Strength evaluation and behaviour studies of Hybrid Natural Fibre Reinforced Composites using compression moulding

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Abstract— **This project proposes the composite materials made up of natural fibres is improving in engineering applications such as Automotive, Marine and Aerospace, due to its properties such as high specific strength, renewable, non-abrasive, low cost, bio-degradability. Many researchers have identified different natural fibres used to substitute glass fibre, among them jute appears to be favourable material because of its low cost, high strength, high aspect ratio, good insulating, and low thermal conductivity. The goal of this work is to investigate the effects of mechanical and tribological behaviour of hybrid fibre, but the content of composition of matrix and reinforcement the fibre is Ratio-1: glass fibre at 15% and bamboo at 15%, Ratio-2: glass fibre at 15% and cotton at 15%, and Ratio-3: glass fibre is 10%, bamboo fibre is 10%, and cotton fibre is 10%.With a constant amount of 70% epoxy resin, After that, a specimen will be prepared and assessed in accordance with ASTM E8 Standard. (such as tensile, flexural, impact strength, to investigate the wear resistance perform a wear test on the Pin-on-Disc method will be followed. Monitoring of water absorption will be examined into periodically.**

***Keywords*— Composite materials, Natural fibres, Mechanical behaviour, Tribological behaviour Epoxy resin**

I. INTRODUCTION

In the current quest for improved performance, which may be specified by Numerous criteria comprising less weight, more strength and lower cost, currently used materials frequently reach the limit of their utility. Thus material researchers, engineers and scientists are always determined to produce either improved traditional materials or completely novel materials. Composites are an example of the second category. Over the last thirty years composite materials, plastics and ceramics have been the prevailing emerging materials. The volume and numbers of applications of composite materials have developed steadily, penetrating and conquering new markets persistently. Modern composite materials establish a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. Composites have already proven their worth as weight-saving materials; the current challenge is to make them cost effective. The hard work to produce an economically attractive composite component has resulted in several innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. India endowed with an ample availability of natural fibre such as Bamboo, Ramie, Jute, Sisal, Pineapple, Coir, Banana etc. has focused on the improvement of natural fibre composites mainly to explore value-added application avenues. Such natural fibre composites are well matched as wood substitutes in the housing and building sector. The development of natural fibre composites in India is based on two cleft strategies of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibres. The developments in composite material after meeting the 2 challenges of aerospace industry have poured down for catering to domestic and industrial applications. Composites, the spectacle material with lightweight; high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like wood, metals etc. The material experts all over the world focused their attention on natural composites to cut down the cost of raw materials

II. LITERATURE REVIEW

Christopher Chella Gifta [1] et al were conducted on Juliflora fibre-reinforced concrete to evaluate the mechanical properties of hardened concrete. Juliflora fibres are available abundantly in nature, causing serious environmental and economic problems to all livelihoods in many developing countries. Hence, these natural fibres could be effectively utilized in concrete composites to improve their hardened properties. In this paper, three different volume fractions 0.25%, 0.5%, and 0.75% of juliflora fibres were chosen and its influence on mechanical properties such compressive strength, impact strength, and modulus of elasticity were determined. Raghu M.J [2] et al were investigated the effect of water absorption on mechanical properties of calotropis procera fibre reinforced epoxy polymer composites. The calotropis procera fibre chemical and mechanical testing was done to evaluate chemical composition and strength of the fibre. The composites are fabricated by reinforcing calotropis procera fibre in epoxy matrix by varying the fibre wt. % by traditional hand layup method. The water absorption of calotropis procera reinforced epoxy polymer

composites at room temperature was found to increase with increasing fibre loading. The mechanical testing results of moisture exposed composites indicated decreased strength which may be due to degraded bonding between fibre and matrix.
S. Satheesh Kumar [3] et al were analyzed such as tensile, flexural, compression, impact and hardness properties were investigated. The tensile strength Fig. 6. FTIR analysis of bio-composite specimens. S.S. Kumar and V.M. Raja Composites Science and Technology 208 (2021) 108695 10 Fig. 7. (a) Storage modulus, (b) Loss modulus, and (c) Tan δ of natural fibre bio composites. Fig. 8. Variation of rheological attributes (a) storage modulus (b) loss modulus. Fig. 9. (a) 2-D roughness surface texture, (b) 2-D line diagram for roughness measurement of NF, (c) 3-D roughness surface texture, and (d) Roughness parameters. S.S. Kumar and V.M. Raja Composites Science and Technology 208 (2021) 108695 11 and modulus value of the alkali treated specimen F has reached 251.63 MPa and 8.2 GPa respectively. The specimen F compared with untreated specimens A, B, C, D and E the tensile strength were enhanced 29.08%, 24.59%,15.68%,7.81% and 4.33% respectively. However, the tensile modulus also improved 15.85%, 13, 4, 8.53%, 6.09% and 3.65% respectively. The flexural strength of the 19alkali treated specimen F has reached the maximum value of 104.7 MPa. The specimen F compared with untreated specimens A, B, C, D and E, the flexural strength has enhanced 34.38%, 29.51%, 22.44%, 12.7%, and 5.53% respectively. C.M. Ravi Raghul [4] et al were found the specimen 1 with 8% of fibre content has better Tensile, Impact and Flexural strength. As the ratio of fibre is increased the Tensile, Impact and Flexural strength gets decreased. The specimen 3 with 16% fibre content has high compressive strength. As the ratio of fibre is increased the compressive strength also gets increased. Puttegowda Madhu [5] et al were recognized the effect of laminate stacking sequence of Prosopis juliflora fibres (PJFs)/E-glass/carbon fabrics reinforced hybrid epoxy composites under five different composite designations. Manual hand layup method is used as the fabrication method, while studies on physical, mechanical, and morphological properties have been conducted in this research work. From the results obtained, it is obvious that the properties of PJFs/E-glass/carbon fabrics reinforced epoxy composites enhanced due to the hybridization with the addition of E-glass and carbon fabrics in PJFs and augments its suitability in the use of engineering structural applications. Elayaraja. R [6] et al were develop a polymer composite with Prosopis juliflora and mango tree as reinforcements of a natural composite epoxy resin matrix. Composite plates were produced using a compression mould method with a composition ratio of 60:40, 65:35 and 70:30. The resin and hardener proportions were 10:1 respectively. The manufactured composites were tested following ASTM standards to assess mechanical characteristics such as tensile strength, compressive strength, flexural strength, impact strength, hardness value, and water absorption test. From the results of mechanical characteristics, 65:35 of composition shows a better value in the tensile test, Compressive, flexural test and impact test. Parallel the test values are shows nearly to the synthetic fibre composite values. Jignesh K. Patel [7] et al were developed banana fibre reinforced composite using general purpose polyester resin and carrying abrasive waterjet cutting on composite plate. The surface roughness (Ra) and kerf tapper ratio (TR) parameters are focused during abrasive water jet machining. Full factorial design of experiments is applied to determine influence of machining parameters such as hydraulic pressure (P), traverse speed (S) and standoff distance (D) on output response Ra and TR. It is observed that surface roughness (Ra) and taper ratio (TR) are reduced by increasing the hydraulic pressure. It is also observed that traverse speed and standoff distance are significant parameters for output response. It is felt that increase in traverse speed and standoff distance leads to increase in both Ra and TR increases. Jayprakash Umap [8] et al were developed carbon fibre reinforced polymer composites by using compression moulding technique and the process parameters were further optimized using GRA and Taguchi method. Regression models were developed for correlation with actual generated data using experiments. The result obtained using Optimization technique and Taguchi method is confirmed using confirmation experiment. The parameters were optimized for Kerf Width of carbon fibre with reference to input parameters by using AWJM. Alberdi. A [9] et al were concluded the machinability index of different composite materials is very different, so they have to be studied separately. This index may be related to the tensile modulus and/or to the fibre content of the composite materials, but further research is required in order to relate the machinability index with the material properties. The separation speed has to be re-defined for this kind of material as the traverse rate at which the material can be cut without delamination. Tool selection is an important aspect to take into account in order to increase productivity. The taper angle may be a function of the absolute traverse feed rate more than a function of its respective percentage to the separation speed The machinability model can be used to adapt the traverse feed rate for the required roughness. D. Rajamani [10] et al were investigated focused on abrasive waterjet cutting (AWJC) of natural fibre reinforced nano clay filled polyester composites with the objectives of maximizing material removal rate (MRR) and minimizing the kerf taper (KT) and surface roughness (Ra). The influence of nano clay addition, traverse speed (TS), jet pressure (JP) and stand-off distance (SOD) on the AWJC characteristics of fabricated composite laminates are investigated Increasing the wt% of nano clay and decreasing the stand-off distance, traverse speed and jet pressure resulting improved cut quality with abridged cracks and fibre debonding in cut surfaces has been evident from SEM morphologies.

III. PROBLEM IDENTIFICATION AND OBJECTIVES

A. *Problem identification*

An exhaustive literature survey and market survey were performed to identify the topic for project and the parameters to concentrate. At present, NFRCs are of high demand for various manufacturing industries and advanced machining processes are necessary in order to produce components that are free from failure. Therefore, we should know what the mechanical properties is such that tensile test, flexural test, impact test, hardness test and. According to strength we have to decide it can be with stand for particular application. All tests were conducted as per mentioned in the ASTM standards and journals referred from the literature survey.

B. Objectives of the present work

1. Fabrication of a new class of epoxy-based hybrid composite reinforced with the combination of E-glass fibres Bamboo fibre and cotton fibre with various ratio percentages.
2. Evaluate the mechanical properties like that tensile, Flexural and Hardness.
3. Evaluate the wear and Water absorption characteristics.
4. To identify the applications of hybrid composite developed and implementation.

IV. Materials And Methodology

A. Glass fibre

FRP plastics use material glass strands; textile fibres are not quite the same as otherforms of glass fibres utilized for insulating purposes. Textile glass fibres start as shifting combos of SiO_2, Al_2O_3, B_2O_3, CaO, or MgO in powder structure. These mixtures are then heated through an immediate melt procedure to temperatures around 1300 ○C, after whichdies are utilized to extrude fibres of glass fibre in distance across extending from 9 to 17 µm. These fibres are then wound into bigger strings and spun onto bobbins fortransportation and further handling. Glassfibre is by long shot the most mainstream intendsto strengthen plastic and in this manner appreciates a abundance of generation methodologies, some of which are pertinent to aramid and carbon fibres also owing to their imparted fibrous qualities.

B. Bamboo fibre

Most of the developing countries, a demand for steel is increasing day by day for usage as a reinforcing material. There are circumstances when the manufacturing is not set up sufficient to confront the requirement for steel. Accordingly, it is important to discover elective arrangement which is esteem contrasted with steel. Bamboo accessibility is plentiful and strong. Hence, bamboo can be used as a reinforcing material and become a perfect replacing material for steel. The bamboo is noticeable as a reinforcing material since it has the tensile strength as the focal prerequisite and equated with other different materials together with steel. As a natural habitat, it has good resistance capacity to withstand the wind forces by its hollow tubular structure. Hence the drawbacks of bamboo can be properly identified and coming with the solution of improvement of bamboo as a structural steel replacing material is a natural substitute. Selection of bamboo is according to:

1. Color and Age – should be brown in color and age of minimum 3 years.
2. Dimensions – Usage of lengthy huge culms.
3. Harvesting – Avoiding the cutting of bamboos either during spring or summer seasons.
4. Species – The best one should be checked, tested among 1500 species of bamboo, in order to satisfy requirements as a reinforcing material.
5. Select the diameter of longest culms available.
6. Avoid usage of 8whole culms of green, fresh and unseasoned bamboo.

Sl.No	Property	values	units
1	Specific gravity	0.575 to 0.655	-
2	Average weight	0.625	Kg/m
3	Flexural strength	610 to 1600	Kg/Cm^2
4	Young's Modulus	1.5 to 2.0×10^5	Kg/Cm^2
5	Maximum compressive stress	794 to 864	Kg/Cm^2
6	Safe working stress in compression	105	Kg/Cm^2
7	safe working stress in tension	160 to 350	Kg/Cm^2
8	safe working stress in shear	115 to 180	Kg/Cm^2

Table 1: Properties of bamboo fibre

C. Cotton fibre

Cotton fibres are natural hollow fibres; they are soft, cool, known as breathable fibres and absorbent. Cotton fibres can hold water 24–27 times their own weight. They are strong, dye absorbent and can stand up against abrasion wear and high temperature. In one word, cotton is comfortable. Cotton is the most widely produced natural fibre on the planet. Other natural fibres include silk, made from the cocoons of silkworms; wool, made from the fur of sheep or alpacas; and linen, made from fibres in the stems of flax plants. Cotton fibres come from cotton plants. Cotton is known for its versatility, performance and natural comfort. Cotton's strength and absorbency, makes it an ideal fabric to make clothes and homewares, and industrial products like tarpaulins, tents, hotel sheets, army uniforms, and even astronauts' clothing choices when inside a space shuttle.

D. Project plan

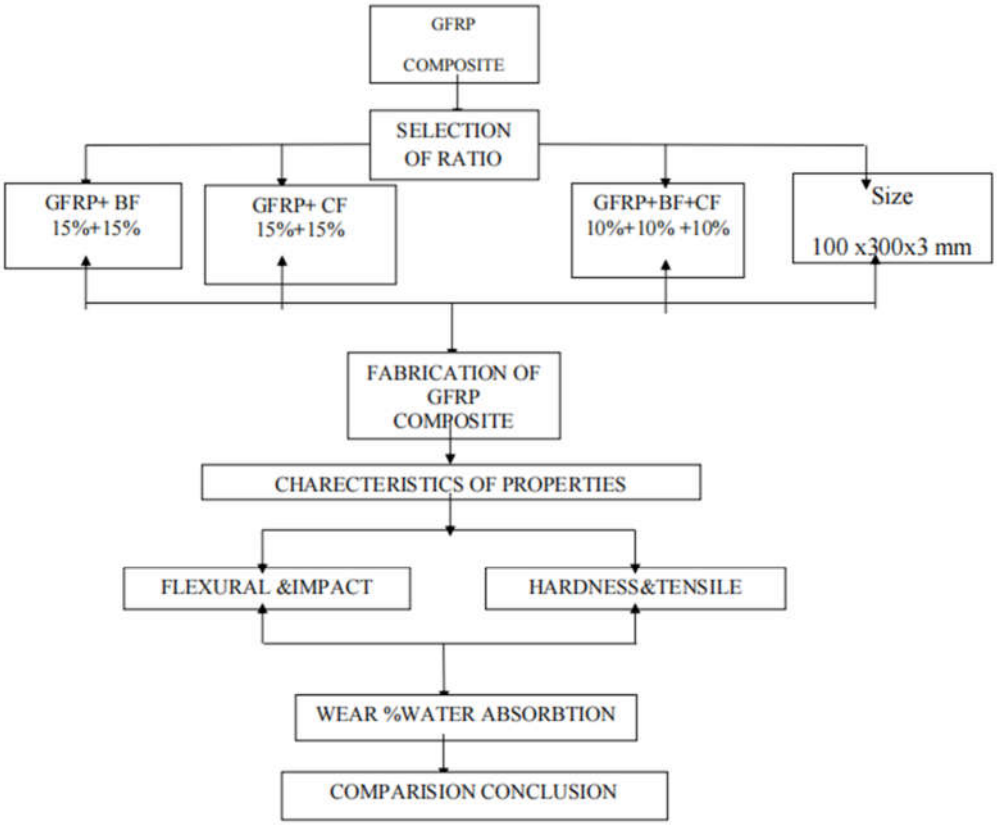

Fig 1 Flow chart

E. Stack formation & mixing ratio

LAMINATES	STACKING SEQUENCE	PERCENTAGE	SIZE mm
R_1	BF+GF	15+15	100*300*8
R_2	GF+CF	15+ 15	100*300*8
R_3	GF+CF+BF	10+ 10+10	100*300*8

Table 2 Mixing ratio

F. Material requirements

Fiber 1	Fiber 2	Fiber 3	Resin
Bamboo fiber-1/2 meter	Glass fiber- 1-meter	Cotton fiber-1/2 meter	Epoxy (1Ltr
Hardener 100 gm			

Table 3 Material requirements of HYBRID composites

G. Selection of epoxy resin

Polymers generally act as a good binder for fibres as observed from several references. Their carry availability coupled with their lower cost has provoked the selection of polymer as the binder for these fibres. Unsaturated polyester offers the advantage of easy mouldability, better handling, and better flow properties. Easy fabrication and better mixing of polyester provoke their usage. They have a low density of 2.02g/cc adding to our main objective of fabricating a low weight composite. Epoxy resins, also known as poly epoxies, are a class of reactive polymer high mechanical properties, temperature, and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/ electrical components, high tension electrical insulators, fibre-reinforced plastic materials and structural adhesives.

Fig 2 fabricated fibre sheets

V. RESULT AND DISCUSSION

A. Hardness test

Hardness test shows that the reading of glass fibre and cotton fibre exhibits maximum hardness strength of about 72 HRM and followed by combined of glass fibre and bamboo fibre results show 68 HRM. But glass and cotton fibre achieved minimum hardness value of about 65.

RATIO	MATERIAL	HRB
R_1	BF+GF	68
R_2	GF+CF	72
R_3	GF+CF+BF	65

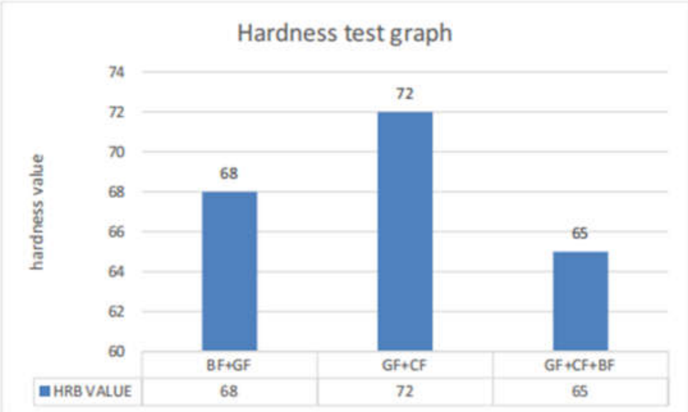

Fig 3 Hardness value and graph

B. Tensile test

Tensile test result shows that the reading of synthetic and natural fibre noted glass fibre and cotton fibre exhibits maximum tensile strength of about 199.276 N/mm^2 and followed by combined of synthetic and natural fibre results show 175.046. But glass and bamboo fibre achieved minimum tensile strength of about 98.285 N/mm^2.

Identification	Thick mm	Width mm	CSA mm^2	TS N/mm^2
BF+GF	2.95	16.9	49.855	98.285
GF+CF	2.75	17.08	46.970	199.276
GF+CF+BF	2.87	16.8	48.216	175.046

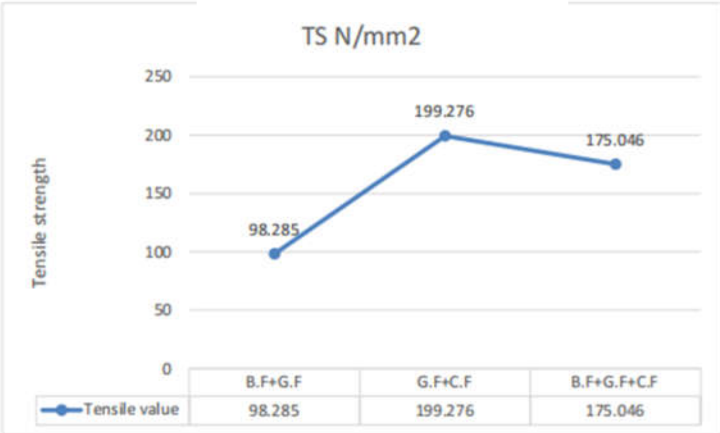

Fig 4 Tensile test value and graph

C. *Impact test*

During that investigation of impact test the reading shows of glass, cotton and cotton fibre exhibits maximum impact load 3.8 joules and followed by glass and bamboo fibre results show 3 joules. But glass and cotton fibre achieved minimum impact load 1.8 Joules

S No	Sample	Izod Impact value in (J)
1	BF+GF	3
2	GF+CF	1.8
3.	GF+CF+BF	3.8

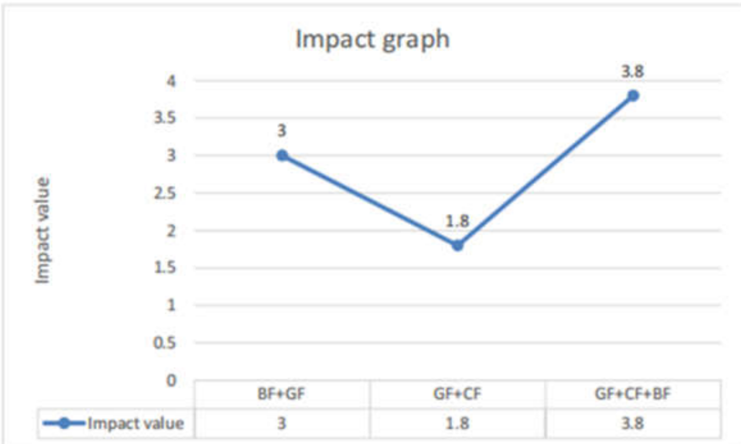

Fig 5 Impact test values and graph

D. Flexural strength

Flexural strength test result shows that the reading of synthetic and natural fibre noted glass fibre bamboo fibre and cotton fibre exhibits maximum flexural strength of about 300 N/mm^2 and followed by combined of glass and bamboo fibre results show 103.85. But glass and cotton fibre achieved minimum flexural strength of about 98.285 N/mm^2.

Identification	Span length (l),mm	Flexural load ,(W) KN	Flexural Strength (N/mm2)
B.F+G.F	140	0.18	103.85
B.F+C.F	140	0.12	69.23
B.F+G.F+C.F	140	0.52	300.00

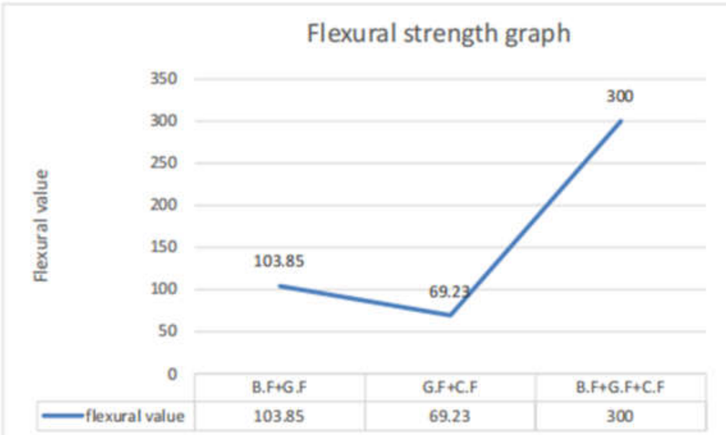

Fig 6 Flexural strength values and graph

VI. Conclusion

Synthetic and natural fibre composites had been successfully developed in this project. The mechanical properties (tensile, impact, flexural) of the composite has been studied and discussed here. The following conclusions have been drawn from this study. This work shows that successful fabrication of natural and synthetic fibre reinforced composites by compression moulding method. Composite samples are suitable for analyze mechanical properties such as tensile. It has given information about the suitability of hybrid fibre as a source of reinforcement in epoxy matrix composites. NFR composites have higher fibre content for equivalent performance which reduces the amount of more polluting base epoxy resin. Nowadays many automobile field used instead of aluminium natural fibre and synthetic fibre for interior components with extraordinary strength characteristics.

- Hardness test shows that the reading of glass fibre and cotton fibre exhibits maximum hardness strength of about 72 HRM.
- Glass fibre and cotton fibre exhibits maximum tensile strength of about 199.276 N/mm$^{2.}$
- Impact test the reading shows of glass, cotton and bamboo fibre exhibits maximum impact load 3.8 joules.
- Flexural strength test result shows glass fibre bamboo fibre and cotton fibre exhibits maximum flexural strength of about 300 N/mm^2
- The minimum wear rate occurred on the Ratio 1 - Glass fibre and Bamboo fibre composite obtained very low wear rate.

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