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Production of Bamboo Fibre Reinforced Epoxy Hybrid Composite with Nano SiO_2 Particles

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This paper focus on the process of fiber reinforced composites a significant portion of the paper emphasis the use of different machine, basic concept introduced in this paper of molding method and pouring of epoxy, hardener and nano silica mixture with hand lay-up technique. This study aims to develop fibre-reinforced epoxy hybrid composites by using hand lay-up method. In this work different material used are Epoxy LY556, Hardner HY951, SiO_2 nano particle (Particle size 60-70nm) and 90 degree bidirectionl wooven bamboo fibre. Sample designated are as A10 (One layer Babboo fibre, 0% SiO_2) , A12 (2%SiO_2), A14 (4%SiO_2),B20 (Two-layer bamboo fibre,0% SiO_2), B22(2%SiO_2), B24(4%SiO_2), C30 (three layer bamboo fibre, 0% SiO_2),C32(2%SiO_2) and C34(4%SiO_2). Samples were prepared by handlayup method. The effect of various weight percent of SiO_2on mechanical property were investigated. The maximum value of tensile strength was found for sample C32, higher value of flexural strength was found for sample C32, higher value of izod impact test was for sample C32 and maximum value of barcol hardness was for sample B22.

Keywords: Natural Fibres, Bamboo fibre reinforced nano composites, Hand lay -up technique, Epoxy matrix, Hardener

1 Introduction

Composite material is formed by mixing two or more material, the main component of which may be epoxy, hardener and the properties of the material to be made the details of the material to be made by hand lay-up technique the mechanical properties of the substance have also been widely investigated. In today's era composite materials are being used in abundance such as it is also used in home use, automotive application air craft, industries and sporting goods at present, the composite materials are being developed using natural fibre because natural fibre composites are relative eco-friendly. Some research on the fabrication method of composite has been done. Hand lay-up is that the simplest and oldest open molding technique for development of composites. Jindal[1] *et al*. explained in his work emphasized on the work with natural fiber at present engineers and scientists working on this area mainly utilizing natural fiber, developing environment friendly materials. Gunasekaran *et al*.[2] studied and presented useful analysis, which is important for quality development of bamboo based organic compound for different applications. Analysis of changes and traits from mixing bamboo charcoal particles with other fibre sources is essential. Kim *et al*.[3] presented the method in his paper Hand Lay-up, which is an easiest process with low investment, comparably favourably with resin transfer molding processes and Vacuum Infusion, which require high tooling cost. However, the technology, which uses vacuum pressure to force resin into a composite laminate, better structure of GFRP with higher properties which is said to be used in ship technology. Sharma and Wetzel[4] discussed, the techniques of manufacturing of GFRP structure include the fabrication method hand lay-up, filament winding, vacuum infusion and resin transfer molding. Kumar *et al.*[5] performed experiments which includes analysis of tensile properties of natural bamboo fibres. It consists calculation of tensile strength of laminate bamboo fibre with sodium hydroxide. The development of various bamboo fibre hybrid composites samples was made by hand layup method. Study shows that the tensile strength of bamboo-epoxy composite increases to the certain level of fibre loading and then starts decreasing on further fibre loading. On basis of obtain value tensile strength of bamboo fibre is high[6,7]. Various researchers have used the herbal fibers containing polyolefin's, polystyrene, polyester and epoxy resins. Vikram *et al.*[8] reported that natural bamboo fiber strengthened epoxy-primarily based

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totally on polymer composite and its mechanical behaviour was improved. It is acquired through, Rao *et al.*[9] that have said of their works of the properties of hybrid composites relies upon at the availability of fibre, ratio of fibre in composites, fibre matrix interface. Prabhu *et al.*[10] presented on fabrication of hybrid composite and analysis of their physical, mechanical, and tribological property[11,12,13]. Composite panels made using same technique and properties are tested as per an ASTM standard. The hardness of the composites was found to decrease with the rise in percentage of BF and CP. For few years past plant fibres space variety of renewable supply that are revived naturally inside their variation in properties and characterization. Abedom *et al.*[14] used fibres from natural sources however natural fibres alone aren't meeting the desired strength properties. the objective of this work was experimental study of composites developed from pulp fibre bamboo charcoal for industrial and engineering applications by investigation its various mechanical and thermal insulating properties. For this investigation, 5 hybrid composites with bagasse fibre: bamboo charcoal proportion of 100:0, 70:30, 50:50, 30:70, and 0:100 with sixty-five percentage polyurethane altogether by exploitation of compression molding method and their mechanical properties were analysed. Vandam *et al.*[15] studied that, the many major advantage of bamboo like high strength, light weight, bio-degradability, stiffness and roots keep along the soils and shield it via. the reflection of sunlight[16,17]. Strengthened fibre composites have high strength and modulus the explanation is high strength of the fibre and good adhesive properties between fibre and polymers[18,19]. In polymer family, use of thermoplastic matrix sparked an increasing interest, due to their advantages over thermosetting materials in terms of short process time, potential recyclability. The thermoplastic composites are employed in several fields, admire in automotive, armed service and sports[20]. Different kinds of natural fibers, obtained from stems, seeds or roots, and flax attracted additional interest as a result of their good mechanical properties such as stiffness and strength. Kolli *et al.*[21] presented with the objective to analyse the practicability of utilization of bamboo fiber mat with completely different filler like Alumina, silica and Graphene materials as reinforcement for fiber strengthened composites. The bamboo fiber is excellent material to be used as natural fibers in composite materials. Yongli *et al.*[22] have determined that enduringness of bamboo-fiber strengthened plastic (BFRP) composite is relatively similar to that of the mild steel, whereas their density is just 12 percent of that of the mild steel. Hence, the BFRP composites are often very useful in structural applications. Thermoplastic matrix composites materials provide assistance in Nursing extended resolution in several applications in automotive applications. Different papers discuss various methodology of fabrication of material, hand lay-up is also a basic method that involves laying down the reinforcement and applying the polymer by hand.

2 Materials and Methods

2.1 Experimental Setup

In the present work the hand lay-up technique has been selected for fabrication of the composite materials. Different machines used in this process, are explained below and important apparatus, method and design criteria are described by the use of flow chart and cause and effect diagram for easily understand the technique.

2.1.1 Compression Moulding Machine

Compression moulding is a moulding technique in which the moulding material is first layed up manually and then it is heated on the same machine, in the mild steel mould. Compression moulding is used to prevent formation of cavities and blow holes by applying pressure together with the heat. There is comparatively little wastage of material, so one can work with expensive compounds once, heating the metal mould and then softening it by the heat, forcing it to develop into the shape of the mould as the mould closes. After completing the shaping, the excess flash material can be removed.

2.1.2 Magnetic Stirrer

A magnetic stirrer or magnetic mixer is an apparatus which uses rotating magnetic flux to move a stir magnetic bar dipped in the liquid, very quickly making the liquid to spin and mix properly. Magnet or a group of stationary electromagnets that are placed under the container with the liquid. The magnetic stirrer consists of a magnetic rod that is placed in the liquid and provides the stirring effect. The movement of the stir bar is driven by another rotating magnet or a set of electromagnets.

2.1.3 Ultrasonic Cleaning (Sonicator)

Ultrasonic cleaning uses ultrasonic vibrations to move a liquid. Normally cleaning require 5 to 10 minutes depending upon the type of material to be cleaned. All traces of dirt adhering or embedded in solid surfaces are thoroughly removed. Depending upon material to be sonicated, solvents or water are often used. In the present work the ultrasonic bath is used for ultra-sonification of the nano SiO_2 particles mixed in epoxy resin for uniform mixing.

2.1.4 Laboratory Oven

Laboratory ovens are standard devices for material processing of electrical and electronic components, curing of polymers, annealing, bond hardening, evaporation and similar applications in laboratories. These ovens typically provide precise temperature control and uniform temperatures throughout the heating process. In the present work a vacuum is used for evaporation of acetone after ultra-sonification and post curing of polymer composite samples.

2.2 Procedure For Development Of Bamboo Fiber Composites

Thermosetting epoxy grade LY556, hardener grade HY951 and bamboo fibre mat type (bidirectional) purchased from Go Green private limited, Chennai, India. Nano SiO_2 purchased from BVS Enterprise, Bhopal, India. The procedure used is to cut the bamboo mate as per required size and heat it a little so to remove moisture. Taking the epoxy 150gm (ratio of epoxy and hardener can be changed as desired, here we used ratio as 10:1) in the beaker and heat it in the oven to a constant temperature (at least 30 minutes at 80^0C for decreasing viscosity of epoxy) after this we used two different processes as shown in Fig. 1 (Method A and Method B) because we have to make composite once without nano SiO_2 and later with nano SiO_2 particles.

After cooling the epoxy to room temperature, 15 gm of hardener was added to it by stirring slowly, the

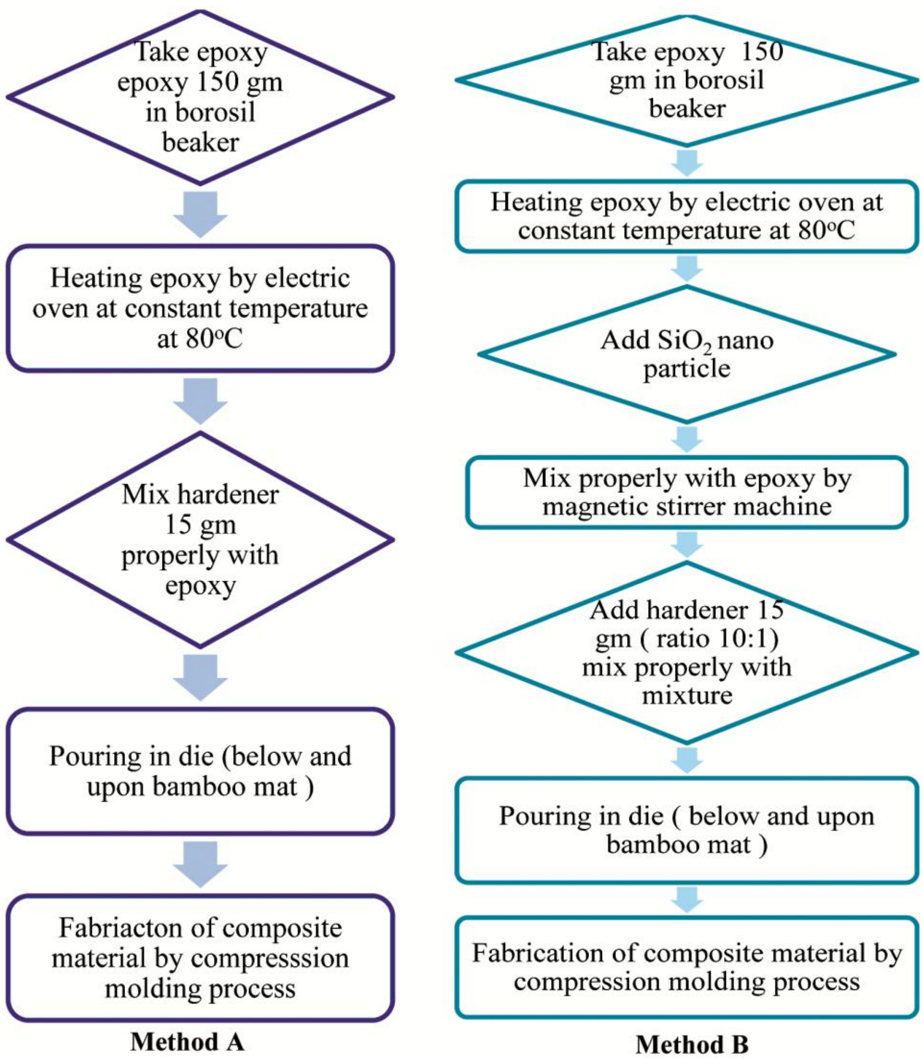

Fig. 1 — Flow chart of fabrication process.

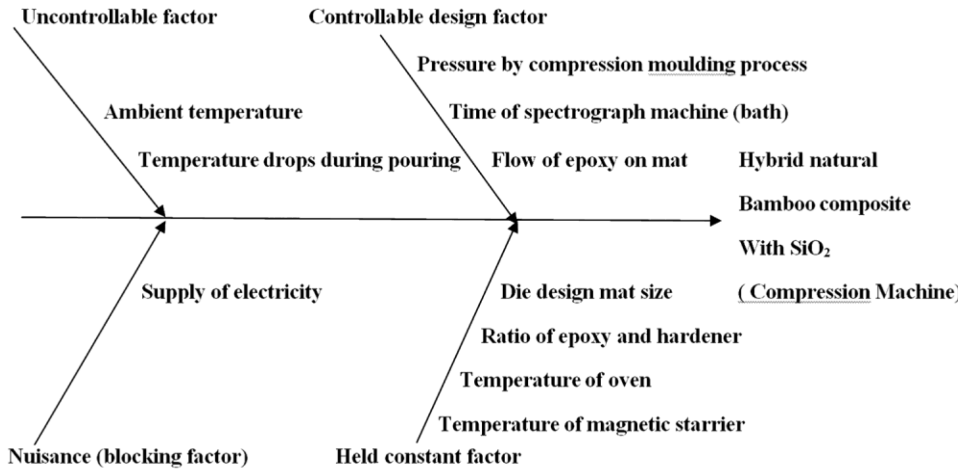

Fig. 2 — Process Parameters and their effect in the Hand Lay- up Technique.

mixture is spread in the die in which composite is to be made. In the moulding die (lower part), wax was pre-applied so that the composite plate can be removed easily after curing. The cut bamboo mate was placed on the spread mixture of epoxy and hardener after which metallic roller was moved on and then again applied the mixture in the moulding die (mentioned procedure was repeat with required layer) after that mould was closed by the upper part of die and put in the compression moulding machine. Load was applied up to 550bar.In the second process (method B) 10ml acetone was added to the heated epoxy, after that the nano $SiO_2$was mixed of in required weight percent which was varied in this study as 0%, 2% and 4% of total weight, and was kept in magnetic stirrer for 45 minutes (500 rpm at 80°C) to mix nano SiO_2 completely in epoxy. After that mixture was put in the ultrasonic bath for 10 minutes and then taken out the beaker from ultrasonic bath, cooled down to room temperature. The same process was repeated with different composition of nano SiO_2 particles. Figure 2 shows the process parameters and their effect in the Hand Lay- up technique.

2.3 Mechanical Testing

2.3.1 Tensile Test

Tensile tests of laminated composite were done on UTM as per ASTM D638 standard the dimension of the test specimen (115mm×19mm×5mm). Specimen was placed in the grips of the universal testing machine at a specified grip separation and pulled up to failure. The tensile test was used to calculate the tensile strength of the composite. The two specimens were taken for each sample and reported the average value for best result.

2.3.2 Flexural Test

The flexural strength testing machine are useful for flexural/ bending property of composite material. Flexural strength was tested as per ASTM D790 standard the specimen size is127mm×12.7mm× 3.2mm. The two specimens were taken for each sample and reported the average value for best result.

2.3.3 Impact Test

The Izod impact test was done for measuring the absorbed energy before the failure of composite material. ASTM D256 standard was used for specimen preparation. The size of specimen is 12.7mm×64mm×3.2mm. For obtaining the average value of impact test two specimens were taken for each composition.

2.3.4 Barcol Hardness Test

Barcol hardness test was done on a digital barcol hardness testing machine as per ASTM D2583 standard tester for measuring the hardness of composite materials. The specimen size is 50mm×50mm. For obtaining precise value of hardness five readings on each specimen were taken and average values were reported.

3 Results And Discussion

3.1 Tensile Properties

After performing this test on the UTM with ASTM D368 standard different value were obtained which are presented in Table 1 and Fig. 3, which shows the improvement of tensile strength with rising wt.% of the nano silica particles in the hybrid composites. The maximum value of tensile strength was found with sample C32 in which three layer of bamboo fibre mat

Table 1 — Tensile strength of composites

S. No.	Composites	Test value (MPa)
1	A10	8.94
2	A12	12.6
3	A14	14.2
4	B20	21.2
5	B22	22
6	B24	26
7	C30	27.3
8	C32	31.8
9	C34	28.7

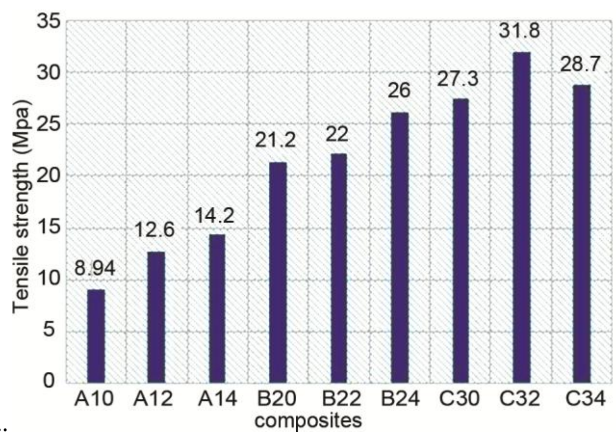

Fig. 3 — Experimental Data of Composite -Tensile strength.

Table 2 — Flexural strength of composites

S. No.	Composites	Test Value (MPa)
1	A10	32.3
2	A12	32.4
3	A14	32.5
4	B20	32.35
5	B22	33.0
6	B24	33.6
7	C30	41.26
8	C32	41.6
9	C34	35.5

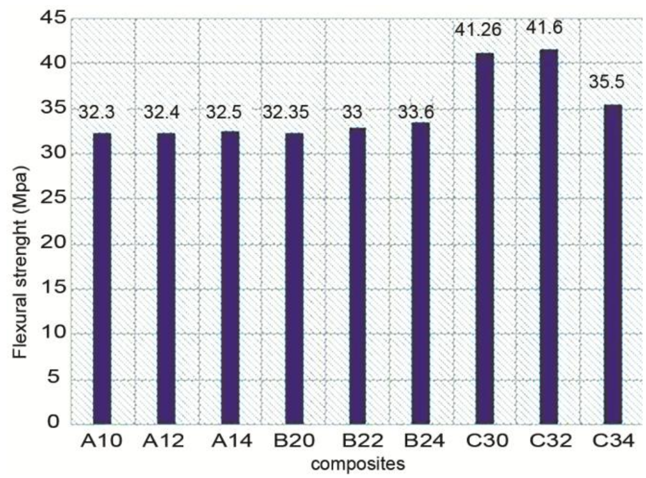

Fig. 4 — Experimental Data of Composite- Flexural strength.

and 2 weight percent of nano SiO_2 which is 16.48% higher than the C30 and after that, it is gradually decreased by 9.74% for sample C34. Reduction in tensile strength beyond C32is caused by non–uniform dispersion or agglomeration of nano particles within the matrix material[7].

3.2 Flexural test

Flexural test was performed on universal testing machine as per ASTM D790 standard and the results for different compositions are presented in the Table 2 and Fig. 4, in which the highest strength was obtained for the sample C32 (three layer of bamboo fibre mat and two percent of nano SiO_2). The flexural strength is an important property of laminated composite material. Flexural strength was increased as wt. % of SiO_2 increased from 0 to 2 %. By increasing the filler content up to 4wt.% SiO_2, a gradual decrease in flexural strength was experienced. This will be outlined by the actual fact that overloading the organic compound part with the silicon dioxide particle will increase the consistence of resin phase that afterward cut back its flexural strength. In strengthened polymers, it's unremarkably determined that flexural strength is higher than the tensile strength[23].

3.3 Izod Impact Strength Test

The Izod impact tests were performed on impact strength testing machine as per the ASTM D256 standard and the results obtained are presented in the Table 3 and Fig. 5. Based on the values obtained after the test the maximum impact strength (energy absorbed) was obtained with C32 specimen in which three layer of bamboo fibre mat and 2 weight percent of nano SiO_2 were mixed. Increasing the wt.% of nano silica in the hybrid composite enhances the impact strength up for layer one (A10, A12, A14) and also for layer two (B20, B21, B24) But with three layers of bamboo fibres C30 to C32 impact strength increase then decrease gradually for C34 due to agglomeration of SiO_2 nanoparticles. The addition of nano SiO_2 and bamboo fibre increases impact strength up to 3-layer 2wt.% SiO_2. Uniform desperation of silica nano particles in the epoxy are two important factors in improving the impact strength of composites[24].

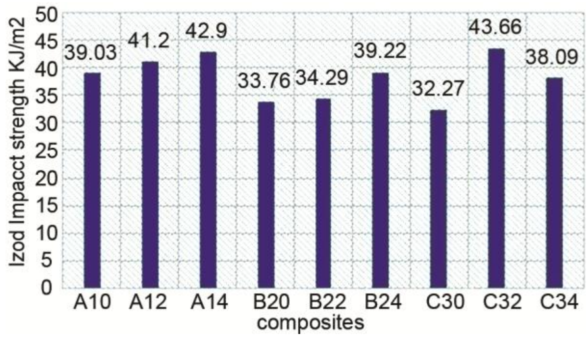

Fig. 5 — Experimental Data of Composite- Impact test (Izod test).

Table 3 — Izod Impact (notched) strength of composites

S. No.	Composites	Test Value KJ/m^2
1	A10	39.03
2	A12	41.20
3	A14	42.9
4	B20	33.76
5	B22	34.29
6	B24	39.22
7	C30	32.27
8	C32	43.66
9	C34	38.09

3.4 Barcol Hardness test

The barcol hardness values were obtained by performing five tests on each specimen in the Barcol hardness testing machine as per the ASTM D2583 standard. The average values of five readings for different specimen are shown in Table 4 and Fig. 6. The highest value was obtained for the B22 sample (two layer of bamboo fibre mat with 2 weight percent of nano SiO_2). The Hardness is a property which measure the resistance of a material to surface indentation and abrasion. Hardness property is the durability and life span of the composite[26]. The hardness of the hybrid composite improved with nano-silica particle and bamboo fibre from sample A10 to B22. Then after increasing the wt. % of SiO_2 decrease the hardness. For three-layer bamboo fibre composite samples barcol hardness first increase and then decrease for C34 sample. The increase in hardness of bamboo fibre epoxy composites from 0 to 2 wt.% nano SiO_2 particles is due to the homogeneous distribution of the nano SiO_2 in the matrix with minimization of voids and stronger interfacial adhesion between matrix and particles, while the gradual decrease in hardness with higher particle loading can be due to particle agglomeration which favours the formation of voids and poor interfacial adhesion between matrix and particles[25].

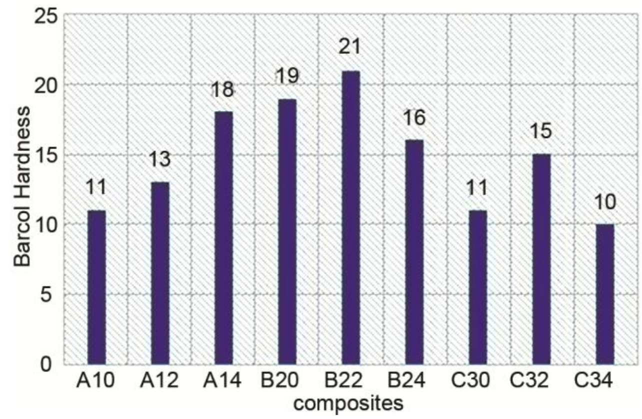

Fig. 6 — Experimental Data of Composite- Hardness test.

Table 4 — Barcol Hardness test of composites

S. No.	Composites	Test value Barcol Hardness Number
1	A10	11
2	A12	13
3	A14	18
4	B20	19
5	B22	21
6	B24	16
7	C30	11
8	C32	15
9	C34	10

4 Conclusion

The hybrid polymer composites were developed by hand layup technique assisted by compression moulding. Compression moulding machine was used to apply pressure of 550 bar so as to prevent forming of blow holes and cavities. This process is very good for development of polymer composite material, it is cheaper and better as compared to other methods, based on the time taken and room temperature curable epoxy-based composites, the work can be done smoothly. Bamboo mat should be cut into the accurate size in advance and remove moisture so that the composite sheet can be made without blowholes**.** After performing the tensile test, flexural tests, Izod impact test and hardness test on the basis of different values, it is found that mixing of 2 wt. % of nano SiO_2 yields maximum increase in tensile, flexural, impact strength and hardness values. The tensile, flexural and impact strength were maximum for 3 layers of bamboo fiber mat while barcol hardness was maximum for 2 layers of bamboo fibre woven roving. At 4 wt. % of nano SiO_2 with increasing layer of bamboo fibre, above mention, mechanical properties of the composites deteriorate, which is because of clustering of very small size nano SiO_2 particles at higher weight percent.

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