Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 05, Issue 04, December-2022
Available at www.rjetm.in/

A Study on Composite Material Types and Mechanical Behaviour

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Abstract: *An assembly of layers of fibrous composite materials that can be linked to provide the necessary engineering qualities, such as in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion, is known as a composite laminate in the field of materials science. High-modulus, high-strength fibers embedded in a polymeric, metallic, or ceramic matrix material make up the individual layers. Cellulose, graphite, glass, boron, and silicon carbide are examples of common fibers, and epoxies, polyimides, aluminum, titanium, and alumina are examples of common matrix materials. A hybrid laminate can be created by layering various materials. Composites have been used in a variety of industries. This ranges from furniture to hardware for building. Window frames, bathtubs, and doors are a few domestic goods that use composites.*

Keywords: Cantilever Beam, Composite Material, Laminated Composite Plates, Mechanical Behavior

I. Introduction

Composite beam structures, columns, and rods have been widely used in the civil, mechanical, aeronautical, and aviation industries during the past several years due to their desirable qualities, such as high strength-and stiffness-to-weight ratios and anisotropic properties of a material. Fiber-reinforced composite materials have become more popular than conventional materials like mild steel, structural steel, and stainless steel in various industries. In lightweight components like aircraft wings and wind turbine blades, composite beams—often referred to as spars—are employed to provide the principal stiffness against bending deformation. A result of their ability to withstand significant pressure and temperature changes, they are also frequently used in the aviation industry. Because of their superior mechanical qualities, they are also frequently employed in the production of space vehicles, missiles, rockets, rudders, elevators, wing flaps, spoilers, floor beams and panels, and plane fuselage and wings, among other things. To make sure a structure is secure, a vibration study must be performed on it. The two key factors that define a structure's safety in this approach are natural frequency and static structural analysis. It's fairly typical to feel the want to vibrate when a cyclic load is applied. One of the most crucial and important areas of designed-based mechanical engineering study is dynamics. Specifically, the modal is concerned with the dynamics of mechanical structures under dynamical excitation. Resonance occurs when the amplitude of a beam's natural frequency and the periodic load applied to the beam are equal. The current comparative study is concerned with free vibration and static structural analysis of a cantilever beam with different materials. Cantilever-like structures are used extensively in the aerospace, civil, mechanical, and wind sectors [1–6].

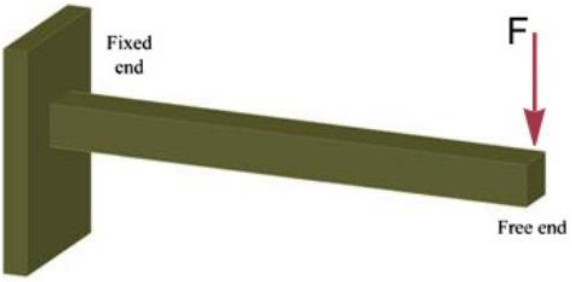

Figure 1 Cantilever Beam

II. Materials And Their Properties

The theoretical foundation, design criteria, and processing technologies of isotropic materials have all advanced. The development of materials has been constrained by single and homogeneous material features. Numerous uses have prompted research on composite materials, such as Bitable morphing composites for energy harvesting [7]. By using magnetostrictive actuation, thermal, shape memory alloy, and piezoelectric actuation, the composite structure may produce kinetic energy. In order to create bitable laminate composites, Ventra Siva C. Chillara [8] coupled thermosetting reinforced polymer laminates with shape memory alloys as fiber reinforced elastomers. In the fields of manufacturing and application, discussions of applications in biomedical magnesium alloy metal composites are also frequent [9,10].

The aerospace, automotive, and biomedical industries frequently use magnesium alloys due to their resilience. However, processing is severely hampered by it. Surface metal matrix composites were created by B. Ratna Sunil [9] using the friction stir processing method, and the characteristics of composites made of magnesium alloy are also covered. High performance composite materials are now increasingly used due to improvements in material science and our growing understanding of anisotropic materials. Traditional metal materials have been replaced by fiber-reinforced polymer composites. Composites made of epoxy resin with fiber reinforcement are very frequently utilised in engineering. Polymer materials are used as the foundation for composite materials. The purpose of common processing techniques like drilling, cutting, and joining is to make the material more usable. Parasitism-predation algorithm (PPA) optimizer was proposed by Amar H. Elsheikh [11] and was optimised for drilling the parameters of non-laminated glass fiber-reinforced epoxy composites (GFREC). A method of estimation for the optimisation of cutting parameters for basalt fiber-reinforced polymer composites was also put out by him [12]. Long Short-Term Memory (LSTM) and the Chimp Optimization Algorithm (CHOA) make up this estimating model . This technique may effectively assess and improve the quality traits of composites that have been laser cut. Vibration welding method was employed by Ezzat A. Showaib [13] to join GFRP. The effect of fiber orientation on the strength of the combined materials' weld joints was investigated. This is mostly due to the benefits of lightweight, highly specific specific strength, and high specific rigidity offered by composite materials. These benefits have led to the usage of a number of laminated composite materials in the building, manufacturing, and aerospace industries. However, the mechanical properties of composite materials, material selection, and the best structural design are major areas in current research. In the 1940s, glass fiber-reinforced polymer was used as the foundation for the first composite materials used in aircraft construction. Boron and carbon fibers were developed in the 1960s, and aramid fibers, developed in the 1970s, have also been successfully used in aviation structures. Due to its benefits including low cost and ease of processing, carbon fiber-reinforced polymer (CFRP) has evolved into the foundation of composite materials. An application of CFRP is shown in the outer panel of the F-16 fighter fin . The waste produced by related composite materials has increased along with the gradually rising demand for CFRP applications. The thermosetting glass fiber composite waste market is anticipated to reach 304,000 tonnes in Europe each year, while 2 million tonnes is anticipated for the US. As a result, the method for treating waste made of composite materials is becoming more and more crucial. At the moment, discarded composite materials can be cut and crushed to reuse them. The recycled composite material components are then ground into a powder to create the composite material. Thermosetting composite powders are often found in fillers. For example, thermosetting composite powder is often added to cement to increase its strength.

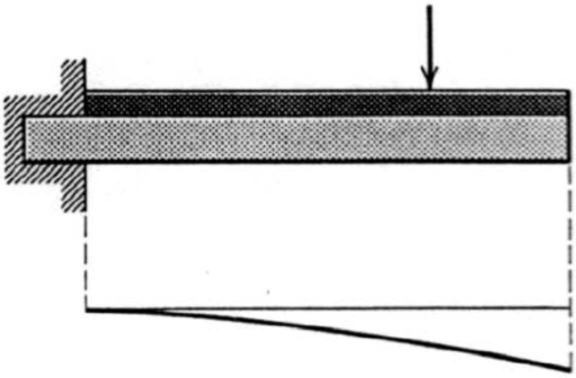

Figure 2 Deflection diagram of Cantilever Beam

III. Functionally Graded Materials (FGMs)

Certain material properties are necessary for a number of mechanical and structural applications, but they cannot be found in a single material (such as metal, polymer, ceramic, or alloy) or in conventional composite materials (such as longitudinal, chopped, and laminated fiber composite materials) [14,15]. Engineering materials, including metals [16], alloys [17, 18], ceramics, polymers, and conventional composites [19], were once produced to have homogeneous features and little to no variation in their mechanical properties [20]. It was necessary to improve materials with opposing qualities for the graded structure in order to meet the application requirements due to the limitations of applying typical homogenous materials [21]; these materials are known as FGMs (Functionally Graded Materials) "Functionally graded materials (FGMs) are a broad research area and attract considerable tremendous attention today in the materials science and engineering society" [22]. Functionally grade materials (FGMs) are a category of composite materials where the material's properties are intended to change gradually and continuously from one surface to the next in order to eliminate the discontinuity effects in the properties. [[23], [24], [25], [26], [27]]. When the mechanical properties of beams and plates are improved in order to overcome the drawbacks of the traditional composite materials by using FG materials, as shown in Refs. [22, 15,16], the mechanical features of any construction are improved. As a result, FG beam and FG plate were used in a number of applications, including the aerospace, automotive, defense, and biomedical engineering industries. Examples of significant applications for axially functionally graded materials are cutting tools and nuclear reactor nozzles [22].

IV. Literature Review

(Prombut P et. al., 2019) [1] In the aerospace and wind energy industries, laminated composite beams are frequently employed as structural elements. The beams, also known as spars, offer the main rigidity against bending deformation of the structures for wind turbine blades and aero plane wings. In the current study, composite cantilever beams with a constant I-cross section are the main subject. For the composite material, a unidirectional (UD) Glass/Epoxy lamina was selected. The beam is 50 x 55.2 x 2,500 mm in total. Different stacking orders were assigned to the beam's flanges and web. A weight was applied to the upper flange in a uniform distribution. The deflection results from first-order shear deformation theory (FSDT) and finite element analysis (FEA) are in good agreement. The bending stiffness and beam deflection are significantly influenced by the flanges' effective longitudinal modulus (Ex). I-beam design can be improved by comprehending the crucial functions that various materials and the way that beams are constructed play. The study of realistic spars, which are based on an I-cross section as well as curvature, taper, and twist along the length, can be added to the scope of the validated FEA technique.

(Talekar N et al., 2020) [2] Composites are well known for their unique strength and particular modulus, and as a result, they are increasingly being used in engineering. In this paper, a mathematical technique for the free vibration analysis of layered composite cantilever beam is described using a first order shear deformation theory. For the modal analysis, the 281 Shell elements with 8 nodes and six degrees of freedom at each node are used to create the finite element (FE) model. By taking into account a four layered composite cantilever beam, it is possible to study the precise impact of the lay-up sequence, length-to-thickness ratio, and lay-up angle on the natural frequencies of different modes. To investigate their impact on bending, transverse, and torsional vibration modes, four distinct lay-up sequences and five various length-to-thickness ratios are taken into consideration. The results obtained are compared with the previously published literature to validate the efficacy and accuracy of the model. The analysis results show distinct modal characteristics due to change in lay-up sequence and length-to-thickness ratio. This study could be used to choose the right lay-up sequence and length-to-thickness ratio to modify modal parameters like the cantilever beam's natural frequency and prevent resonance.A parametric investigation would be extremely difficult to conduct using analytical models; hence, FE models are used. The order of the layup is discovered to have a significant impact on the natural frequencies of all modes, and the effect of the length-to-thickness ratio must also be considered. An ant symmetric layup sequence has a higher natural frequency of the bending mode across the whole range of layup angles than a symmetric layup sequence. The natural frequency of the torsional mode is greater when the layup pattern is symmetric up to a layup angle of 45°.

(Satheesh P et al., 2013) [3] The majority of manufacturers and their subcontractors have been seeking to lighten the members in recent years as natural resources continue to diminish and to fulfil the demands of natural resource conservation and energy economy. In this method, they look for low-cost materials with a good strength-to-weight ratio. Because composite materials have higher specific stiffness and strength, replacing traditional metallic structures with them has many benefits. Along with other benefits like outstanding corrosion resistance, superior torsional buckling and fatigue strength, and high specific strain energy storage capacity, composite materials have the key advantage of having a high strength to weight ratio with continuously reducing cost. By determining the best fiber orientation stacking sequence and tailoring laminate thickness/width for optimum stiffness and minimal weight design of laminated composite beam, the current work seeks to demonstrate the acceptability of using composite materials. Utilizing optimization approaches to maximize stiffness and reduce weight, the structural response of a typical metallic structure is assessed. To retain strength with the established optimization algorithm, these metallic optimum values are first applied to composite beams. Later, the algorithm of the beam is analyzed using ideal fiber orientations and stacking order to retain strength as well as the additional benefit of less weight for composites. This is done by tailoring cross-sections and optimizing topology. The basis for tailoring is a steady reduction in cross-sectional area along the length in both the thickness and width directions. Numerical results are presented for cantilever beam with different geometries showing the maximizing stiffness and with minimum weight. The results indicate that the devised strategy is well suited for finding optimal fiber orientations and laminate thickness/width in the tailoring design of slender laminated composite structure.

(Malik S et al., 2021) [4] Recent years have seen a significant increase in the demand for composite materials due to their special mechanical characteristics and wide range of applications, including aerospace, medical equipment, sensors, actuators, automobiles, and many more. In this investigation, a composite beam made of chicken feather fiber (CFF) and epoxy-resin will be subjected to a uniformly distributed 500 N load and a high 500 ℃ temperature in order to assess its structural integrity. The analysis predicts that 51.53 MPa of pressure will be applied to the structure during UDL, causing a displacement of 0.1127 mm. Modal analysis has been taken into account for the first eight modes in order to assess the vibrational frequency for the composite beam at a high temperature of 500℃elsius for both the cantilever beam type condition and the both end fixed type condition. Results show that frequencies for the cantilever beam type boundary conditions range from 205.91 Hz (mode1) to 2939.4 Hz (mode8), while for the conditions with both ends fixed, frequency is very high as compared to the cantilever type condition, it varies from 1174.4 Hz (mode1) to 4890.3 Hz (mode8). This study helps us to ensure a safe working environment while working with these composite beams.

(Sayyad AS et al., 2017) [5] Sandwich and laminated composite structures are lightweight ones that are used in a wide range of fields, including civil, mechanical, and aerospace engineering. The need for novel theories that are appropriate for the bending, buckling, and vibration analysis of composite structures has arisen from the rapid expansion of their industrial use. In the previous few decades, there have been a lot of review papers on laminated composite plates and shells documented in the literature. The body of literature as a whole, however, contains very few review papers that are entirely concerned with laminated composite and sandwich beams. This article presents a critical review of the literature on the analysis of shear deformable isotropic, laminated composite, and sandwich beams under bending, buckling, and free vibration based on equivalent single layer theories, layerwise theories, zig-zag theories, and exact elasticity solutions. Additionally, a survey of the literature on laminated and sandwich beam finite element modelling based on classical and refined theories is also done. For the benefit of other researchers working in this subject, the displacement fields of various equivalent single layer and layerwise theories are compiled in the current study. This article has 515 references and highlights the potential areas of future study for laminated composite and sandwich beams.

(Ahmed N et al., 2021) [6] When a structure has a crack, there is a greater chance that it may collapse. When the natural frequencies of the periodic force and the structure are in a condition of superposition, failure results. Calculating the natural frequency is crucial to avoiding this problem. This study's objective is to examine how natural frequency responds to various characteristics, including crack position,crack depth, crack opening, and mesh sensitivity. The first five vibration modes of both cracked and un-cracked I beams have been extracted for this investigation. Additionally, resonance for a fixed vertical force has been examined. The behaviour of the fractured structure has been investigated using a combination of hexahedral and wedge elements. It is quite difficult to come up with an analytical solution to this problem because it is a discontinuity problem. In order to analyze the cracked structure, one of the most widely used finite element analysis programmes, ABAQUS CAE, was employed. The results of this investigation show that the existence of a crack reduces the beam's natural frequency, and that this reduction is related to the location, opening, and depth of the crack. This investigation also revealed that when the break reaches the web segment of the I beam, vibration has a significant impact on the beam. Additionally, it was shown that resonance occurs earlier if the crack profundity is greater or its location is closer to the fixed end.

(Elsheikh al., 2022) [7] Due to their capacity to change their shape and retain two different states without any external loading, bistable morphing composites have demonstrated interesting uses in energy harvesting. The use of these composites in energy harvesting is covered in this review article. Actuating techniques used to change the shape of a composite structure from one state to another is discussed. The dynamic behaviour of these composite structures is explained mathematically. Finally, applications of artificial intelligence to bistable structure design optimisation and response prediction under various actuating schemes are presented.

(Chillara et. al., 2017) [8] Because they can display significant deflections without actuation and a dramatic change in shape when activated, bistable laminated composites are ideal for morphing structures. Traditional thermally cured fiber-reinforced polymeric laminates have coupled stable forms that are the consequence of a globally prestressed matrix and cannot be customised separately. In order to overcome this constraint, we offer a comparable laminated composite in this study. Mechanical prestress is given to the matrix of a few chosen laminae in order to achieve bistability, and forms are uniquely designed by varying the magnitude of prestress in each lamina. Multifunctional morphing composites are produced when smart materials with regulated stress states are combined with the application of mechanical prestress, which is connected to an irreversible non-zero stress state. A core is placed between two prestressed fiber-reinforced elastomers in the proposed bistable composite, which is actuated by shape memory alloy wires. By including the material and geometric nonlinearities of prestressed elastomers and the 1-D constitutive behaviour of a shape memory alloy (SMA), composite mechanics is analytically analysed . The accuracy of the experimentally validated passive composite model is 94%. The design of active bistable composites is guided by the results of a sensitivity analysis that demonstrates the impact of prestress and SMA characteristics on composite curvature. Simulations with the chosen parameter set resulted in the exact compensation of the nonlinear effects of applied stress and phase transformation kinetics to yield a linear response of composite curvature to Martensitic volume fraction.

(Sunil, B.R. et.al., 2016) [9] Surface metal matrix composites (MMCs) are a class of contemporary engineered materials where the surface is changed by dispersing secondary phase in the form of particles or fibres while the core of the material retains its chemical composition and structural integrity. The automotive, aerospace, biomedical, and power industries all have potential uses for surface MMCs. Friction stir processing (FSP) is a method that has recently become very popular for generating surface composites in solid state. FSP has successfully treated magnesium and its alloys, which are challenging metals to work with, to create surface MMCs. The purpose of the current paper is to offer a thorough overview of the state-of-the-art in FSP fabrication of magnesium-based composites. Influence of the secondary phase particles and grain refinement resulted from FSP on the properties of these composites is also discussed

(Krishnan,R et. al., 2022) [10] Stainless steel, titanium alloys, and materials like Co-Cr are being used to create the latest medical implants. For many medical implant circumstances, these conventional implant materials produce toxic ions and a stress shield effect. This results in additional operations that are performed to remove the implant. In order to avoid secondary operations, many researchers have suggested using a magnesium metal matrix composite (Mg-MMC) as an implant material. Magnesium composites are treated to various engineering techniques such as reinforcing elements, surface treatment, and changing the synthesis processes to improve their mechanical and biocompatibility properties. This review paper summarizes the influence of various reinforcing materials' reactions with the matrix and synthesis processes on the microstructure, mechanical properties, and corrosion behavior of biodegradable magnesium matrix composites in this context. This paper aims to provide academicians, industry personnel, and researchers with a comprehensive understanding of biodegradable Mg-MMC used in biomedical implants.

V. Composite Laminates [28]

An assembly of layers of fibrous composite materials that can be linked to provide the necessary engineering properties, such as in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion, is known as a composite laminate in the field of materials science. High-modulus, high-strength fibers embedded in a polymeric, metallic, or ceramic matrix material make up the individual layers. Cellulose, graphite, glass, boron, and silicon carbide are examples of common fibers, and epoxies, polyimides, aluminum, titanium, and alumina are examples of common matrix materials. Different materials can be layered to produce a hybrid laminate. Depending on whether the individual layers are orthotropic (that is, have principal properties in directions that are orthogonal to each other) or transversely isotropic, the laminate will then exhibit anisotropic (with variable direction of principal properties), orthotropic, or quasi-isotropic properties (with isotropic properties in the transverse plane). Although not limited to isotropic out-of-plane (bending) response, quasi-isotropic laminates show isotropic (i.e., direction-independent) in plane response. Depending upon the stacking sequence of the individual layers, the laminate may exhibit coupling between in plane and out-of-plane response. An example of bending-stretching coupling is the presence of curvature developing as a result of in-plane loading.

Deformation in orthotropic materials is typically direction-dependent. When loads are applied in natural (material) coordinates, an exception happens. By definition, these are coordinates in the lamina's plane, with the longitudinal coordinate aligned with the fiber reinforcement and the transverse coordinate aligned perpendicular to the fiber reinforcement. In a unidirectional reinforced composite, the longitudinal and transverse directions are the material axes of symmetry. The material responds to loads in these natural coordinates similarly to isotropic materials, i.e., normal stresses only cause normal strains and shear stressors only cause shear strains. The transverse and longitudinal axes are present here. Composites with unidirectional reinforcement are frequently referred to as particularly orthotropic. Additionally, isotropic properties of unidirectional reinforced laminas in the out-of-plane (normal to the plane of the lamina) direction.

5.1 Classical Laminated Plate Theory

The Kirchhoff-proposed classical plate theory for isotropic and homogeneous materials is directly extended by the classical laminate theory. To account for the inhomogeneity non thickness direction, various adjustments must be made before this theory can be applied to laminates. The presumptions for both the classical plate theory and this theory are listed in the paragraphs that follow.

There are two methods used to derive the strain-displacement field. In the first method, the laminate is deformed using the Kirchhoff-Law assumptions for bending and stretching. The displacement field is developed using the laminate's unreformed and deformed geometries. The transverse strain components arising from the aforementioned assumptions are used in the second method. Additionally, employing definitions of these strain components the displacement field is obtained.

5.2 Composite Beams with I-Cross Section

I-cross section composite beams are thought of as thin-walled, open-section, orthotropic beams. The flat laminates used to create the I-beam might have a variety of characteristics. The upper flange, lower flange, and web can all have distinct effective modulus. As a result, the cross-section's equivalent tensile and equivalent bending stiffness must be determined [29].

The material was a unidirectional (UD) Glass/Epoxy lamina. The flanges received four stacking sequences. They were chosen such that they would induce various degrees of deformation coupling [30].

5.3 Composite Structures

In the past few decades, considerable work has been reported on composite structures with different forms of geometric non-uniformities.

In their modal analysis of a square composite plate with a hole in the middle, Deepanshu et al. [31] found that while the natural frequency varied very slightly for smaller cutouts, it changed significantly for bigger ones. Mondal et al. [32] investigated that sandwiched composite plate with a hole in the middle revealed that the natural frequency decreased with increasing core thickness. Moshin et al. [33] explored how the natural frequency of the composite plates changed with the boundary conditions by doing a modal analysis on composite plates with various cut-out forms. To the best of the authors' knowledge, no work has been published in the literature that combines process characteristics such aspect ratio, fiber orientation, hole size, boundary conditions, etc. for the dynamic analysis of composite plates. However, there is a dearth of literature that presents the dynamic analysis of plates using more than two or three parameters. In order to comprehend the dynamic behavior of geometrically non-uniform laminated composite plates made of various materials, an attempt has been made to combine different parameters in this study.

5.4 Shear Deformation Theories –Laminated Composite Plates

Atteshamuddin S. Sayyad, Yuwaraj M. Ghugal, and Bapusaheb A. Mahaska developed a four-variable plate theory for the thermoelastic bending analysis of laminated composite plates (Sayyad, 2015) [35] The thermoplastic bending analysis of laminated composite plates subjected to heat stress linear throughout the thickness is provided in this article utilizing the four variable refined plate theory. Other higher-order theories including first-order shear deformation theory include five unknown variables, whereas this theory has only four. Shear correction factors are not required because the theory is variationally consistent. When a plate is subjected to a thermal load linear across its thickness, numerical results for thermal displacements and stresses are reported.

5.5 Benefits and Drawbacks of Using Composites

When two or more distinct materials are laminated together, composite materials are created. Due to their excellent strength to weight ratio, resistance to corrosion, and surface degradation, these laminae were found to have a wide range of applications. In order to produce composites as efficiently as possible, laminates—multiple adjusted layers—are used. The qualities of the material can be adjusted to meet the necessary properties in a structure by altering the orientation of the fibers in the resin. The structural qualities of a composite material are mostly governed by the fibre reinforcement. The final part's qualities, such as strength and stiffness, are optimized while still minimising weight since the fibre is held together with the matrix resin. The major function of the fibers is to transport weights in their longitudinal directions.

The most used resin systems are polyesters. Epoxies are more expensive than polyesters but have better adhesion and less shrinkage, therefore they come in second place in terms of cost. Utilizing composites offers both benefits and drawbacks. When using composites in a design, trade-offs should be taken into account depending on their intended use.

Composites have been used in a variety of industries. This ranges from furniture to hardware for building. Window frames, bathtubs, and doors are a few domestic goods that use composites. [36] Carbon nanotubes and carbon fibre reinforced composites (CFRP) are both used in sporting products like rackets and bicycles, respectively. Many bridges and utility poles in public infrastructures have been built with composite materials. Composites have a high strength-to-weight ratio, which makes them very popular in the aerospace industry. Aerospace weight is a crucial factor. It influences an aircraft's ability to fly. In the past, metal was the sole material used to construct aircraft, which made the whole construction hefty. After composites were developed, it was discovered that they could significantly alleviate the aircraft's weight while yet offering structural integrity that was on par with or even superior to that of metals.

These days, composite materials are being used in the design of an increasing number of aircraft to make them lighter. A lighter aeroplane uses less fuel, which allows for a reduction in greenhouse gas emissions. Among commercial aircrafts which incorporated composites in its design are the Airbus A380 and Boeing 787 Dreamliner. The A380 contains about 25-30 tons of composites, 85% of which is CFRP. On the other hand, 50% of the B787 Dreamliner is comprised of composites, with the remainder being 20% aluminum and 30% titanium.

Due to their high specific stiffness, fiber-reinforced composite materials serve a variety of purposes in most industries, particularly the aerospace sector. However, the price of traditional composites is clearly apparent. Due to their mass production capabilities and low cost, haphazard divided fibre reinforced composite materials typically appeared as the most exceptional alternative materials for special manufacturing challenges [37]. They also joined the methods and fundamental material selection considerations for multi-material lightweight structures. For instance, it was noted that the car industry might use it. Careful material characterization is required if the application is to be expanded. The significant difficulty in the relatively unexplored geometry models at the micro-level of 35–40% fibre volume ratios, which is even more apparent at the highest aspect ratio among the various types of reinforcements [38].

Glass-fibre reinforced composite materials have only recently begun to see limited use in the building and construction sector. In order to quickly adapt and repair ageing infrastructure, fiber-reinforced composite materials have recently shown to have a wide range of uses [39]. Additionally, the characteristics of the component materials, such as void content, type, orientation, fibre distribution, and quantity, strongly influence the mechanical properties of fiber-reinforced composite materials. The fundamental idea of interfacial bonding and the method of load transmission at interlaminar interfaces, on the other hand, are equally important [40]. As a result, numerous academics talk about how short fibre reinforced composite materials are designed. Due to their documented effects on the morphologies of the fibres in short-fiber glass composite materials, they are thus ready to be used to draw attention to the strength qualities of composite materials [41]. By taking into account the effects of fibre orientation and length on mechanical characteristics, the flexural strength and vertical stress generated by bending moment of composites reinforced with avoided short fibres were examined. The usage of short-fibre reinforced injection moulding thermoplastics in fatigue-sensitive applications has also recently expanded as a result of efforts to lower the weight of automobiles through increased use of plastics and their composites [42]. Short-fiber-resin matrix composite materials primarily have lower fatigue resistance than appropriately continuous-fiber reinforced composites, which are widely used in pressure vessels, piping, and pipeline systems for all major chemical industries [43].

VI. Conclusion

The composite beams, also known as spars, are utilized in lightweight components like aircraft wings and wind turbine blades to provide primary stiffness against bending deformation. We have shed light on these composite beams in this study. Numerous uses have been reviewed for composite materials, such as Bitable morphing composites for energy harvesting. Additionally, we have reviewed how various mechanical and structural applications require specific material qualities, which cannot be obtained in a one material (such as metal, polymer, ceramic, or alloys) or conventional composite materials (i.e. longitudinal, chopped and laminated fiber composite materials).

References:

[1] Prombut P, Anakpotchanakul C. Deflection of Composite Cantilever Beams with a Constant I-Cross Section. IOP Conference Series: Materials Science and Engineering, vol. 501, Institute of Physics Publishing; 2019.

[2] Talekar N, Kotambkar M. Modal Analysis of Four Layered Composite Cantilever Beam with Lay-Up Sequence and Length-To-Thickness Ratio.Materials Today: Proceedings, vol. 21,Elsevier Ltd; 2020.

[3] Satheesh P, Reddy K, Bhargavi K, Nagaraju C. Tailoring of composite cantilever beam for maximum stiffness and minimum weight.IOSR Journal of Mechanical and Civil Engineering vol. 9. n.d. (2013)

[4] Malik S, Singh DK, Bansal G, Paliwal V, Manral AR. Finite element analysis of Euler's Bernoulli cantilever composite beam under uniformly distributed load at elevated temperature. Materials Today: Proceedings, vol. 46, Elsevier Ltd; 2021, p. 10725–31.

[5] Sayyad AS, Ghugal YM. Bending, buckling and free vibration of laminated composite and sandwich beams: A critical review of literature.Composite Structures, vol.171, Elsevier Ltd; 2017;171:486–504.

[6] Ahmed N, Mamun M, Ahmed A. Vibration Response Analysis of a Structural Metal Mild Steel under the Effect of Crack. IOP Conference Series: Materials Science and Engineering 2021;1092:012037.

[7] Elsheikh, A. Bistable Morphing Composites for Energy-Harvesting Applications. Polymers 2022, 14, 1893. [CrossRef]

[8] Chillara , V.S.C.; Dapino, M.J. Bistable Morphing Composites with Selectively-Prestressed Laminae. In Behavior and Mechanics of Multifunctional Materials and Composites 2017, Proceedings of the SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, Portland, OR, USA, 25–29 March 2017; SPIE: Bellingham, WA, USA, 2017; Volume 10165, p. 10165. [CrossRef]

[9] Sunil, B.R.; Reddy, G.P.K.; Patle, H.; Dumpala, R. Magnesium based surface metal matrix composites by friction stir processing. J. Magnes. Alloy. 2016, 4, 52–61. [CrossRef]

[10] Krishnan, R.; Pandiaraj, S.; Muthusamy, S.; Panchal, H.; Alsoufi, M.S.; Ibrahim, A.M.M.; Elsheikh, A. Biodegradable magnesium metal matrix composites for biomedical implants: Synthesis, mechanical performance, and corrosion behavior—A review. J. Mater. Res. Technol. 2022, 20, 650–670. [CrossRef]

[11]. AElsheikh, A.H.; Abd Elaziz, M.; Ramesh, B.; Egiza, M.; Al-qaness, M.A. Modeling of drilling process of GFRP composite using a hybrid random vector functional link network/parasitism-predation algorithm. J. Mater. Res. Technol. 2021, 14, 298–311. [CrossRef]

[12] Najjar, I.M.R.; Sadoun, A.M.; Abd Elaziz, M.; Abdallah, A.W.; Fathy, A.; Elsheikh, A.H. Predicting kerf quality characteristics in laser cutting of basalt fibers reinforced polymer composites using neural network and chimp optimization. Alex. Eng. J. 2022, 61, 11005–11018. [CrossRef]

[13] Showaib, E.A.; Elsheikh, A.H. Effect of surface preparation on the strength of vibration welded butt joint made from PBT composite. Polym. Test. 2020, 83, 106319. [CrossRef]

[14]Saleh Bassiouny, Jinghua Jiang, Aibin Ma, Dan Song, Yang Dong-hui,Effect of main parameters on the mechanical and wear behaviour of functionally graded materials by centrifugal casting: a review,Met. Mater. Int., 25 (2019), pp. 1395-1409, 10.1007/s12540-019-00273-8

[15] R. Fathi, A. Ma, B. Saleh, Q. Xu, J. Jiang,Investigation on mechanical properties and wear performance of functionally graded AZ91-SiCp composites via centrifugal castingMater. Today Commun., 24 (2020), 10.1016/j.mtcomm.2020.10116

[16]M.E. Kassner, K.K. Smith, C.S. Campbell,Low-temperature creep in pure metals and alloys,J. Mater. Sci., 50 (2015), pp. 6539-6551, 10.1007/s10853-015-9219-2

[17]Q. Xu, A. Ma, Y. Li, B. Saleh, Y. Yuan, J. Jiang, et al.,Enhancement of mechanical properties and rolling formability in AZ91 alloy by RD-ECAP processing,Materials, 12 (2019), p. 3503, 10.3390/ma12213503

[18] Saleh Bassiouny, Jinghua Jiang, Qiong Xu, Fathi Reham, Aibin Ma, L.W. Yuhua Li,Statistical analysis of dry sliding wear process parameters for AZ91 alloy processed by RD-ECAP using response surface methodology,Met. Mater. Int., 27 (2020), pp. 2879-2897, 10.1007/s12540-020-00624-w

[19]Qiong Xu, Aibin Ma, Saleh Bassiouny, Yuhua Li, Yuchun Yuan, Jinghua Jiang, Chaoying Ni,Enhancement of Strength and Ductility of SiCp/AZ91 Composites by RD-ECAP Processing,Mater. Sci. Eng. A (2019), 10.1016/j

[20] B. Saleh, J. Jiang, R. Fathi, Q. Xu, L. Wang, A. Ma,Study of the microstructure and mechanical characteristics of AZ91–SiCp composites fabricated by stir casting,Arch. Civ. Mech. Eng., 20 (2020), 10.1007/s43452-020-00071-9

[21], I.M. El-Galy, B.I. Bassiouny, M.H. Ahmed,Empirical model for dry sliding wear behaviour of centrifugally cast functionally graded Al/SiCp composite,Key Eng. Mater., 786 (2018), pp. 276-285

[22]Bassiouny Saleh, Jinghua Jiang Reham Fathi, Tareq Al-hababi, Qiong Xu, Lisha Wang, Dan Song, Aibin Ma,30 Years of functionally graded materials: an overview of manufacturing methods, Applications and Future Challenges,Composites Part B, 201 (2020), p. 108376, 10.1016/j.compositesb.2020.108376

[23] W.S. Ebhota, T.C. Jen,Casting and applications of functionally graded metal matrix composites,Adv. Casting Technol., 59 (2018), p.

[24]S. Jamian,Application of Functionally Graded Materials for Severe Plastic Deformation and Smart Materials: Experimental Study and Finite Element Analysis,Doctoral dissertation,Nagoya Institute of Technology (2012), p.

[25]R. Singh, V. Bhavar, P. Kattire, S. Thakare, S. Patil, R.K.P. Singh,A review on functionally gradient materials (FGMs) and their applications,Mater. Sci. Eng., 229 (1) (2017), p. 12021

[26] S.H.B. Helal,The Static Analysis of a Functionally Graded Euler Beam under Mechanical Loads,Master Thesis, University of Kufa (2020)

[27] Walaa Mohammed Hashim, Luay S. Alansari, Mohanad Aljanabi,Investigating of Static Deflection of Non-Prismatic Axially- Functionally Graded Beam(2022)

[28] Komal U. Navale , Dr. C. P. Pise, 2021, A Review on High Order Shear Deformation Theory for Orthotropic Composite Laminates, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 10, Issue 01 (January 2021),

[29] Mohamed Ali J S, Hrairi A and Mohamad M 2015 ARPN Journal of Engineering and Applied Sciences 10 10088-95

[30] Sompong N and Prombut P 2017 International Journal of GEOMATE 12 15-20

[31] Deepanshu, Yogesh Mishra, P. K. Sharma, “Modal Analysis of Center Circular Cutout of Laminated Composite Plate and Square Skew Plate by using FEM” IJESRT (2014), 2277-9655.

[32] Mondal, S., A. K. Patra, S. Chakraborty, and N. Mitra. "Dynamic performance of sandwich composite plates with circular hole/cut-out: A mixed experimental–numerical study." Composite Structures 131 (2015): 479-489.

[33] Al-Shammari, Mohsin Abdullah. "Effect of Hole Shape On Free Vibration Characteristics of Unidirectional Composite Plates." Iraqi journal of mechanical and material engineering 15.1 (2015): 31-48.

[34] Kishore, ML Pavan, Sreenivasulu Bezawada, and BC Raghu Kumar Reddy. "Modal Analysis of Rectangular Plate with Central Hole Subjected to Various End Conditions." Materials Today: Proceedings 4.2 (2017): 1653- 1661.

[35] 25. Sayyad, A. S. (2015). "A four-variable plate theory for thermoelastic bending analysis of laminated composite plates." . Journal of Thermal Stresses 38.8: , 904-925.

[36] Loganathan TM, Sultan MTH, Jawaid M, Shah AUM, Ahsan Q, et al. (2020) Physical, thermal and mechanical properties of areca fibre reinforced polymer composites-an overview. Journal of Bionic Engineering 17(1): 185-205.

[37] McIlhagger A, Archer E, McIlhagger R(2020) Manufacturing processes for composite materials and components for aerospace applications. In Polymer composites in the aerospace industry, Woodhead PublishingPP. 59-81.

[38] Ashraf W, Ishak MR, Zuhri MYM, Yidris N, Yaacob AMB, et al. (2019) Investigation of different facesheet materials on compression properties of honeycomb sandwich composite. Semin. EnauKebangs. Bahau, Negeri Sembilan, Malaysia 129-132.

[39] HazrolMD,Sapuan SM,Zuhri MYM,Ilyas RA (2019) Electrical properties of sugar palm nanocellulosefiber reinforced sugar palm starch biopolymer composite. In Prosiding Seminar EnauKebangsaanPP. 57-62.

[40] Ilyas RA,Sapuan SM,Norizan MN,Atikah MSN,Huzaifah MRM,et al. (2019) Potential of natural fibre composites for transport industry: a review. In Prosiding Seminar EnauKebangsaan pp. 2-11.

[41] Johari AN, Ishak MR, Leman Z,Yusoff MZM,Asyraf MRM,et al. (2019) Fabrication and cut-in speed enhancement of savonius vertical axis wind turbine (SVAWT) with hinged blade using fiberglass composites. In Proceedings of the Seminar EnauKebangsaan pp. 978-983.

[42] Alias NA,Fauzi NM, Yusuf B, Razali MM (2020) Lab Scale Study on Integrated GSI for Urban Drainage Systems. In Journal of Physics: Conference Series. IOP Publishing 1529(4): 042008.

[43] Najeeb MI, Sultan MTH,AndouY, Shah AUM,EksilerK, et al. (2020) Characterization of lignocellulosic biomass from malaysian’syankee pineapple ac6 toward composite application. Journal of Natural Fibers 1-13.