Evaluation of mechanical strength of combined natural fiber reinforced polymer composites

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Abstract: By witnessing the evolution of material science in the engineering fields, many engineering products are manufactured by fiber reinforced composites instead of metals. Most of the industries shows interest in these polymer composites than the metals because of their advanced properties and their easiest way of manufacturing processes. In this project natural fiber reinforced polymer composites (NFRPCs) were fabricated using hand layup method. This project aims at investigating the mechanical properties of the NFRPCs in order to fabricate this material by the cheapest and easiest way. Here three composite plates were manufactured, where Bamboo bark or (Bamboo Culm) and typha angustifolia (cattail) were used as reinforcing material and General epoxy resin was used as a strong adhesive material to bind these fiber. These three plates are to be compared. One of the plates is random chemical treated; the second is bi-directional chemically treated and the third plate is unidirectional chemically treated. The mechanical properties in this study include the tensile, impact strength and flexural modulus. The flexural test was taken at these plates and with the help of test’s results. Mechanical properties of the plates were compared and the plate which has more strength can be selected.

Key words: Composite, Fibre reinforced, Bamboo, Flexural strength

I.Introduction

By looking at the past two centuries where industrialization begins its mass growth, it is obvious that every engineering field had encountered serious issues on manufacturing certain products with only metals. Not just because metals cause more weight to the product but it also leads to corrosion which was overcome only by rapid replacements of the same product which reflected in huge capital loss. This made the industries to concentrate on developing the fabrication techniques to avoid these problems and that gave them a bright side on discovering the usage of non metals. Speaking of the present, the unrelenting passion of the engineering fields on working with the non metals paved the path of inventing the fiber reinforced polymer (FRP) composite materials. The FRP are composites which are highly been used in almost every type of automobile areas in manufacturing the engineering structures. Reinforcement plays a role in increasing the mechanical properties of a pure system. Concrete is the best example for a reinforced material as it tends to fail in tension when left in its pure form. But when added with steel it gains enormous strength to withstand any load or tension applied to its surface. Hence the reinforcing of polymer matrix with fibers is known as fiber reinforced polymers.
The marine industries are especially interested in these fiber reinforced plastics as it helps in enhancing the performance of commercial and military vessels [1]. Fiber reinforced plastics (FRP) composite materials possess superior performance in corrosion resistance, incredible sound and thermal insulation and strength and stiffness to weight ratios. The enhancement of various engineering structures by using FRP composites are achieved by designing a perfect manufacturing methods. On speaking of fibers, they are classified into two categories namely Synthetic fibers and Natural fibers. Synthetic fibers are manmade fibers which are manufactured by chemical synthesis method. Natural fibers are the ones that are obtained from natural sources. Some of the examples of the natural fibers are cotton, silk, wool. Since the natural fibers are eco-friendly in nature, many industrial sectors show great interest in working with these fibers. The composite materials are also considered as homogeneous material in the case of a microscopic scale that it tends to have the same physical property at any portion of the composite material [2]. The composite materials are produced by combining two different materials, whose properties may not be similar to each other, into a new material which are suitable for any specific application.

The concept of fabricating the composites are made up of individual materials referred to as constituent materials [3]. The two main categories of the constituent materials are matrix and reinforcement. The role of matrix in composite materials are to give shape to the composite part, protect the reinforcements to the environment, transfer loads to reinforcements and toughness of material, together with reinforcements [4]. The matrix material basically consists of adhesive property which enables to support the reinforcement material, maintaining their relative positions. Epoxy resins are mostly used as matrix in many fiber reinforced composites and glass fibers are the most frequently used reinforcing material in the current days. Mechanical properties of fiber reinforced composites always depends on the constituent material properties such as orientation, void content and quality of the material [3]. For further better performance of these composites a filler material is added to the composite material. The purpose of filler is not just to increase the stiffness and temperature resistance but also to reduce the cost of processing significantly. This project focuses on fabrication and evaluating the mechanical properties of the natural fiber reinforced polymer (NFRP) composites by hand layup method. The hand layup method is highly capable at the production of very complex parts which exhibit high performance, but can be an expensive and also be a variable process (M.Elkington, D.Bloom, C.Ward, A.Chatizimichali & K.Potter., 2015) [7]. For a cost effective production, wet hand layup becomes a favourable technique than the vacuum infusion technique which involves high investments in tooling [8].

In this study, the short history of FRP boats, mainly in USA and Europe, is given. Future trends of FRP applications in marine industry in terms of materials, production methods and environmental issues are presented to the interest of naval architects and the potential research topics are also underlined briefly [9] stated that the use of compatibilizers in jute fiber increases its mechanical properties. The usage of filler may not be necessary, but its presence in the process could assure more stiffness to the composite. Abdullah Al Mahmood [10] had concluded that the mechanical strength of the composite increases as the filler material is increased, than the absence of the filler over the composite.

The thought of using natural fiber composites grants various benefits as the cost of extracting the fiber is very less, since the fibers are obtained from natural resources like plants and animals. It also enables a pollution free environment during production which results in causing minimal health hazard and eco-friendly nature. Arora and Mohanty [11] had found that, though the glass fiber reinforced composites are widely used by almost all industries, natural fiber reinforced composites are environmentally superior at particular applications. Therefore the objective of this study is to fabricate a composite material which is eco-friendly in nature especially when used under water, where it prevents from any toxic reactions when the material is exposed to water. The main focus of this project is to make a composite material which possess high corrosion resistance that could be a major preference on replacing the metal
bodies of underwater machines. Mechanical properties assessed in this study include tensile, compressive and in-plane shear properties.

Hybrid composites with three sets of vacuum infusion layers showed the highest tensile mechanical properties while those with two sets had the highest mechanical properties in compression. The batch homogeneity, for the GFRP fabrication processes, is evaluated using the experimentally obtained mechanical properties [12]. In this experimental and numerical results indicate that architected core structures can be utilized to tailor the bending properties as well as failure mechanisms. These findings offer new insights into the study of nonlinear mechanical response of sandwich structures, which can benefit a wide range of industries and applications. The findings presented here provide new insights into the development of sandwich composite structures with unique mechanical properties for a wide range of mechanical and structural applications [13].

The aim of this work is to study the structural behavior and the effect of the flexibility of composite panels on hydrodynamic loads and the dynamic deformation response experimentally and numerically. To study these effects, composite panels with two different rigidities were subjected to various impact velocities and investigated. It should be noted that all the panels tested at a 10° dead rise angle. A high velocity shock machine was used to maintain constant velocity during water entry. The results of this study can help vessel designers to understand the influence of the elastic structural behavior on hydrodynamic loads. Moreover, this facilitates the decision-making process by enabling designers to concentrate on and optimize the design of critical regions, especially close to the chine edge of the panel [14]. The objective of current study of fiber reinforced polymer matrix got considerable attention in numerous applications because it has good properties and greater advantages of natural fiber over synthetic fibers in terms of its relatively low weight, low cost, less damage to processing equipment, good relative mechanical properties.

2. Materials and Method

In this work, fibers were collected from two natural materials namely Bamboo Bark or (Bamboo culm) and Typha angustifolia L.(cattail). These fibers were used as reinforcing material and epoxy resin was used as adhesive agent to fabricate two combined natural fiber reinforced polymer composite plates. Plywood is used to make the square mould and bolts, nuts, screws are used to fasten the mould. Brushes are used to apply the resin uniformly above each layer of the reinforcement and paint rollers are used to level the layers. Mixing containers and mixing sticks are used to mix the resin solution. Rubber gloves, aprons, a pair of leather shoes and safety glasses were used to ensure clean and safe fabricating environment. A drilling machine is used to drill holes on the plywood for placing the bolts and nuts. In this project Hand Layup method was used for preparing the layered composite samples.

2.1 Hand Layup Technique

In Figure.1 shows the Hand Layup methods, Is the simplest composites moulding method, offering low cost tooling, simple processing and a wide range of part sizes. The initial step of the hand layup method is to prepare the mould to the required structure to obtain the final product. A mould can be made of any material like iron, wood, plastic etc., depending upon the processing cost. The second step involves in determining the type of fibers to be used and their required amount of weight. Gel coat is first applied to the mould, using a spray gun for a quality surface. When the gel coat has been cured sufficiently, the natural fiber reinforcements is manually placed on the mould. Once the first layer is placed, the laminating resin is applied by pouring, brushing, spraying or also by using a paint roller. Using a roller provides better benefits as it squeezes the resin over the reinforcement and removes the entrapped air, thus prevents the layers from the presence of voids. Subsequent layers of fiber reinforcements are added consecutively to build the laminate thickness. In certain situations the process may require some additional materials to increase the stiffness of the composites. Hence, low density core materials such as End Grain Balsa, foam and honeycomb are commonly used to stiffen the laminate. This technique is also known as sandwich construction. When the required thickness of the composite is obtained, a releasing sheet was put on the top of the composite to cover its surface from the open air and a light rolling operation is done before curing. A weight of approximately 5 kg of a wooden block or any other material is placed on the top of the composite and it is left undisturbed to cure for about 48 to 72 hours. When the composites are
dried to solid, demoulding operation takes place where the moulds are removed and the composites are then allow for hardening operation.

**Figure 1** Flow chat of the Hand Layup method

3. Experimental Details

3.1 Procedure

Initially a plywood board was taken with dimensions 3ft by 1ft to make the mould for the required pattern. Plywood was considered instead of metal mould because of its lower cost, light in weight and its ease of handling. A square shape for the mould was cut at the centre of the plywood to desired dimensions. The fibers from bamboo culm and cattail were extracted by mechanical crushing and the extracted fibers were chopped into strands. The combined fibers were weighed with the help of electric weight balance machine. The epoxy resin was weighed based on the weight of the fiber mixture on different compositions. Three types of composite plates were made for evaluating the mechanical properties for each.

At first, the chopped strands was taken randomly and filled inside the square mould. When the first layer is filled, resin was poured into the mould and was distributed evenly at all corners of the mould with the help of a brush. Once the first layer is done, the second layer of chopped fibers were filled over the matrix surface and compressed by a small wooden block with a mild pressure to level the layer and to remove the presence of excess resin. The process was repeated for each layer of resin until the mould is completely stacked. Once the desired thickness is achieved, the composite plate were set to be cured for 48 hours at room temperature.

After the composites is completely dried, the plate is withdrawn from the mould by cutting the plywood around the sides of the mould. The unnecessary edges of the composites were cut by grinding machine. By using universal testing machine, tensile test for the samples were taken according to ASTM D3039 test standard. Compression test for the test specimens were performed according to ASTM D3140. According to ASTM D790 test standard, flexural strength test for the samples was taken.

4. Results and Discussion:

The strength of the material increases when constant loading on the composite plates was performed. Here, fiber act as the main load carrying agent in these composite plates. It has been found that very small gaps were created during the testing period. These small gaps are
known as voids. The presence of these voids result in affecting the mechanical properties of the samples.

Figure 2. Shows the resultant obtained from the stroke length force of the arm when there is a change in stroke length of the arm. Here, stroke represents the length of the vertical motion of the arm during the testing period. When the stroke length is at 7mm, a force of 325 N was given as a load to the sample specimen and it has been found that at this stroke to force ratio the maximum Tensile Strength of 1.30 MPa was obtained for the short fiber. During testing, the change in stroke length from 8.7 mm to 23 mm results in decrease in the force exerted from the arm.

Figure 2. Resultant force obtained from the stroke length for Short fiber

Figure 3 shows the variation of force given at varying stroke length to the long fiber. Unlike the test taken to the short fiber previously, the length of the arm was gradually increased and a sudden increase of force of 890 N was given to the sample at a stroke length of 9.6 mm and the maximum tensile strength of 4.24 MPa was obtained for the long fiber. Thickness, width and area of both short and long fiber composite plates varies during the testing period. The thickness of the short fiber was 9.33 m, width of 26.76 mm and its area was 249.67 mm² whereas the long fiber has thickness of 9.00 mm, width of 23.52 mm and with an area of 211.68 mm².

Figure 3. Change in force by change in stroke for determining the maximum tensile strength for long fiber
Figure 4 shows the variation of force to the varying stroke length of the arm for determining the flexural load of the short fiber sample specimens. The thickness of the short fiber sample was 9.33 mm, its width was 24.54 mm and its area was 228.96 mm$^2$, while testing it has been determined that the maximum flexural load of 0.20 KN was obtained when a force of 202N was given to the sample at a stroke length of 1.98 mm.

Figure 5 shows the force to stroke ratio for determining the flexural load of the long fiber sample specimen. The maximum flexural load of 0.23 KN was obtained for the long fiber when a force of 230 N was given to the sample specimen at the stroke length of 2.23 mm. The thickness of the specimen was 8.69 mm, width was 26.74 mm and its area was 232.37 mm$^2$. The impact values were also determined in the testing. It has been determined that both short fiber and long fiber types obtain same impact values of two joules (2J). The testing of the composite plate samples was taken at a room temperature of 27$^\circ$C. In Fig 5, it is clear that the force of the arm tends to decrease gradually when there is a constant increase in the stroke length of the arm. The force of the arm obtains its minimum state when the stroke length of the arm is at its highest state.
5. Conclusion

The combined natural fiber reinforced polymer (NFRP) composites were successfully fabricated using Hand Layup method. Tensile strength, Flexural strength and Impact strength values were derived and investigated for two different composite samples. Considerable amount of force was obtained only when the stroke length of the arm is maintained at 0.2 mm to 9.5 mm. On comparing the properties of both short and long fiber composites, the tensile strength and flexural load values of long fiber composite plate were superior than the short fiber composite plate samples. The impact strength values of both the plates were similar. Breakage of the plates occurred during machining operation. This might have happened due to the imperfection in applying the resin over the reinforcing material.

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