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Studies on natural fiber particle reinforced composite material for conservation of natural resources

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ABSTRACT

The invention is an effort to utilize the advantages offered by renewable resources for the development of composite materials based on polymer and particles of natural fibers for Conservation of natural resources. Natural fibers have the advantage that they are renewable resources and have bio degradable properties. In this invention, powder material of natural fibers Sisal (Agave sisalana), Banana (Musa sepientum) & Roselle (Hibiscus sabdariffa) , Sisal and banana (hybrid) , Roselle and banana (hybrid) and Roselle and sisal (hybrid) are fabricated with polymer using molding method. This invention focuses on establishment of superior mechanical and material properties of the hybrid composite. The disclosure includes the process to make the composite for bone implant and also the variety of products in automotive, furniture, upholstery, house hold goods and computer goods.

Key words: Eco fibers; Fabrication; Properties; Conservation of natural resources.

INTRODUCTION

The present research work relates to an effort to utilize the advantages offered by renewable resources for the development of composite materials based on polymer and particles of natural fibers. [2, 7] Natural fibers have the advantage that they are renewable resources and have bio degradable properties. In this research, powder material of natural fibers Sisal (Agave sisalana), Banana (Musa sepientum) and Roselle (Hibiscus sabdariffa), Sisal and banana (hybrid), Roselle and banana (hybrid) and Roselle and sisal (hybrid) are fabricated with polymer using molding method. This research focuses on establishment of superior mechanical and material properties of the hybrid composites. In this disclosure, flexural rigidity test, tensile test, impact test of hybrid composite at dry and wet conditions have been reported. Also this present work focuses on the prediction of thrust force and torque of the hybrid composites, and the values, compared with the artificial neural network. In this research, microstructure of the specimens was scanned by the scanning electron microscope, and composition is analyzed by the electron dispersive thermodetector. This research work focuses a new method of using data obtained from CT images combined with digital CAD and rapid prototyping model for surgical planning and this new application enables the surgeon to choose the proper configuration and location of internal fixation of plate on humerus bone during orthopaedic surgery. The aim of this research work is to compare the metallic and natural fiber reinforced polymer composite bone plates used in humerus bone fractures. A 3D finite element model was developed to analyze the performance of both types of plates. The disclosure includes the process to make the composite and also the variety of products in automobile accessories and bone grafting substitutes.

BACKGROUND

Fiber reinforced polymer composites have received widespread attention in the past four decades because of their high specific strength and modulus. Commonly, composites using high strength fibers such as graphite, aramid and glass are used in broad range of applications from aerospace structure to automotive parts and from building materials to sporting goods. But, this type of composites was imported from overseas and need high cost to produce it. This situation has led to the development of alternative materials [9]. Therefore different technologies have been developed. With the classic fibre reinforced polymers, however, there are often considerable problems with respect to re-use or recycling after the end of the life time, mainly due to the compound of miscellaneous and usually very stable fibres and matrices. A simple landfill disposal is more and more excluded when regarding the increasing environmental sensitivity. Therefore environmentally compatible alternatives are looked for and examined, e.g. recovery of raw materials, CO_2-neutral thermal utilisation, or biodegradation in certain circumstances. An interesting option may be given by construction materials from renewable resources consisting of natural fibres, embedded into so-called biopolymers as well as economically and ecologically acceptable manufacturing technologies.

MATERIALS AND METHODS

Table 3.1 Materials

Material	Type	Supplied by	Application
Matrix	Bio epoxy resin	Lab chemicals, Chennai	For Bone Plate Material
Catalyst	Bio epoxy Hardner		
Releasing agent	Poly vinyl acetate		
Matrix	General purpose polyester resin	Lab chemicals, Chennai	For Automobile accessories
Catalyst	Cobalt		
Releasing agent	Poly vinyl acetate		
Reinforcement 1)Sisal & Roselle (hybrid) particle reinforced composite 2)Banana & Sisal (hybrid) particle reinforced composite 3) Banana & Roselle (hybrid) particle reinforced composite	Particle	India (especially in South India regions)	For both Bone Plate Material and automobile accessories

3.1 Chemical Treatment

The fibers were cleaned normally in clean running water and dried. A glass beaker was taken and a solution comprising 6% NaOH and 80% distilled water was prepared. [4] After adequate drying of the fibers in normal shading for 2–3 hours, the fibers were taken and soaked in the prepared NaOH solution. Soaking was carried out at different time intervals depending on the required strength of the fiber. For our study, the fibers were soaked in the solution for 3 hours. After completing the soaking process, the fibers were taken out and washed in running water and dried for another 2 hours. Subsequently, the fibers were taken for the next fabrication process, namely the procasting process.

3.2 Moisture Absorption Test Procedure

Water absorption tests were carried out according to ASTM D570 by immersing the specimens in deionized water bath at 25^0C [4]. After immersion for 48 hours, the specimens were taken out from the water and all surface water removed using a clean dry cloth. The specimens were reweighed to the nearest 0.1 mg within 1 minute of removing them from water. Then, the samples were tested to flexural, tensile, and impact analysis.

3.3 Advantages of chemical treatment

Chemical treatment with NaOH removes moisture content from the fibers thereby increasing its strength. Also, chemical treatment enhances the flexural rigidity of the fibers. Last, this treatment clears all the impurities that are adjoining the fiber material and also stabilizes the molecular orientation.

3.4 Mechanical testing:

After moisture absorption tests, the tensile strength of the composites was measured with a universal testing machine in accordance with the ASTM D638 procedure at a crosshead speed of 2mm/min. Flexural tests were performed on the same machine, using the 3-point bending fixture according to ASTMD790 with the cross-head speed of 2 mm/min. In the impact test, the strength of the samples was measured using an Izod impact test machine. All test samples were notched. The procedure used for impact testing was ISO 180. The test specimen was supported as a vertical cantilever beam and broken by a single swing of a pendulum.

3.5 Prediction of thrust force and torque in drilling operation

3.5.1 Manufacturing process

A mold of 60-mm length and 40-mm diameter was created using GI sheet mold.An OHP Sheet was taken and a releasing agent was applied over it and fitted with the inner side of the mold and allowed to dry. A glass beaker and a glass rod or a stirrer were taken and cleaned well with running water and subsequently with warm water. Then, calculated quantity of resin was added and the mixture was stirred for nearly 15 min. Stirring was done to create a homogeneous mixture of resin and accelerator molecules. Subsequently, calculated quantity of fibers was added and the stirring process was continued for the next 45 min. Then, the mixture was poured into the mold and rammed mildly for uniform settlement. The mold was allowed to solidify for nearly 24 hours.

3.5.2 Factorial Design

A 3^3 full factorial design with a total of 27 experimental runs were carried out. The thrust force and torque were the response variables recorded for each run. [1,3,5]. The effect of the machining parameters is another important aspect to be considered.

Table 3.2 Assignment of the levels to the factors

Level	Drill size,d (mm)	Revolution ,N (rpm)	Feed rate,f (mm/rev)
1	3	600	0.1
2	4	900	0.2
3	5	1200	0.3

3.6 FINITE ELEMENT ANALYSIS

Analysis package using for Stress Analysis on Humeral Shaft along with plate: ANSYS 11.0 Element types used in the finite element model were SOLID92 and SHELL99.SOLID92 was used in case of metallic bone plates while SHELL99 was chosen in case of composites. Metallic plate materials were taken as isotropic, NFRP composites and the fractured bone as orthotropic materials. Computerized tomography scanning image [CT scan] of humerus bone in .stl file was converted in to .iges file then imported to ANSYS for the stress analysis on humeral shaft with plate and without plate. CAD solid model can be directly converted to .stl format for use in subsequent rapid prototyping process.

Figure 3.1 Model of humerus bone fabricated by Fused Deposition Modeling

Dimensions of plate

Length of the plate (l) : 150mm
Thickness of the plate (t) : 4.5mm
Width of the plate (w) : 10mm

Manual Calculation

The project case is mainly for youngsters during the bike riding. The weight of the person was assumed to be around 60 kg.

Assumption made in this research:
Initial velocity of Vehicle V_1 =60kmph
Final velocity of Vehicle V_2 = 0
Mass of human body =60kg
External diameter of bone bone [D] = 22 mm
Bending Stress on Solid Shaft:

$\sigma b_{max} = (32 \times M_{max}) / (3.14 \times d^3)$

RESULTS AND CONCLUSIONS OF THE PROJECT

Hybrid composite materials (Bio epoxy resin)

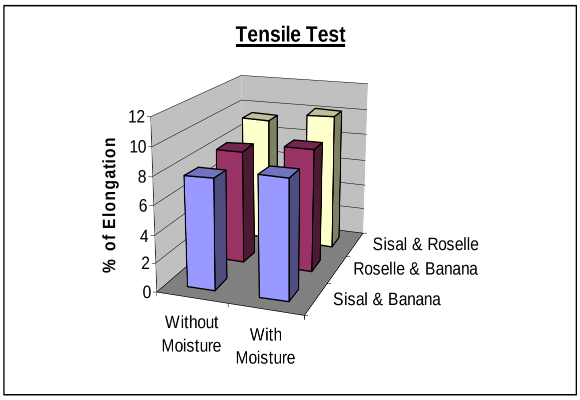


Figure 4.1 Comparison of % of elongation

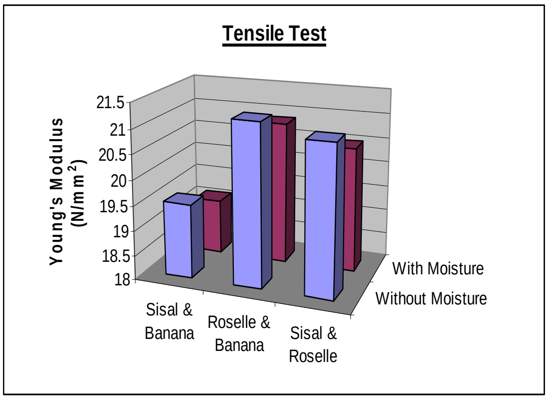


Figure 4.2 Comparison of Young's modulus

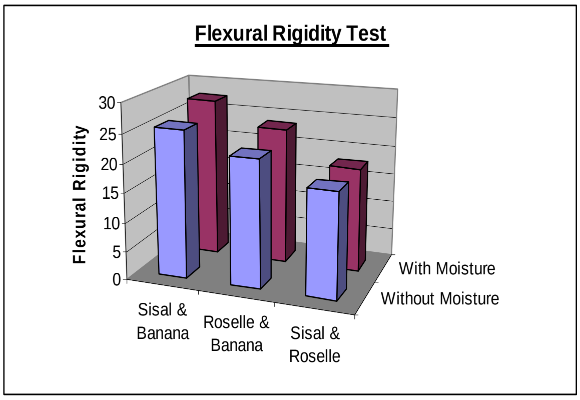


Figure 4.3 Comparison of flexural rigidity

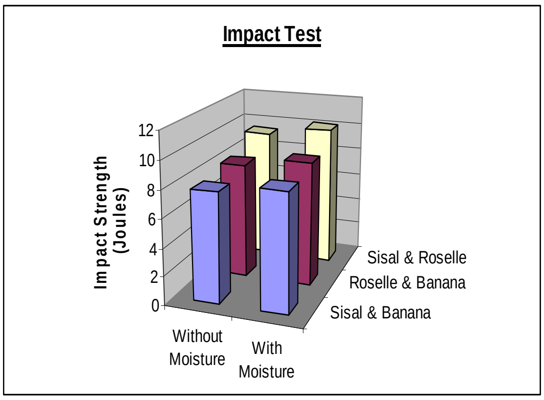


Figure 4.4 Comparison of impact strength

Hybrid composite materials (General purpose polyester resin)

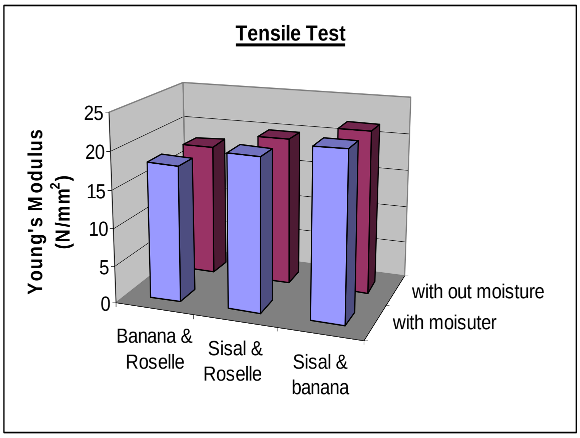


Figure 4.5 Comparison of % of elongation

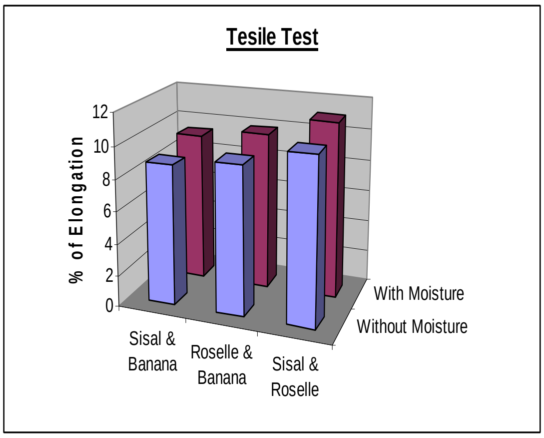


Figure 4.6 Comparison of Young's modulus

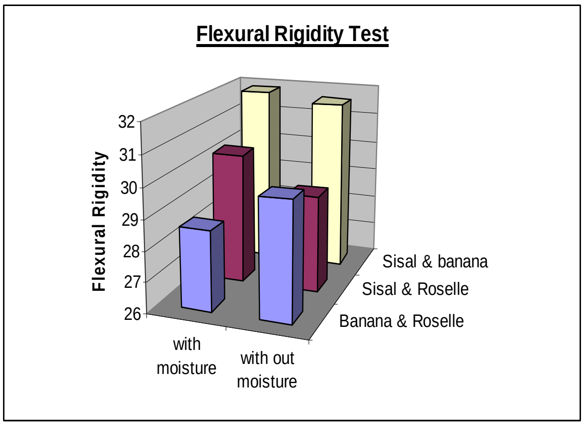


Figure 4.7 Comparison of flexural rigidity

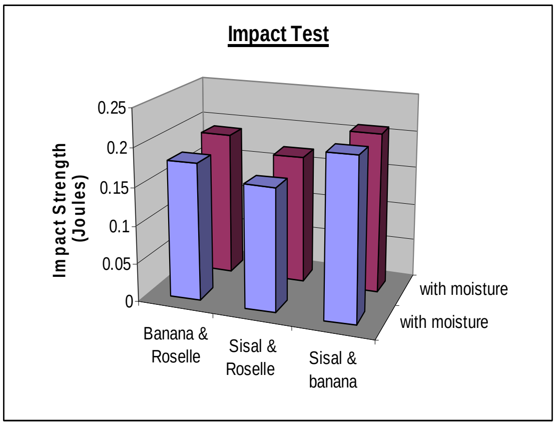
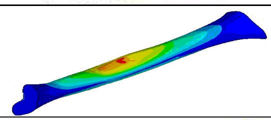
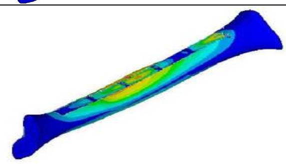
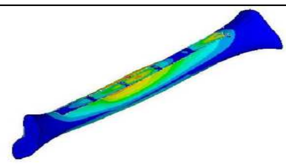
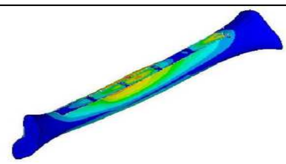
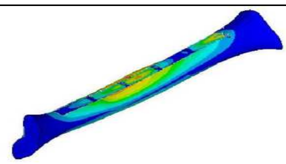
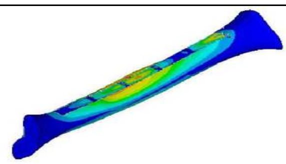
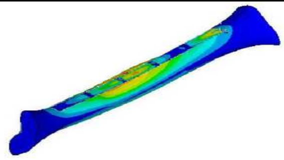
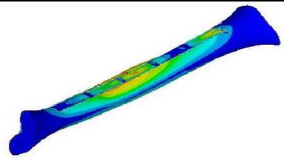


Figure 4.8 Comparison of impact strength

Table 4.1 Comparison of results

Material	Manual (N/mm²)	ANSYS (N/mm²)	ANSYS
Bone	64.32	74.709	
Stainless steel	65.37	74.953	
Cobalt chrome	65.46	75.124	
Titanium	65.56	75.221	
Zirconium	65.48	74.973	
Roselle and sisal (hybrid)	65.032	73.111	

Sisal and banana (hybrid)	65.010	73.233	
Roselle and banana (hybrid)	65.014	73.523	

Hybrid composite materials (Using Bio epoxy resin)

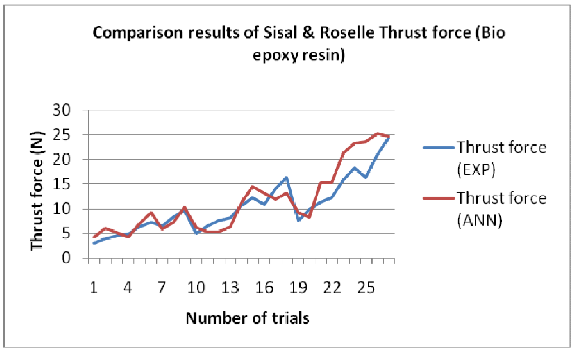


Figure 4.9 Comparison of Sisal and Roselle Thrust Force

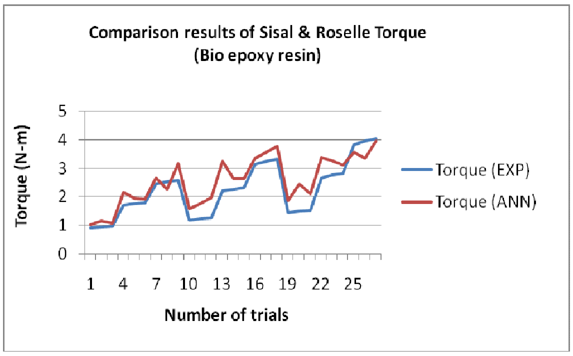


Figure 4.10 Comparison result of Sisal and Roselle torque

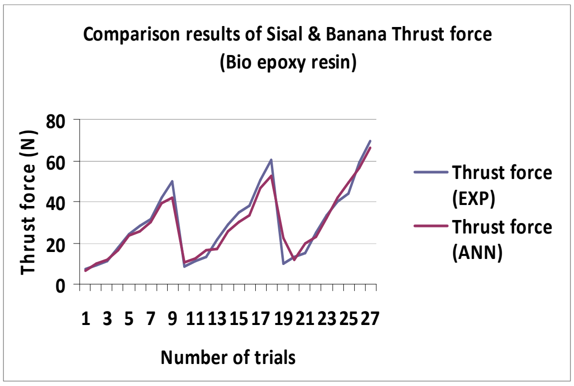


Figure 4.11 Comparison of Sisal and Banana Thrust Force

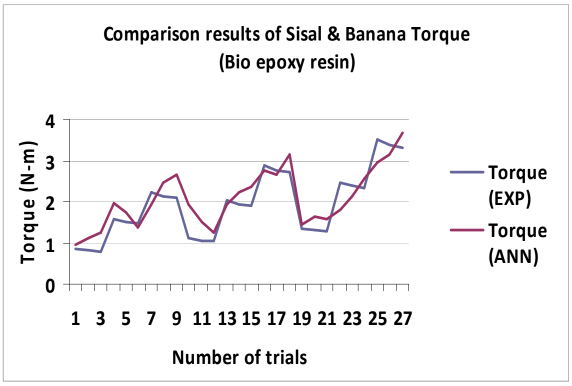


Figure 4.12 Comparison result of Sisal and Banana torque

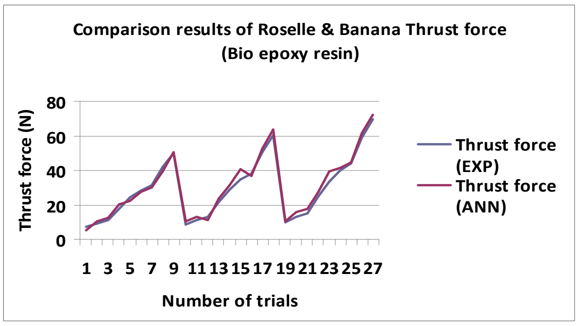


Figure 4.13 Comparison of Roselle and Banana Thrust Force

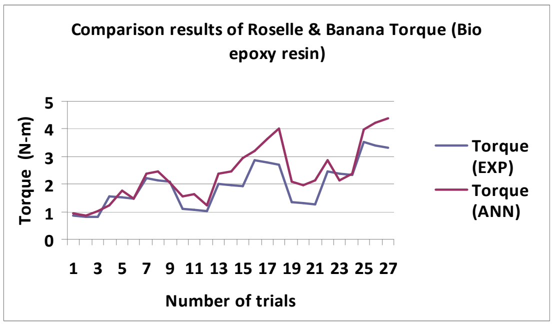


Figure 4.14 Comparison result of Roselle and Banana torque

Hybrid composite materials (Using General purpose polyester resin)

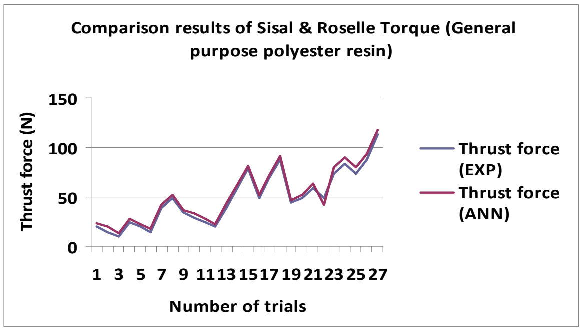


Figure 4.15 Comparison of Sisal and Roselle Thrust Force

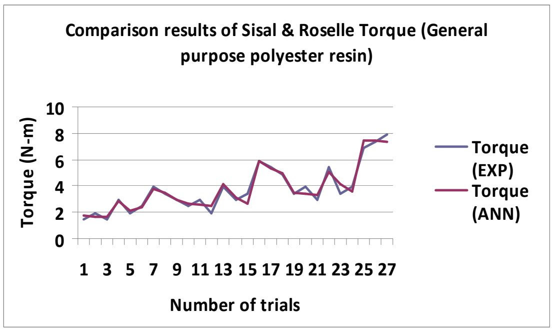


Figure 4.16 Comparison result of Sisal and Roselle torque

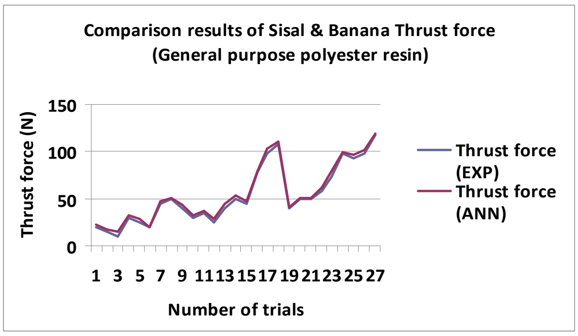


Figure 4.17 Comparison of Sisal and Banana Thrust Force

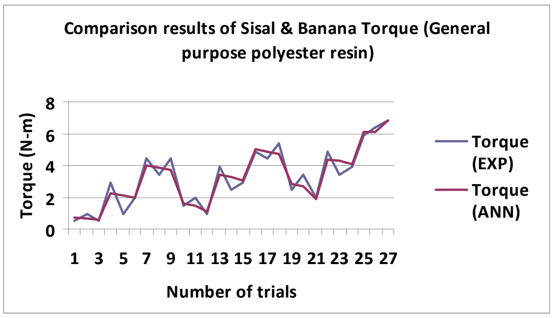


Figure 4.18 Comparison result of Sisal and Banana torque

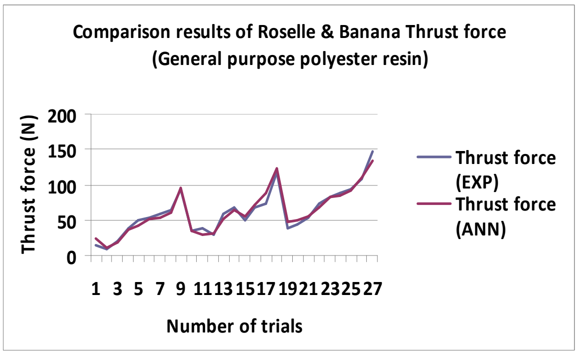


Figure 4.19 Comparison of Roselle and Banana Thrust Force

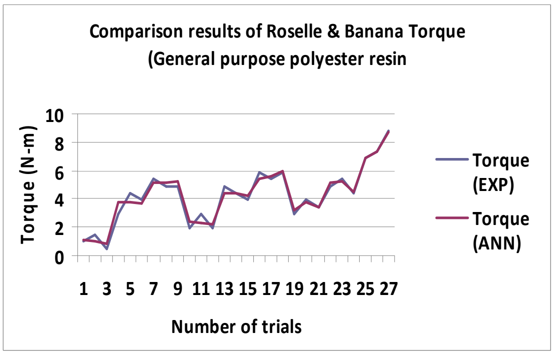


Figure 4.20 Comparison result of Roselle and Banana torque

APPLICATIONS

In the latest years industry is attempting to decrease the dependence on petroleum based fuels and products due to the increased environmental consciousness. This is leading to the need to investigate environmentally friendly, sustainable materials to replace existing ones. The tremendous increase of production and use of plastics in every sector of our life lead to huge plastic wastes. Disposal problems, as well as strong regulations and criteria for cleaner and safer environment, have directed great part of the scientific research toward eco composite materials. Among the different types of eco-composites those which contain natural fibers (NF) and natural polymers have a key role. Since few years polymeric biodegradable matrices have appeared as commercial products, however their high price represents the main restriction to wide usage. Currently the most viable way toward eco friendly composites is the use of natural fibres as reinforcement.

The hybrid composite material finds a lots of application. This material can be used in the automobile sector as replacement of plastic fibres which is already existing . The plastic fibre, which has a high carbon composition causes a problem for environment and moreover it is not a degradable one. Therefore these plastic fibres are not eco friendly. In order to over come this problem the hybrid composite material used in this project can be replaced with plastic fibres. This hybrid composite material has less carbon composition and it is a degradable one.In this project a rear view mirror, visor in two wheeler, billion seat cover, indicator cover, cover L –side, writing pen, name plate has been fabricated and it can be replaced with the existing above said fabricated with plastic fibres. While comparing both (Hybrid) composite materials has greater impact strength than the plastic fibre.

Applications of Hybrid Composite Materials (Using General Purpose Polyester Resin) in Automobile accessories

Figure. 4.21 Visor in two wheeler

Figure. 4.22 Billian seat cover in two wheeler

Figure. 4.23 cover l – side of two wheelers

Figure .4.24 Indicator cover

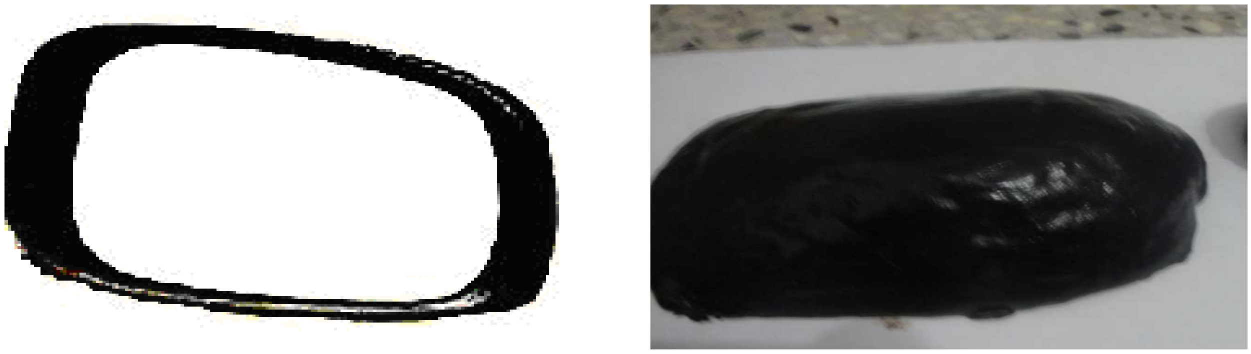


Figure. 4.25 Rear view mirror

After determining the material properties of natural fiber–reinforced epoxy composite using six different tool materials and geometrices by using tensile test, flexural test and Izod impact test can be drawn.

The hybrid composites showed comparatively better performance, as evidenced by the micrographs taken for the fractured sisal, banana, roselle, and hybrid composites. Sisal fiber composites, on tensile loading condition, showed a brittle-like failure. Elliptical cracks and their fast propagation could be observed. Less fiber pullout was observed, and this could be the reason for the reduction in the tensile strength, as shown by the tensile fracture micrograph for the fiber-based composites. Plastic deformation and more fiber pullout also could be observed. This nature is justified, where more percentage elongation could be observed for the hybrid fiber composites. Hybrid fiber composites exhibit partial brittle nature of fracture because of the presence of sisal fibers. The presence of moisture in the composites reduces the flexural properties. The absorption of moisture leads to the degradation of fibers matrix interface region creating poor stress transfer, resulting in a reduction on the flexural strength. Both in the banana and sisal fiber composites, the percentage elongation are found to be increasing after immersing the components into water. The reason could be the presence of water attack on the cellulose structure, allowing the cellulose molecules to move smoothly. Hence, for the applications where flexural loading conditions are dominating, sisal and roselle composites could be selected. The increase in the impact strength could be observed for banana, sisal, roselle, and hybrid fiber composites. This could be attributed to fiber bridging through fiber pullout. The greater level of fiber pullout, which is observed in the specimen fabricated by hybrid reinforcement, leads to superior impact strength. Hybrid fiber composite exhibits reduced impact strength. The reason could be the reduced fiber bridging effect resulting from lower fiber pullout. The complete breaking of the fiber rather than pullout is observed through SEM analysis.

Based on the experimental results obtained, the following conclusions can be extracted:
Effect of Thrust Force:
In general, the thrust and torque parameters will mainly depend on the manufacturing conditions employed, such as feed, cutting speed, tool geometry, machine tool, and cutting tool rigidity. A larger thrust force occurs for larger diameter drills and higher feed rates. In other words, feed rate and drill diameter are recognized as the most

significant factors affecting the thrust force. Worn-out drill may be one of the major reasons for the drastic increase in the thrust force as well as for the appearance of larger thrust forces when using multifacet drill than those when using twist drill at high cutting speed. Although tools are worn out quickly and the thrust force increases drastically as cutting speed increases, an acceptable hole entry and exit is maintained. We found that the thrust force is drastically reduced when the hole is predrilled to 0.4 mm or above. Although it is known that the thrust force increases with the increase in the feed, this study provided quantitative measurements of such relationships for the present composite materials. In general, increasing the cutting speed will decrease the thrust force. This work has shown that the cutting speed has an insignificant effect on the thrust force when drilling at low feed values. At high feed values, the thrust force decreases with an increased cutting speed.

Effect of torque:
It can be observed that thrust force and torque increase with the drill diameter and feed rate. By examining these results, it can be concluded that the torque slightly increases as the cutting speed increases. However, we found that the increase in torque was much smaller than that in thrust force, with the increasing cutting speed. The average torque appearing when using a multifacet drill was larger than that using the twist drill at low drilling speed, and the average torque when using a multifacet drill was smaller than that when using twist drill at high drilling speed. It was noticed that the average torque decreased as the drilled length increased for twist drill. The results indicate that the torque increases as the feed increases. This increase is owing to the increasing cross-sectional area of the undeformed chip. The results also indicate that the torque increases with the increase in the fiber volume fraction. Increasing fiber volume fraction increases the static strength, and thus, the resistance of the composite to mechanical drilling increases. This leads to the increase in the required thrust force and torque. The result also indicates that the torque decreases when increasing the cutting speed.

An artificial bone model was fabricated using ABS (Acrylonitrile Butadyine Styrene) by Rapid Prototyping Technology. This technique helps to analyze the actual bone structure and plate fixation can be done more accurately. Due to RP technologies doctors and especially surgeons are privileged to do some things which previous generations could only have imagined. However this is just a little step ahead. There are many unsolved medical problems and many expectations from RP in this field. Development in speed, cost, accuracy, materials (especially biomaterials) and tight collaboration between surgeons and engineers is necessary and so are constant improvements from RP vendors. This will help RP technologies to give their maximum in such an important field like medicine and new technologies can not only improve and replace conventional methods; they also offer the chance for new types of products and developing procedures.The stress analysis of humerus bone and fixation of plate for the fractured bone has been carried out with stainless steel, cobalt chrome, titanium, zirconium, Roselle and sisal (hybrid), Sisal and banana (hybrid) and Roselle and banana (hybrid). After plate fixation, the stress induced on the bone with plate and without plate is calculated both manually and using ANSYS software. A result from material testing, mechanical testing and ANSYS this research work concluded that sisal and roselle (hybrid) is one of the best material.In future, this plate material can be externally coated with calcium phosphate and Hydroxy Apatite (hybrid) composite. Furthermore, this plate material can be used for internal fixation and also external fixation in fractured bones in human body. The most important point that researchers have to have in mind is that these steps taken will help humans to develop and have a more pleasant life.

The hybrid composite materials (using general purpose polyester resin) find lots of application. This material can be used in the automobile sector as replacement of plastic fibres which already exists. The plastic fibre, which has a high carbon composition, causes a problem for environment and moreover it is not a degradable one. Therefore these plastic fibres are not eco friendly. In order to over come this problem the hybrid composite materials used in this project can be replaced with plastic fibres. This hybrid composite material has less carbon composition and it is a degradable one. The material properties also allow aiming at applications which are today dominated by glass fibre reinforced plastics. Nevertheless, there a restrictions with respect to extreme environmental conditions. An essential branch of applications is to be seen e.g. in covering elements with structural tasks in automobile accessories.

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