort has been made to study the centre point deformation of the V-shaped plate when it is made with Dyneema composite. A series of numerical simulations have been carried out on V-shaped plate under the blast loading using LS-DYNA. To study the effect of the internal angle of the V-shaped plate on the centre point deformation, the plate has been modelled with different internal angles (i.e. 60°, 90°,120°, 150° and 180°). The explosives of various weights and stand-off distance from the centre point of the plate

have been taken into consideration. The location of the charge is considered to be at the mid-point of the V-shaped plate. It has been found out that the V-shaped plate of Dyneema composite deformed more and transmitted lesser force through it when compared to the V-shaped plate made with steel. It is recommended that the Dyneema can be used to make V-shaped plate which is placed under the armour personal carriers,

Keywords: *Blast loading, Numerical simulation, V-shaped plate, Dyneema composite*

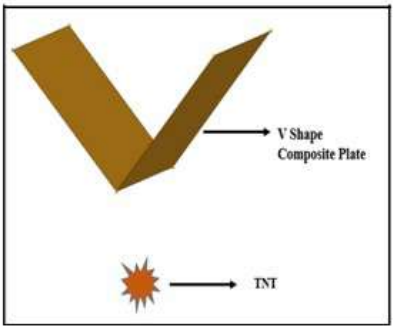

Fig 1 Blast loading on V-shape composite plate

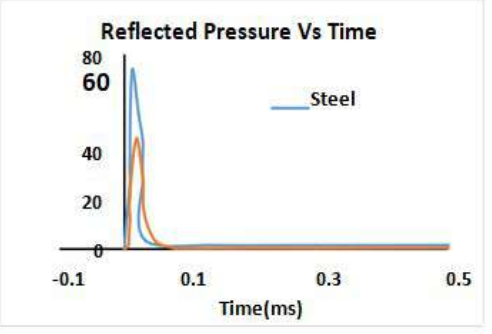

Fig 2 Comparison Between Steel and Dyneema Plate

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Effect of Ply Orientation Sequence on the Compression After Impact Strength of A Carbon Fiber Reinforced Composite Laminates

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Abstract: Generally the laminate under compression will have lower strength than that of the laminate under tension as the fibers are weak in compression and under compressive loading condition, most of the load is then taken by the matrix. The main difficulties with the FRP (Fiber Reinforced Polymer) composites is that even with the smaller magnitude of impact, its performance will degrade. One of the main modes of the failure of the impacted laminate under compression is the buckling of the sub-laminates in the delamination zone formed at the impacted site. The size of this

delamination zone increases with the increase in the impact energy which reduces the CAI (Compression After Impact) strength of the laminate. The CAI strength also depends upon the microstructural configuration, mechanical properties of constituent materials such as fibers, resins and fillers, ply orientations and thickness of the laminate. There are numerous studies which presented the work on CAI behaviour of the FRP laminates. In the present work we are going to study the effect of stacking sequence of different ply orientations on CAI behaviour of the composite laminates. The laminates are first subjected to low velocity impacts of different energy levels and then tested for their compressive strengths. Upon completing the study it has been found that even with the barely visible impacts the compressive strength of the laminate has been reduced drastically. The main mode of the failure is buckling of the laminate in the region of the delaminated zone due to impact.

Keywords: *FRP, CAI, Low Velocity Impact*

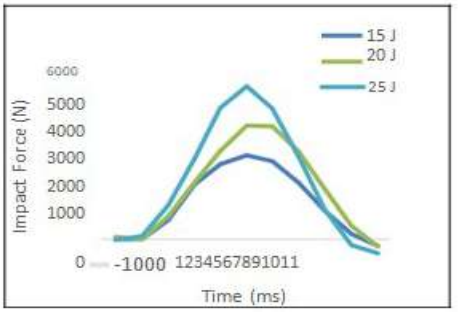

Fig.1 Force-Time history of the LVI test on the sample [0/45/90/-45]s

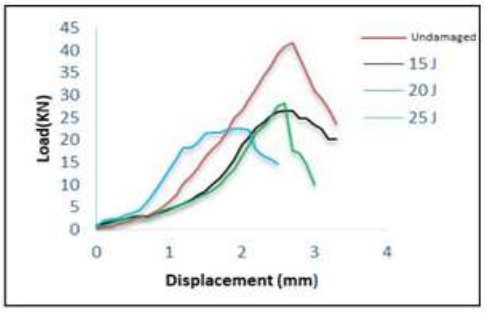

Fig.2 Load-Disp of the Compresstin test on the sample [0/45/90/-45]s

* * * * *

Qualification of 3-D Printed AlSi 10 mg Part for Military Airborne Applications

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[1,2,3]*AERDC, HAL, Bengaluru, India*

Abstract: The quality of parts manufactured through additive manufacturing (AM) is dependent on many inter connected process parameters. The qualification of the parts made through the additive manufacturing is also complex due to this interconnection.

The complete qualification procedure can be broadly divided into three categories i.e. qualification of input materials, qualification of process related characteristics and qualification of final product. Qualification of input material requires the morphology, shape, particle size, chemical composition, mass flow rate, apparent density, tap density etc. Qualification of process related characteristics requires scan speed, laser power etc. for the process. Qualification of final product involves tensile, shear and hardness tests, microstructure evaluation, residual stress measurement etc. These tests are carried out on specimens concurrently produced with the parts as well as on specimen extracted from parts. The qualification is aided by the presence of existing part made of forging or casting so that the comparison of properties can be made between this part and additive manufactured part. The comparison helps to restructure the certification procedure to iron out any flows in the certification procedure. Thus a comprehensive certification procedure is established and carried out for airborne application to qualify additive manufacturing processed AlSi10Mg part for military application. The part is certified and successfully used in aircraft.

Keywords: *3-D printing, AlSi10Mg, morphology, residual stress*

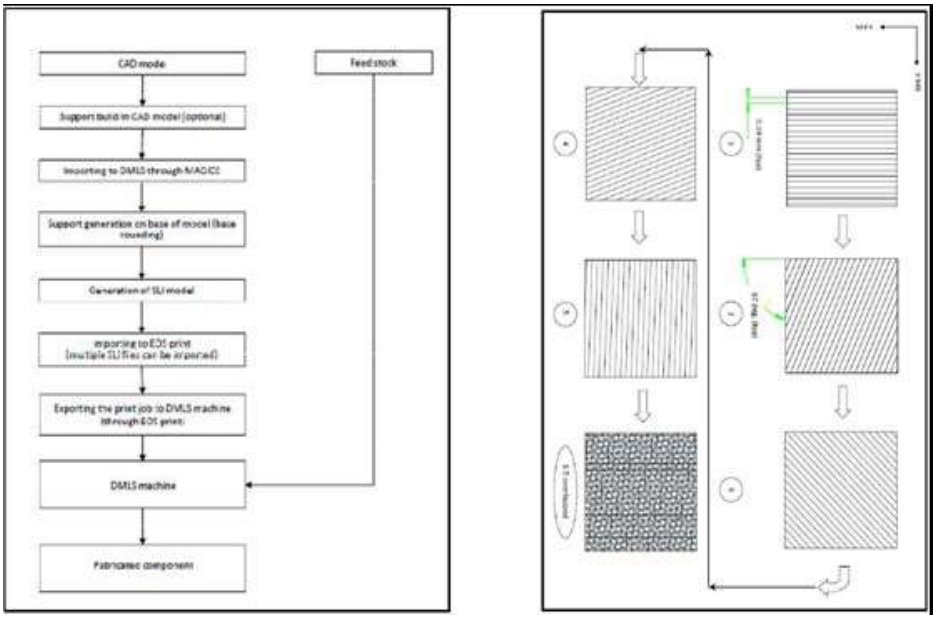

Fig. 1 Flow of operation for AM and Hatch distance and pattern for AM

* * * * *

Parametric Analysis and Response Surface Optimization of Cutting Speed and Surface Roughness in Machining of Hastelloy-X Using WEDM

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Abstract: Hastelloy-X or Alloy-X is a combination of nickel-chromium-iron-molybdenum alloy. As the nickel-based alloys have high-temperature strength it can be used in afterburners, combustor cans, tailpipes, spray bars and flame holders etc. The high-temperature strength and thermal diffusivity it leads to damage in both tool and workpiece. Wire electric discharge machining (WEDM) a non-contact spark eroding technique was found to be the most precise machining process. Different input parameters like cutting speed override, pulse on time, pulse off time, servo voltage were employed. The cutting speed was calculated from average instantaneous speeds recorded by the machine. The surface roughness was measured as the average of five values from surface roughness tester. Cutting speed and surface integrity were examined by response surface methodology. The response surface optimization was used to get the favourable cutting speed and surface roughness with controls both economy and product quality. The cutting speed override is a machining parameter that helps in smooth cutting operation while complex profiling, inferior wire quality and rough machining conditions. It was noticed that as it increases the cutting speed and surface roughness increased. Similar effects were observed for pulse on-time parameter. Whereas the pulse off time was observed to have very minor effects on cutting speed and surface roughness. In the case of servo voltage, the cutting speed and surface roughness increase with decrease with servo voltage.

Keywords: *Wire electric discharge machining, Cutting speed, Surface roughness, response surface optimization*

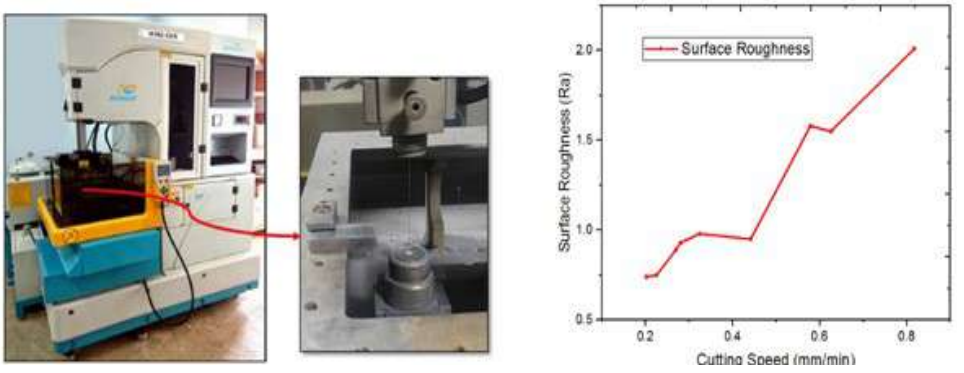

Fig. 1 WEDM of Hastelloy-X and Variation of surface roughness with cutting speed

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Experimental Comparison of Hardness of 3D Printed PLA and Carbon Fiber Reinforced PLA Printed Under Same Printing Conditions

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Abstract: 3D printing is used as method to manufacture low volume parts in automobile and aviation industries. Various materials have been developed that can be successfully printed with the help of fused deposition. This wide array of materials ensures that 3D printed parts can be used in various application. One of material is 20% carbon fiber reinforced PLA, in which carbon fiber filaments are molded during the process of manufacturing.

The aim of the paper is to compare the hardness of 3D printed PLA and carbon fiber reinforced PLA with the help of Brinell hardness testing after printing the materials using the same printing conditions. For the experiment, specimens of PLA and carbon fiber reinforced PLA were printed at the conditions nozzle temperature 250^{o}C, Bed temperature 700C, density 100% and print speed of 80mm/s. These print temperature is slightly higher than that of PLA. The print conditions that are slightly higher than ideal condition for PLA. The printing was done on ender 3 FDM machine

In our investigation it was determined that Brinell hardness number were approximately equal when printed under similar printing condition, which is antagonistic to findings of some of papers. The findings of the paper can be used to develop 3D printed components of carbon fiber reinforced PLA that require hardness equal to PLA.

Keywords: *Fused Deposition Modelling, Hardness, PLA, Carbon Fiber Reinforced PLA*

Fig. 1 Performance of Brinell hardness Test

* * * * *

Laser-Induced Forward Transfer of NiTi functional material

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Abstract: Laser-induced forward transfer (LIFT) is a non-lithography, nozzle-free printing technique widely used to transfer different materials with high resolutions. It can deposit functional material without phase change for the fabrication of actuators, transducers and other MEMS devices. In this work, LIFT is deployed to deposit NiTi shape memory alloy using CO_2 laser (λ=10.6 μm) in the form of the solid phase. The silicon wafer is used as the donor substrate since it is transparent to the CO_2 laser wavelength while the silica glass is used as an acceptor substrate. The donor substrate is coated with the PDMS as a sacrificial layer that absorbs the laser energy and induces a

thrust force for the transfer mechanism. Over the sacrificial layer, NiTi Shape memory alloy thin film is deposited with DC sputtering technique at working pressure $2*10^{-3}$ mbar and standoff distance 5 cm. After the donor preparation, the LIFT is deployed at various laser fluences and SOD for the deposition of NiTi on the glass substrate. The surface morphology and structural analysis of the deposited geometry have been analysed using SEM, optical microscope and X-Ray diffraction (XRD). The functionality of the deposited materials has been analysed using Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analysis (DMA).

Keywords: *Laser-Induced Forward transfer, 3D printing, Shape memory Alloy.*

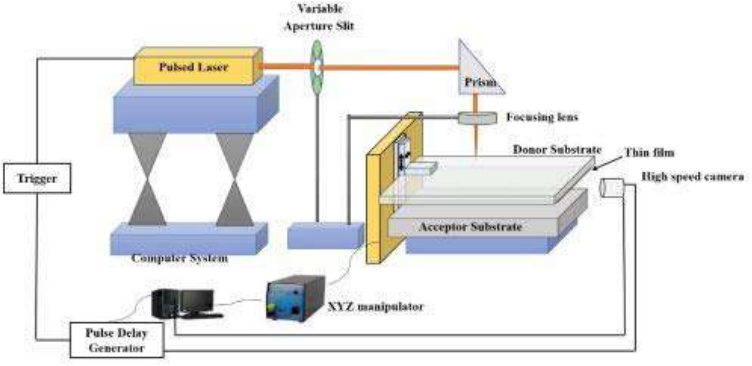

Fig. 1. Schematic of Laser-Induced Forward Transfer

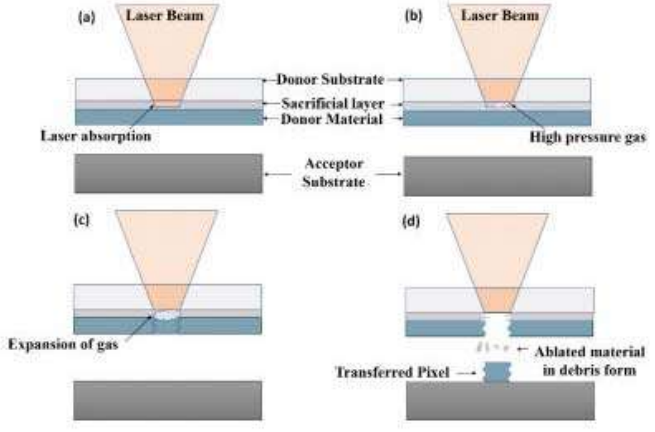

Fig. 2. Transfer mechanism after the laser irradiation.

* * * * *

Study of Microstructure and Mechanical Properties of Bi-Metallic H316 Steel-Inconel 625 Metals Using Wire Arc Additive Manufacturing Process

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Abstract: The development of Bi-metallic materials has become extremely popular in recent years and can result in the enhancement of both strength and ductility. The bimetallic materials comprise two different metals with different properties joined together primarily used for industrial needs such as aerospace, automobile, and nuclear applications. However, there is a limited understanding of its evolution in microstructure and its microstructure property correlation. So our research focus is on the mechanical and microstructure correlation of Bi-metallic H316 steel – Inconel materials using wire arc additive manufacturing process (WAAM). We have fabricated 3D Bi-metallic H316 steel – Inconel 625 metal parts of dimension 150 x 60 x 8mm^3 using a double pulsed MIG-MAG welding process. One of the filler materials (Inconel 625 wire of 1.2mm diameter) is connected to an Automatic MIG-MAG welder and the other (1.2mm H316 steel wire) is connected to the manual welding machine. The microstructure study on the 3D Bi-metallic H316 steel – Inconel metal part shows the presence of both equiaxed α ferrite and Inconel 625 dendritic structures as shown in Figure. The average hardness value was found to be 35.8 ± 4.71 HRC. Also, there are no micropores, cracks generated during the WAAM process. Finally, the heat treatment of the sample will be performed for obtaining beneficial microstructure and mechanical properties

Keywords: *3D Additive manufacturing, Wire arc additive manufacturing, Microstructure, bi-metallic materials, Mechanical properties.*

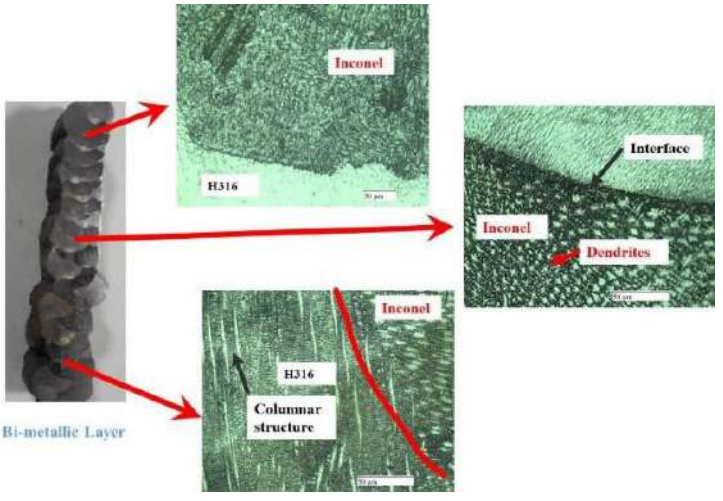

Fig 1: - Bi-metallic H316 steel–Inconel 625 materials using WAAM and its microstructure

* * * * *

Effect of Heating Rate on the Thermo mechanical Cycle of Shape Memory Polymers

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Keywords: Shape Memory Polymer, Thermo Mechanical Cycle, Epoxy Polymer

Abstract: Shape memory polymers have wide applications in aerospace and medical applications due to its ability to change its shape when properly tuned. In the present work, we have studied the thermo mechanical cycle of epoxy based polymer composites by increasing the fibre volume fraction and the number of heating elements to increase the heating rate for reducing thethermo-cycle time. The heating rate is increased to 46 ^{0}C /Min from 14 ^{0}C/Min and the cycle time has been calculated. Experimental set up has been established for heating, loading, unloading and cooling. The performance of glass/epoxy composites with neopentyl glycol diglycidyl ether as filler for establishing the shape memory effect has been studied for the thermo mechanical loading. A cantilever beam of epoxy composites has been considered for the study and its shape

fixity and shape recovery have been studied through the thermo mechanical cycle. The experiment has been repeated for more than 50 clycles and it is observed that the composite beam does not loose its strength even up to 50 complete loading, thermal heating, unloading, cooling and heating. The experimental setup has improved temperature sensing accuracy and the data acquisition system to automatically read and save the time, temperature and displacement values.

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Organizers

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