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Manufacturing and Testing of PAN Nano Fibres, Banana Epoxy Nanocomposite

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Abstract: Over past few decades composite materials, ceramics and plastics have been leading emerging materials. The applications of composite material and the area in which they are being used is growing day by day. The curiosity has gained substantially towards the use of natural fibres in composites in recent few decades. Natural fibre composites are eco-friendly and often used in engineering application such as in construction, automobile, aerospace and household applications. Nano fibres are responsible for a connection between the Nano scale and the macro scale, since their diameters are in the nanometre range and the length is continuous. Nanofibre are attracting very high interest due to their extraordinary micro and Nano structural characteristics, high porosity, mechanical strength, Flexibility and integrally large total surface area. There is increased curiosity about natural fibre based epoxy composites properties to short out engineering necessities. Hence, a matter of concern to overview and check the exiting position and put efforts for sustainable and possible commercial exploitation and additional improvements. This research work shows comparison of strengths with and without added Nano fibres to the Banana fibres composite. Testing data clearly indicates the enhancement in mechanical properties when Nano fibres are added in to Natural fibre reinforced composite..

***keywords*: Natural fiber composite, Nanocomposite, PAN Nanofiber.**

I. INTRODUCTION

Over past few decades composite materials, ceramics and plastics have been leading emerging materials. The applications of composite material and the area in which they are being used is growing day by day. Nowadays, the use of composite materials in our lives has become very common and these are found in our furniture, education, transportation, building, sports and infrastructural system. Main reasons for substituting to composite materials are their comparable performance and properties over conventional materials such as woods, metal, plastic and polymers as to the advantages that they offer such as specific strength and stiffness. Since the mid of 20th century research and engineering interest shifted from monolithic materials to composite materials [1-3]. The curiosity has gained substantially towards the usage of natural fibres in composites in recent few decades.

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Natural fibre composites are eco-friendly and usually used in engineering application such as in construction, automobile, aerospace and household applications. Natural composites are not new materials to the world. Wood is naturally occurring composite which consist of cellulose (reinforcement-phase) in lignin (matrix-phase). Fibre added polymer composites have applications in industries and households because they have more hopeful properties such as greater strength, low thermal expansion, better fatigue performance, high stiffness and low energy consumption during manufacturing, more corrosion resistance and have non-magnetic properties.

Generally these materials are made from two or more element materials with different chemical or physical properties. The properties remains separated and distinct at the macroscopic or even microscopic scale within the structure. Natural fibre composites are combination of fibres made from plant with a plastic binder. The natural fibre component may be coconut, cotton, wood, sisal, flax, hemp, kenaf, jute, banana leaf fibers, abaca, bamboo, wheat straw or other fibrous material and the binder is often recycled plastic [4,5].

Boopalan et al., have studied the thermal and mechanical properties of banana and jute fibre reinforced epoxy hybrid composites. In addition to increase the mechanical properties, jute fibres was hybridized with banana fibres. Impact, flexural, tensile, water absorption and thermal tests were carried out on these hybrid composite samples. This study indicates that the addition of up to 50% by weight banana fibres into jute/epoxy composites shows enhancement in the thermal and mechanical properties and decreasing moisture absorption capacity [6].

Sapuan et al., have studied the flexural and tensile characteristics of the banana fibre composites by varying the direction of fibre woven. They have stated that modulus of the composite and tensile strength have 13% and 300% increased value in the x-direction of the fibres as compared with the y-direction of fibres alignment respectively [7].

Srinivasan et al., have studied on the tensile strength of the flax/banana and glass fibre reinforced polymer composites. The results indicated that the flax/banana glass fibre reinforced polymer hybrid composite had higher ultimate tensile strength of 39 N/mm2 as compared to the banana-glass fibre reinforced polymer composite and the flax-glass fibre reinforced polymer composite, which got tensile strength values of 30 N/mm2 and 32 N/mm2 respectively [8].

Nano science and technology is an interdisciplinary and broad area of research and development, this area has been growing worldwide in the past few years. Nano materials are an important subgroup of Nanotechnology. Nano materials are keystones of Nano science and nanotechnology. A nanomaterial is a material with at least one dimension in nanometer scale i.e. less than 100 nm.

Materials and products are created using this Nano scale range has possiblities for revolutionizing new properties and functionalities that can be access easily. It is already having a important commercial impact, which will definitely raise in future [9].

Nano materials can be divided as: One dimension (e.g. surface thin films), two dimensions (e.g. Nano strands or Nano fibres), or three dimensions (e.g. particles). Common types of Nano materials are quantum dots, nanotubes, fullerenes and dendrimers [10].

Nano fibres are responsible for a connection between the Nano scale and the macro scale, since their diameters are in the nanometer range and the length is continuous. Nanofibre are attracting very high interest due to their extraordinary micro and Nano structural characteristics, high porosity, mechanical strength, Flexibility and integrally large total surface area. Nano fibers can be made from different polymers and hence have different physical properties and application potentials. Nano fibers have two types 1) Natural - chitosan, gelatin 2) Synthetic - PLA, PVP, PAN [11].

Sachin Chavan have shown in his Ph.D. thesis that nylon 6,6 nanofibre are used in composite material in this research work, and he got increased impact threshold force by 38%. Nylon 6, 6 nanofibre is used with solvent formic acid. It has very strong bond of hydrogen, which is due to the arrangement of the monomers. As the Bond is stronger it gives good mechanical strength and resistance to the heat as compared to Nylon 6 [14].

II. EXPERIMENTAL

PAN is one of the most widely used polymers in many areas. PAN solution was prepared by mixing PAN powder with dimethylformamide (DMF). PAN and DMF were products of SIGMA-ALDRICH with product numbers 181315 and DV800161 respectively. Average molecular weight of PAN was 150,000 [13].

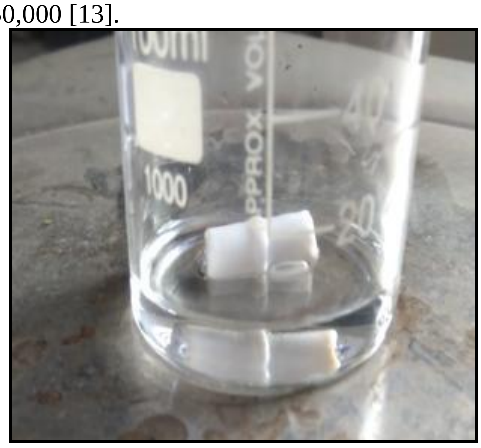

Figure 1: Before dissolving PAN in DMF (transparent colored solution)

Solutions were prepared by using concentrations from 7% to 10% in 10 ml DMF solution. PAN was dissolved in DMF by using stirrer hot plate with temp 500 to 600C and mixing duration was 4 hours. Before dissolved PAN in DMF colour of solution was transparent and after mixing solution colour converts in to light yellow [13]. Figure 1 above is showing PAN dissolution in DMF.

Electro spinning is a simple process which can produce polymer fibres ranging from micrometre to nanometre from melt or polymer solution using an electric field. When an electric potential is applied to melt or solution of polymer the transformed polymer solution forms a cone shaped droplet at the tip of the nozzle [12].

Figure 2: Electro spinning machine actual setup at BVDUCOEP

Procedure to synthesis PAN Nanofibres

First of fill the syringe with PAN solution. Then remove the all the bubbles from syringe before setting syringe into the machine. Properly Place a Banana fabric sheet on to drum collector. Set the certain distance between tip of syringe to drum collector (10-17cm). Close the door of electro spinning machine. Now turn power on the main switch, then switch on light and fan of machine. Set the syringe type (here 2 ml) and Flow rate - 0.8-1.2 ml/hour. Start the collector and syringe. Turn on the voltage button and increase the voltage from 0 to 18 KV. After certain time finally remove Banana fabric sheet carefully on which fibres are deposited from drum collector.

VARTM (VACCUM ASSISTED RESIN TRANSFER MOLDING):

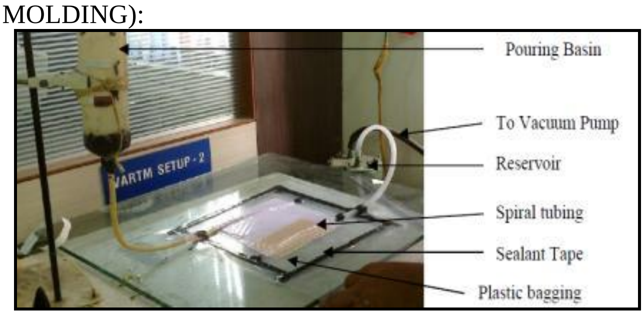

Figure 3: Actual VARTM setup at BVDUCOEP

VARTM Process:

A layer of frekote or wax (the Teflon) film is placed on the mold surface which helps to release the mold easily. This film should be bigger in size by at least 8-10 cm on each side of the sample to cover the resin flow channel. The distribution media is placed on the bottom mold release film, this distribution media is used for constant flow of resin throughout the fabric layup in Z-direction. Here flat faced square composite samples are made. The sample size is determined based on the type of characterization of specimens to be carried out. The number of layers are decided based on requirement of testing or thickness.

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We have made samples of 20 * 20 cm in size and 8 layers of the banana fabric with electro spun Nanofibres.

For resin impregnation, the High-Density Polyethylene (HDPE) tubes with spiral cut is used as suction and supply network.

To seal the whole network, polysulfide sealant tape is pasted around the fabric sample peripheral boarder, nearby to the bottom release film. The sealant tape also called as mask tape, on which bagging material is placed. Extra precaution is to be taken with the portion of sealant tape covering the inlet and outlet of polytetrafluoroethylene (PTFE) extension for resin spiral tubing.

Vacuum bag is then vacuum-packed with sealant tape and mold is kept under 1 bar vacuum pressure. The VARTM setup should be monitored for 15-20 minutes for any loss in vacuum pressure to identify if there is any leakage. While checking for the leakages, the vacuum suction line is kept cut off from the vacuum pump (by placing adjustable clamps on the suction line). The vacuum pump kept turned off while the vacuum leaks are being checked.

Once the vacuum bag is ensured not to have any leaks. Resin is then poured into the resin reservoir and by slightly opening the adjustable clamp to create an opening for proper resin flow. The adjustable clamp on the suction end is kept closed all the time during throughout resin impregnation process. As per the recommendation from axon India (resin supplier), curing cycle for the Biresin is 12 hours at room temperature.

Results and Discussion

Testing

Tensile test of Banana (With Nanofibres) specimen

Figure 4(a):Before Test

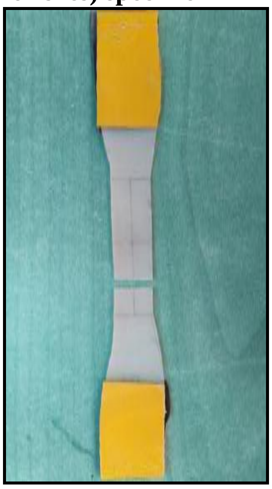

Figure 4(b):After Test

Figure 4 (a) indicates the prepared specimens for tensile test as per ASTM standard measurements i.e. ASTM D 638. The testing is done using Universal Testing Machine to measure the force that required to break a Banana fibre Nano composite sample specimen and the point at which the specimen stretches or elongates to that breaking point. Here Figure 4 (b) shows a damaged piece during the tensile test.

Compression test of Banana (With Nanofibre) specimen

Figure 5(a):Before Test

Figure 5(b):After Test

Figure 5(a) shows the specimens prepared for compression test as per ASTM standard measurements i.e. ASTM D 695. The compressive testing is done using Universal Testing Machine to determine compression strength of Banana fibre Nano composite specimen and at which point specimen deform. Here Figure 5(b) indicates a deformed piece after the compression test.

Flexural test of Banana (With Nanofibre) specimen

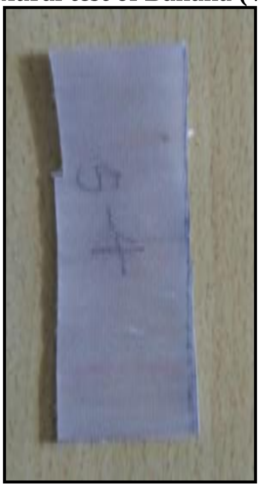

Figure 6(a):Before Test

Figure 6(b):After Test

Flexural strength is defined as the materials' capacity to resist deformation under load. It is a 3-point bend test. This testing is done in Universal Testing Machine. Flexural strength of the material can be described as maximum fibre stress at failure on the tension side of a flexural specimen. Figure 6(a) shows the prepared specimens for flexural test as per ASTM standard measurements i.e. ASTM D 790. Here Figure 6(b) indicates a deformed piece during the flexural test.

III. RESULTS

Some of the results obtained during tensile testing with and without nanofibre addition

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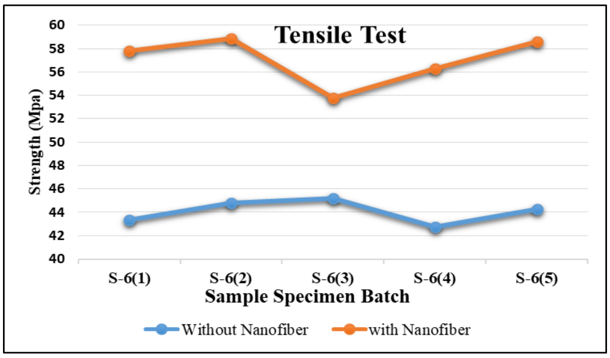
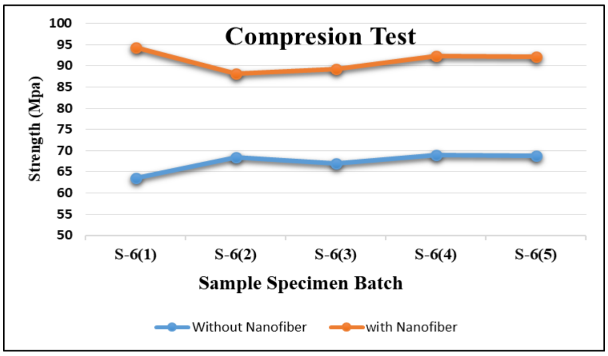


Graph 1: Banana specimen tensile test

In result the tensile test banana (with Nanofibre) composite has more tensile strength avg. 57.07 MPa then banana fibre (without Nanofibre) composite avg. 44.07 MPa, which means there is 22% average tensile strength increment in Banana fibre (with Nanofibres) composite sample.

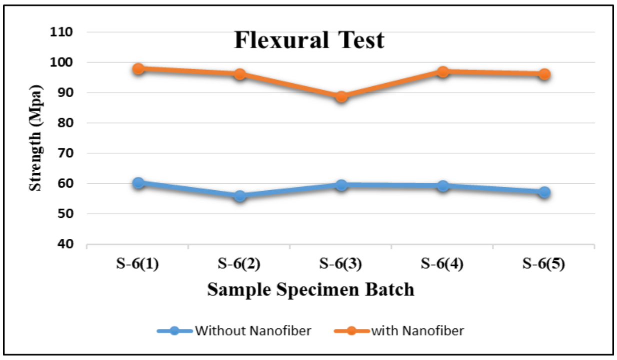
Some of the results obtained during compressive testing with and without nanofiber addition



Graph 2: Banana specimen compression test

In compression test result, banana (with Nanofibre) composite has more compression strength 91.26 MPa then banana fibre (without Nanofibre) composite 67.38 MPa, which means there is 26% average compressive strength increment in Banana fibre (with Nanofibres) composite sample.

Some of the results obtained during flexural testing with and without nanofiber addition



Graph 3: Banana specimen flexural test

In Flexural test result, banana (with Nanofibre) composite has more flexural strength 95.17 MPa then banana fibre (without Nanofibre) composite 58.62 MPa, which means there is 38% average flexural strength increment in Banana fibre (with Nanofibres) composite sample.

IV. CONCLUSION

In summary, Composites has properties like high specific strength and light weight, lower energy etc. which can be used for varied applications. It concludes here that the mechanical properties of natural fibres are quite similar or closer to the properties of glass fiber or other synthetic fibers. As Nano materials have high surface to volume ratio, it results in change its mechanical properties as compared with their bulk sized equivalents. So, on addition of approximately 0.5 to 3% Nanofibres in composite enhances the tensile, compressive and flexural strength of composite material by 22%, 26% and 38% respectively.

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