Effect of Fiber Orientation and Mechanical Properties of Natural Fiber Reinforced Polymer Composites- A Review

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Abstract- Environmental concern has led to more involvement with the use of environmentally-friendly materials. In this review, a polymer and hybrid composite has been developed using natural fibers. Polymer/hybrid and more sandwich composite was created through a hand laying process and subsequently cold-compressed. Various mechanical tests were performed using a universal tensile tester and an impact tester. A thermal gravimetric analyser study of polyester/kenaf composite and plywood was carried out to determine their thermal stability. Those results show that polymer/hybrid sandwich composite composite's properties highest when natural fiber in anisotropy orientation. The wood found in Anisotropic Orientation could minimise the impact forces of the sandwich composite and make it to be more durable. The polymer/hybrid sandwich composite panel showed improved performance regarding thermal insulation than the conventional plywood sheet. Here is an application of printing of kenaf sandwich composite in anisotropic orientation for beam construction.

Keywords – Natural fiber, synthetic fiber, polymer, orientation and mechanical properties

I. INTRODUCTION

The industrialists and scientists become interested in manufacturing processes of natural fiber reinforced polymers (NFPC), because these environmentally friendly materials emerge in automotive and aerospace industries. In this context, machining processes for NFRP composites pose significant challenges due to the complex structure of natural fibers, necessitating extensive tribological research. The aim of this paper is to use the Merchant model to distinguish the shearing energy from the friction energy in order to investigate the effect of natural fiber orientation on the machinability of NFRP composites. By changing the fiber orientation from 0° to 90° with respect to the cutting direction, orthogonal cutting is performed on unidirectional flax fiber reinforced polypropylene composites. Iosipescu shear tests are often used to assess the mechanical shear activity of the fibers in relation to their orientation. The results validate the key model assumptions, demonstrating the applicability of the Merchant model to the machining study of NFRP composites. The shearing and friction energies that govern the cutting behavior and chip forming of the NFRP composite are significantly affected by fiber orientation. The natural fiber orientation is thus intimately connected to the machined surfaces that result[1] In order to investigate the low level scratches of a short glass fiber (SGF) reinforced polybutylene terephthalate (PBT) composite, the low level scratches with the normal test case were prepared under the load. The impact on the scratch behavior of the PBT composites and the underlying mechanisms for scratch damage were investigated. The addition of SGF affects normal critical charges for incipient deformation of the fish-scale and material removal. The fracture of glass fiber was observed and its mechanism of damage analysed. The results show that while enhanced PBT's bulk mechanical properties, glass fibers generally have low scratch strength. The guidelines for the design of SGF-reinforced PBT are also debated[2] The effect of melt electrospun fiber arrangement on cell behaviour has not yet been examined thoroughly. The cellular orientation is particularly important for ligament tissue engineering because the native tissue has a lot of cells aligned. The aims of this study were to investigate the response of hMSC to electrospun scaffolds fabricated by melt electrospinning. An alignment of cellular patterns was present in 4 days cultural values where template position of the hMSCs was illustrated and this effect was maintained over the culture time and rapidly lost in the crimped pattern. By rolling the scaffold, it formed bundles which were braided, and placed with bone compartment. The mechanical properties of BLB constructs were assessed under both quasi-static and cyclic conditions. The in vitro maturation of the BLB tissue resulted in significant decreases in tissue stiffness. The study has shown that the gels tested are flexible and deformable (regardless of the pattern). We can infer that melts electrospinning writing fiber organization can induce spontaneous cell alignment and that, large cellularized BLB can achieve mechanical resilience under cyclic stretching[3]. The study evaluated the effect of muscle fibre orientation and measurement interval on raw lamb meat drip losses. Muscles were obtained from different muscle bellies, 100 semimembranosus muscles and 100 longissimus lumborum muscles. Two semi-spherical cores with vertical and horizontal fibre orientations were removed from each SM. In each LL, one core of the fibre was removed. Then, the drip rate was recorded across four different 24-hour intervals with this paper. This study suggested that fibre orientation had no effect on constant head losses. both SM and LL lost started to increase, linear to measurement interval. For the four measurement intervals, the SL were higher than LL. When testing the lamb meat drip loss using the EZ method, the interval between measurement is advised to be more than four hours[4]. The composite materials include a significant part of most of today's applications because of their properties like high stiffness and strength to weight percentages, excellent stability, fatigue resistance, and good corrosion resistance. The performance of polymers is focused on the mechanical properties such as tensile, compression, flexural, impact, and vibration. It is necessary to have physical performance for a long period in particular conditions. This research examined the effect of fiber orientation on vibration for composite beam under nonuniform boundary conditions. Composite beam specimens were fabricated by glass and epoxy resin with different amount of fiber in the beam. Dynamic properties, such as natural frequency and damping factor, were determined experimentally via modal analysis. The accelerometer is mounted on the specimen and a National Instruments data acquisition system (NI-DAQ) is used to obtain the outputs. A graph in both the time and frequency domain is obtained. Using the time-domain graph, damping ratios were derived by using the logarithmic decrement method, and frequencies from the graph were calculated. An analysis of the numerical simulation was held out during ANSYS with various initial conditions. The influence of fibre content on natural frequency and damping factor was investigated. It was found that fiber orientation increased from 0° to 90° and damping ratio increased[5].

II EFFECT OF FIBRE ORIENTATION ON MECHANICAL PROPERTIES

The mechanics of basalt bidirectional mat fiber based epoxy composites were examined in the present study. Composites are also prepared in different phases such as 45°, 60° and 90° laid up hand lay. The mechanical behaviors like tensile, flexural, impact strength, and hardness were researched. Result indicated that 90 degree fiber orientation composite has the maximum mechanical properties[6]. In this composition, 20% jute is fixed while other was varying with epoxy. The effectiveness of fiber loading, direction, and orientation of was evaluated. In this way, four different orientations were introduced for manufacturing process of the polymeric matrix. The tensile force was determined to be maximum for 30% fiber loading with 15% fiber orientation for polymers. fiber loading for 50% composites resulted in higher void content. Fiber cracking and fiber pull-out was shown by the fractured surfaces morphology of the composite[7].

2.1 Effect on Mechanical and Thermal Properties of Multi-Layer Laminate Composite

The effect on mechanical and thermal properties of multi-layer laminate composite was studied by the use of the fiberglass type and the addition of a very small amount of Nano filler in resin. The results showed that laminate composites can be obtained from the control of fiberglass and dispersing nanos on the resin. Using fiber glass fiber impact strength increase by 17% – 24%. The degree of stiffness of continues composite material is 7 percent greater than that of random fiberglass composite. The results of this study point out that it's possible to produce laminate composite with excellent thermal and mechanical properties[8]-[9]. This article presents analysis of the problem of the research in the direction of the effects of fiber orientation on the properties of polymer composites. The research methodology uses the fabrication of woven fabric composites with 90, 60, and 45-degree components. Tensile testing was done through a tensile machine. The maximum load and the ultimate tensile strength were the highest in the sample with 90-degree orientation. The Young's modulus and also the modulus of toughness are the lowest in 45° orientation. The orientation plays a great role in determining the optimum property for each application[10]-[11].

2.2 Effect of Fiber Orientation on Tool Wear

The wear resulting from edge-trimming fiber orientations on working points when carbide end-mills cut fiber reinforced plastics. The tool wear and production were examined using scanning electron microscopy and digital light microscopy at eight different cutting distances. The 45º plies yielded extensive flank wear while the 90º plies and ductile bars yielded the worst edge radius rounding and worn area regardless of the speed at which they are spun. This is caused by the broken carbon fiber particles interacting with the cutting edge. The 0° ply angle has minimal interaction between carbon fibers and plies with reduced chip formation[12]. The mechanical performance of an SFRP will be affected by several factors like fiber density, fiber orientation, and compaction degree. Parts with complicated geometry and varying wall thicknesses might also have serious problems if a proper testing protocol is not done. By investigating the effect of fiber orientation on its long-term time-dependent behavior, we are looking into the influence of polyphenylene sulfide fiber orientations on the shear strength. It is clear that the composite creep compliance is purely regulated by matrix material properties[13].

2.3 Effect of Stacking Sequence and Fiber Orientation

Interbreeding method in which over one type of fiber can be integrated in the same matrix allows designers to get closer to the true capacity in fiber-reinforced composite materials. It is complicated dynamic conduct of an interlayer hybrid composite because the stiffness of each layer in the composite can induce or alter the modal parameters. This research concerns the dynamic behaviour of the hybrid composite materials. The finite element code is used to get Eigenvalues and Eigen vectors for glass & carbon fiber reinforced hybrid polymer composites (ANSYS). The effects of fiber orientation and inter-layer fiber sequence on the eigenvalues and eigenvectors are being investigated. The presented case will be very helpful in weather forecast research [14].

2.4 Effect of reinforcement ratio

The direct shear performance of rebar-reinforced UHPC was investigated in this paper. Nine distinct specimens were tested using direct tension at both material and component levels. Some of the variables such as reinforcement ratio, fiber length, and fibrous chemical treatment are variable in the experimental session. The experiments demonstrated that the UHPC participants exhibited the fatigue failures with the failure of rebars. A single main crack was revealed, together with a number of minor cracks. It is verified that longitudinal reinforcement can improve elastic post-cracking behavior and their first breaking load. Raising the reinforcement ratio increases yield and overload capacity. Reinforcement increase has very little effect on the pre-cracking rigidity and the first cracking load. Besides, simultaneous flexural strength can greatly increase the post-cracking stiffness, first cracking load, yield load and peak load. However, this method could have little effect on the stiffness at room temperature. Besides, the addition of zinc phosphates had no noticeable effect on the strength development of reinforced fibres. Finally, we were able to express the tensile strength and compression modulus of UHPC members[15]-[16].

2.5 Effect of the injection moulding fibre orientation

The overall fatigue life of the 50wt% fiber reinforced nylon 6,6 composite is based on the effects of the fiber orientation distribution on the fatigue life. A multi-stage approach is formulated to predict the fatigue life of plaque samples cut at various locations. Models for injection moulding, parameter prediction, and cyclic fatigue lifetimes have been tested and applied by state-of-the-art experimental techniques. X-ray images were taken of the plaque to measure the fibre direction at a comparison location away from the side walls. 3-D Digital Image Correlation has been used to quantify full-field strain distributions. Fatigue test was carried to start generating stress-life curves for different fiber direction distributions. The results were highly anisotropic. Strength, stiffness and fatigue resistance were improved with specimens connected with the injection direction. A tensile strength value 20% higher was observed at the core edge compared to that of specimens cut at the reference location. Fasting also lowers fatigue. The models of fatigue predict good results at the reference location and also at locations that are halfway between the reference and the experimental settings[17].

2.6 Effect of through thickness separation of fiber orientation

The effect of fiber-orientation separation on their low velocity impact response is studied through the thickness of thin composites. The unidirectional glass fiber reinforced epoxy glass is used for composites production. The two composites considered have different layups with fibers of the same and different orientations through the thickness. The composites are used to simulate low velocity impact tests. The composites are evaluated by different parameters such as damage degree, first damage, maximum force, first cracking energy, elastic strain energy, elastic, residual, and maximum displacement. Of the two composites, it is observed that the composite with fibers having -45° and 45° orientations separated by two layers with fibers having 90° and 0° orientations that levels of deformation and recorded force and square-root delaminated area are lower and higher, respectively. When in the case of composite of layers with 0° orientations and layers with 90° orientations, recorded force is lower and deformation and square-root delaminated area are higher. The composite with low elongation strength is having a comparatively more lateral spread of delamination and inter-layer opening than that of the composite with high elongation strength. Separating two layers of composite with 90° and 0° fiber orientations helps prevent the spread of the damage across the composite[18]-[19].

2.7 Effect of Fiber Orientation on The Post-Cracking

The experimental study on the tensile behavior of reinforced concrete steel fiber after cracking (SFRC). A broad-based experimental campaign was carried out in this respect on the basis of Uniaxial Tensile Tests (UTT) for notched rods as well as three-point bending tests (3 PBTs) for notched beams. Based on test results, the advantages of adding fibers to the post-cracking behaviour, fibers increasing their toughness with the ultimate breakage width, were thoroughly studied. The uniaxial tensile laws of SFRCs were obtained directly by UTTs and retrieved by three PBTs indirectly by conducting a reverse analysis procedure. The energy fracture was usually higher in the latter case. The SFRC post-cracking performance with the distribution of fiber and orientation was demonstrated to be highly dependent and measured with an image-analysis technique[20]-[21].

2.8 Mechanical strengthening effect

When reinforced by glass fibres, polyester resin improves its mechanical property. In marine applications, these glass fiber enhanced Polyester composites have been widely used. The polymer composite of three different glass fibers has been strengthened with isoptalic polyester resin in this study. By using the 60%-40% volume fraction of glass fibers and polyster resin, 50%-50% & 40%-60% were produced for different forms of glass fibre, such as CSM

450, WRM 610 and COMBO MAT 910 laminates. These composites were manufactured by hand-lay and subjected to 80°C post-curing. The laminates are tested for their hardness by Barcol, tensile testing, flexural testing, absorption of water and glass content to determine the best combination of the composites produced. COMBO MAT 910 was called superior to all the other laminates based on different mechanical property investigations[22] As the production technology for composites materials is becoming advanced, it is becoming increasingly used in engineering applications. The purpose of this work is to explore the reaction of the idealized composite subsystem. The method of Statistical Energy Analysis (SEA) is used to study the vibrational response theoretically. In the prediction of vibration parameters of coupled structural elements and acoustic amounts, S.E.A. techniques depend in large measure on the precise estimate of three parameters: modal densities, loss factors of damping and subsystem coupling load factors. This paper experimentally and theoretically obtains the modal density of the rectangular composite plate made of fiberglass. The effects of fiber orientation changes on modal density of identical plates with various fiber orientation have also been experimentally analysed[23].

2.9 Effect of Fiber Orientation in Fatigue Properties

This research aims to study the influence of fiber pattern and infill type on the tension-tension fatigue properties of FRAM parts with a load ratio of 0.1. The specimen is created with different fibers laid in different orientations. Based on the experimental test, the most resistant specimens turned out to be carbon fiber with 0 rings isotropic infill and 1 ring isotropic infill. In conclusion, increasing the number of rings for spherical infill specimens improves fatigue life, while increasing the number of rings for isotropic infill actually reduces the fatigue life[24].[27-29]

2.10 Effect of fiber orientations on surface grinding process

One of the most challenging problems of weaving the ceramic matrix composite is its machining. For elucidation of the interface of ceramic composites, an innovative model material composed of nonlinear CVI-C/SiC was equipped and ground. The polymer was ground in three typical directions, then investigated in laboratory testing of its surface grinding process. Besides, the performance properties and grinding method of the micro-composite were analysed. The results show that brittle fracture is the dominant removal mechanism for the grinding of the C/SiC composite, while the devastate form of the composite materials is mainly the syntheses of the matrix cracking, interfacial debonding and the solid-fluid interfaces. The gradation of the surface is as follows: Longitudinal-Normal>Transverse-Longitudinal. The grinding parameters (feed speed, feed depth, grinding speed) have a strong influence on the surface roughness and the grinding force of a mill. Based on the data obtained, the porosity of the woven ceramic composite matrix could be predicted. It is expected to provide useful guidelines to the development of the composites[25]-[26][30-31].

III CONCLUSION

The effects of fiber direction concept can be designed to simulate using complex formulas and methods. Macroscopic fiber orientation frameworks are computationally efficient for large industrial applications. The constraint of those models is one's naturalistic nature and the dependency on a fixed set of quantified values. The problem is determining what are acceptable variables for a particular equipment. Microscopic fiber models are computationally expensive, but also have a larger physical basis. Combining factors of both scales can provide useful numerical solutions of the VEP. Another prospect is the forecast of optimal parameters in macroscopic scale by simulation, or the data-based prediction of macroscopic parameter.

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