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Review on Mechanical properties and Fatigue life of E-Glass/Bamboo Fiber Reinforced Polymer Composites

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ABSTRACT

Bio-medical prosthetic devices are artificial replacements that are used in the human body to function as original parts. The materials used for prosthetic aids must be non-toxic, biologically and chemically stable, and have sufficient mechanical integrity and strength to withstand physiological loads. The role of natural and manmade fibers reinforced hybrid composite materials are growing in a faster rate in the field of engineering and bio- medical science due to its favorable mechanical properties. Bamboo is one of the most important renewable, fast growing natural resource and available everywhere around the world. Despite the attractiveness of Bamboo fibers as low cost materials, there suffer from lower strength, lower modulus, and relatively poor moisture resistance, when compared to glass fiber. Glass fiber is the most widely used reinforcing agent. Effective hybridization of Bamboo fiber with stronger E-Glass fiber is one of the solutions to overcome these limitations. The addition of CaCO3, TiO2, SiC and Al2O3 microfillers to the hybrid composites will enhance the mechanical properties of fiber reinforced polymer composites. This paper presents review on mechanical properties and fatigue life evaluation of E-Glass/Bamboo fiber reinforced polymer composites in the field of bio-medical prosthetic devices.

Keywords: *Artificial limb , Bamboo Fiber, E-Glass Fiber, Hybrid Fiber, Mechanical Properties, Fatigue Testing.*

1. INTRODUCTION

The bio-material with natural fibers and synthetic fibers with polymer as matrix has a huge applications in biomedical field. To assess the mechanical properties of biomaterials with composite materials many researchers have carried out extensive research. Synthetic fibre like Glass, Kelvar, Carbon and Aramid has been frequently used in aerospace and automobile industries due to low density, high stiffness and strength. Environmental awareness today motivates the researchers, worldwide on the studies of natural fiber reinforced polymer composite and cost effective option to synthetic fiber reinforced composites. The natural fibres such Jute, Sisal, Banana, Pineapple, Hemp, Bamboo, Areca, Abaca, Kenaf and Bagasse, Lantana-Cammar, and Coir fibers are obtained from various sources like plants, animals and mineral resources [1-10]. Among many of the natural fibers, bamboo fiber is one of the most promising one, because of its low cost, light weight, short growth cycle and high availability. These fibres have potential to replace these synthetic fibres for environmental concern due to its properties such as low cost, lightweight, combustibility, environmental friendly, high flexibility, renewability, biodegradability, non-abrasivity, non-toxicity, high specific strength, high toughness, and easy processing [11-19]. Natural fibres also suffer by some limitations like low strength, lower modulus and high water absorption property [4].These limitations can be improved by using hybridization technique [6]. Hybrid composite are those which have more than one reinforcement in a single matrix or single reinforcement with multiple matrix or multiple reinforcement with multiple matrix. There is an increasing interest in hybrid composites made by combination of two or more different types of fiber in a common matrix because these materials offer a range of properties that cannot be attained with a single type of fiber [6, 8-10]. The stiffness and strength of hybrid composites can be overcome by structural configurations and better arrangement in the sense, placing the fibers in specific locations for highest strength performance. Hybridization can increase the mechanical properties of single fiber polymer composite [20]. The addition of $CaCO_3$, SiC, Al_2O_3, and TiO_2 microfillers to the hybrid composites will enhance the mechanical properties of the materials [21-22]. In this review, mechanical properties, and fatigue life estimation of fibre reinforced polymer composites are discussed.

2. Characterization of bamboo fiber reinforced polymer composites

Many researchers have reported studies on mechanical properties of Bamboo fiber reinforced polymer composites. Shinji Ochi [23] studied the tensile properties of bamboo fiber reinforced biodegradable plastics. Steam explosion method was used to extract bamboo fibers. High strength biodegradable composites were made using an emulsion-type biodegradable resin as the matrix and bamboo fiber bundles as the reinforcement. The unidirectional fiber reinforced composites were fabricated by hot pressing and bamboo fiber bundles with a fiber content of 70% showed high tensile strength of 265 MPa. Kazuya Okubo, et.al.[24] authors presented the development of ecocomposites for ecological purposes using bamboo fibers and studied their basic mechanical properties. Authors reported that when three different types of Bamboo fiber were designated as short fiber bundle, alkali treated filament, and steam exploded filament mixed with polylactic acid. The tensile strength and Young's modulus of polypropylene based composites using steam-exploded fibers increased about 15 and 30%, respectively, due to well impregnation and the reduction of the number of voids, compared to the composite using fibers that are mechanically extracted. Vikram S. Yendhe, et.al.[25] investigated the mechanical behaviour of short bamboo fiber reinforced epoxy based composites. Bamboo fibers with different length and fiber contents were reinforced in epoxy resin to fabricate composite materials. The effect of fiber length and content on the mechanical properties such as tensile strength, flexural strength, impact strength, and micro-hardness of short bamboo fiber reinforced epoxy based composites were studied. Sandhyarani Biswas [26] reported the physical and mechanical properties of short bamboo fiber reinforced epoxy composites were studied. Composites were fabricated using short bamboo fiber at different fiber loading. Sreenivasulu S, et.al.[27] studied mechanical properties of short bamboo fiber reinforced polyester composites with alumina filler. Hand lay-up technique was employed to fabricate composites. Tensile strength of the composite material with filler increases with the increase in filler content by keeping 45% of bamboo fiber constant and flexural strength of the composite material with filler increase with increase in filler content up to 30% by keeping 45% of bamboo fiber constant.. Many researchers have added synthetic fibre with natural fibre reinforced polymer composite and they found positive result of hybridization in terms of increase in mechanical properties of single natural fibre reinforced polymer composite. Thwe M.M., et.al.[28] studied the characterization of bamboo-glass fiber reinforced polymer (BGFRP) matrix hybrid composite and found that the mechanical properties of the BGFR polypropylene hybrid systems depend on fiber weight ratios, fiber length, and adhesion characteristics between the fibers and the matrix. The result with different bamboo fibers 3 mm and 6 mm were obtained using mould press method and 10 % to 40 % bamboo fiber was loading with & without MAPP. Samal S.K., et. al.[29] studied the effect of addition of Bamboo-Glass fiber reinforcements to the polypropylene matrix (BGRP). Comparisons were made between the BGRP and the virgin polypropylene as taken fiber loading as a parameter. Results showed that the composites prepared at 30% fiber loading with 2% MAPP concentration showed optimum mechanical performance.

Krishnaprasad R., et. al. [30] presented the investigation of microfibrils extracted from raw Bamboo Composites based on polyhydroxybutyrate and bamboo microfibrils were prepared with various microfibril loading. The results of tensile strength and impact strength of the composites were found to be increasing with increase in the loading of bamboo microfibrils, reached an optimum and thereafter decreased with further increase in microfibril loading.

3. Fatigue behaviour of fiber reinforced polymer composites

Many researchers have reported studies on fatigue behaviour of fiber reinforced polymer composites [31-38]. Claude Bathias [39] studued the fatigue of high performance polymer matrix composite materials. The specific endurance strength of composite materials subjected to cyclic tensile loading. Cyclic compressive loads lead to important damage of composites. Impact damage was a key factor to predict fatigue endurance especially in compression. The specificity of the fatigue of composites depends on the damage mechanics such as transverse cracks, debonding, delamination, thickness, edge effects, and staking sequence. Abdul Hakim A., et.al.[40] investigated fatigue life of epoxy and its unidirectional kenaf fibre reinforced epoxy composites subjected to tension-tension fatigue loading. The fibres were alkaline treated with 6% Sodium Hydroxide solution prior to composite fabrication using hand lay-up technique. The specimens were cycled to tension- tension fatigue loading at stress ratio of 0.5 and frequency of 5 Hz to determine the fatigue life and its life characteristic at given 5 stress levels. Fibre content ratios were found to affect fatigue life strongly on the low cycle fatigue regime as illustrated with stress level versus cycles to failure, but it may not showed any significant improvement at very high number of cycles. The existing models developed by Mandell, Manson-Coffin and Hai-Tang were adopted to predict the fatigue life. Sharba M.J., et. al.[41] studied the effect of hybridization of kenaf-glass fibers reinforced unsaturated polyester on fatigue life. Kenaf, Glass, and hybrid composites were fabricated using hands lay-up method with 30% of weight fraction. Fatigue specimens were prepared and the fatigue test procedure was followed according to ISO 13003. Fully reversed loading condition (tension-compression) fatigue test was conducted with a stress ratio of 1 and stress levels 55-85 % of the ultimate static stresses, all tests were conducted at 10 Hz of frequency to determine the fatigue stress levels. Chandrashekhar Bendigeri, et. al.[42] investigated experimental fatigue life of the polymeric biomaterial was analyzed through analytical method to matches the results of the experimental values. Fatigue experiment was conducted as per the ASTM D3479 standard with the specimens of different fiber volume fractions of 15%, 22% and 35%. Tension-Tension fatigue was conducted with a stress ratio of 0.5, stress levels 50-90 % of the ultimate tensile strength, and 5 Hz of test frequency. The existing models developed by Mandell, Manson-Coffin and Hai-Tang were adopted to predict the fatigue life of polymeric composites. The FEM method was adapted to further verification of experimental and analytical methods.

4. Development of Artificial Limbs

Prothetists and Orthotists help people who acquire disability or were born with physical defects, by fitting them with artificial supports. Prosthesis is an artificial device used to replace a missing body part, such as a limb, tooth, eye, arms and legs, or heart valve. For optimal prosthetic performances, the socket must be facilitate the motion. The forces, generated by the residual limb through gait motion, must be efficiently transmitted from the limb to the prosthesis; thus, any relative motion exhibited between the residual limb and the socket will challenge successful ambulation, thereby increasing the fatigue and discomfortness. Always Patients except to receive prosthesis with proper fit, ultimate comfort and functionality. Additionally, the prosthesis must be light weight and cosmetically appealing. Majority of the failure of prosthetic components are fatigue related under cyclic walking loads. Materials and mechanical properties of the prosthetic socket were studied by many investigators [43-48]. Current T.A., et.al.[43] reported the structural strength of various transtibial composite sockets. Five different reinforcement materials and two resin type were used to construct the socket. Sam L. Philips, et.al. [44] initiated a data base on material properties of typical laminations used in prosthetic limb sockets. Authors prepared the samples of common prosthetic laminations to tensile and bending tests. Eight varieties of lay-up materials were each laminated separately with one of three common resins resulted in 24 combinations of fiber/resin laminates. Neama,et.al.[45] presented analyses for below knee prosthetic socket. Socket stress distribution was performed on three types of sockets, polypropylene (5mm), polypropylene (3mm) and standard laminate (8 layers of nylglass) (3mm) sockets to determine the stress path through the prosthetic socket during gait cycle. Ibrahim [46] investigated the structural strength of the syme prosthesis by proposing two laminate with different reinforcement materials. Mohammed S.H. [47] investigated the ankle-foot orthoses numerically and experimentally using perlon-carbon-fibers-acrylic materials instead of typical used polypropylene materials. Kahtan, et.al.[48] studied the tensile and fatigue Characteristics of Lower-Limb Prosthetic Socket Made from composite materials with Epoxy reinforced with five types of woven fibers and particles such as perlon, glass, carbon, hybrid (carbon and glass) with micro & nano Silica particles. Carbon reinforced epoxy composites gave optimum experimental, numerical and theoretical results which make them the best candidate to improve the fatigue characteristics of trans-tibial prosthetic socket.

5. Biocompatibility Tests

Biocompatibility is the capability of artificial replacements that are used in the human body to function as original. Various Biocompatibility tests [49-53] to be performed on material or bio-medical prosthetic devices are as listed

- Cytotoxicity
- Dermal Sensitization
- Primary Dermal Irritation (PDI)
- Intracutaneous Reactivity Test
- Acute Systemic Toxicity
- Pyrogenicity Testing
- Tests for Genotoxicity
- Implantation
- Eye Irritation Test
- Hemolysis
- Thrombogenicity
- Water Absorption Test
- Carcinogenicity.

6. Conclusions

The following conclusions can be drawn with regard to development, testing and analysis of E-Glass/Bamboo with epoxy resin.

- Mechanical properties like tensile, compression and flexural property of single fibre reinforced polymer composite can be improved using hybridization technique.
- Fiber lengths, orientation, concentration, dispersion, selection of matrix, and chemistry of the matrix need to be investigated thoroughly.
- The results of fatigue experiment values will provide useful life of the material that can be used with various applications of biomedical industry.
- Biocompatibility tests to perform shows the material being compatible to use in bio-medical prosthetic devices.

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