Experimental Investigation and Analysis of Mechanical Properties of Chopped Strand Mat-E Glass Fiber Polyester Resin & Silica Powder Composite

Narendra Kumar Attili[*1], Ch Siva RamaKrishna[2]

[1,2]Department of Mechanical Engineering, Vignan's Institute of Information Technology,
Jawaharlal Nehru Technological University, Kakinada,
Duvvada, Visakhapatnam-530049, Andhra Pradesh, India
[*1]attilinandu@gmail.com; [2]srkchadaram@gmail.com

***Abstract*-Composite materials play a vital role in many industrial applications. Researchers are working on fabrication of new composite materials worldwide to enhance the applicability of these materials. In view of this the mechanical performance of the composite material is essential. The objective of the present work is to analyze the effect of silica powder content on the mechanical behavior of chopped strand mat 450 GM-Glass fiber reinforced. Five different types of composites are fabricated using 0%wt, 5%wt, 10%wt, 15%wt and 20%wt of silica powder with Chopped Strand Mat-E glass fiber and polyester resin. The polyester resin, catalyst and accelerator are mixed in 50:1:1 weight ratio in polyester matrix with silica powder. The aim of the project is to investigate the effect of silica powder with chopped strand mat 450GM for making the composite material stronger and tougher. The investigation is carried out by mixing different weight percentages of the powder with the polyester resin and preparing individual samples. After CSM preparation, the materials were properly mixed using the hand-lay techniques and different specimens were prepared with different compositions of the silica powder. After all the samples were prepared, mechanical tests were carried out on the samples to ascertain the changes observed due to the composition of silica powder. The obtained results of various samples specimens were compared and graphically charted to characterize the new composite material.**

Keywords- Chopped Strand Mat (CSM) 450 GM-Glass Fiber; Silica Powder; Polyester Resin; Hand- Lay; Catalyst; Accelerator

I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc. It is noted that the present industrial scenario is subjected to rapid changes in various trends. Unlike the olden days, the present focus is improving material aspects of a product rather than finding new ways of synthesis. This fundamental shift in thinking has made Material Science an important subject for every industrial discipline. Under the same aegis, the researchers started exploring avenues within material science that could lead to a useful application through future development. This prompted us to start investigating with composites, particularly those with polyester resin as the fillers. With the present project, contributed successfully on investigation of the mechanical properties of various combinations of matrix and reinforcement. A Composite, in engineering sense, is any material that has been physically assembled to form one single bulk without physical blending to foam a homogeneous material. The following list presents a gist of the main papers referred to, throughout the duration of the project. The objective of this project is as follows: to acquire information about composite materials and study the various techniques that are in use for preparing such materials, to select a suitable matrix and a reinforcement for the composite, to prepare and fabricate the composite using the studied techniques with the selected material, to prepare specimens according to ASTM standards for the tests, to identify and perform suitable tests on the samples/specimens prepared to characterize the findings and analyze the results.

II. LITERATURE REVIEW

A composite consists of a matrix as well as a reinforcement. The matrix surrounds the reinforcement and supports it by maintaining its relative position. Composite materials have been an emerging field with a lot of innovation going on since the past few years. A lot of technical papers and manufacturing processes were studied before deciding upon the most feasible process for characterization of a composite. The following list presents a gist of the main papers referred to develop the new composite and investigate the properties.

Naidu et al. [1] studied the compressive and impact properties of hybrid composites. Their research is on Natural and Synthetic fibers. They have found a significant improvement in compressive and impact properties of Sisal/Glass fiber hybrid composites. They considered Chalk powder (additive) to the resin (unsaturated polyester) in proportions of 1%, 2%, 3% by weight of resin respectively and Sisal/Glass fiber hybrid composites were prepared by using this resin to study the effect of Chalk powder.

R. Sakthivela et al. [2] studied mechanical properties of hybrid polymer composite plates through experimental investigation. In their project, the natural fiber and glass hybrid composites were fabricated by using epoxy resin combination of hand-lay method and cold-press method. They considered ASTM standard for different experiments of tensile test, flexural test, and impact test for specimen preparation. They obtained a significant improvement in tensile strength by the woven fiber glass hybrid composites and hybrid composite laminates banana-glass-banana (BGB) and glass-banana-glass (GBG) that exhibited higher mechanical properties.

Dr P K Palani et al. [3] analysed the mechanical properties of chopped strand mat of E Glass fiber, epoxy resin and Nano clay combination. They took three different types of composites to fabricate 1wt%, 5wt% and 7wt% of Nano clay with 30% wt of fibre, epoxy resin and hardener. They considered proportion of epoxy resin and hardener in 10:1 weight ratio. The objective of their work was to analyse the effect of Nano clay content on the mechanical behaviour of chopped strand mat E-glass fibre, reinforced in epoxy matrix with Nano clay filler. Their results showed that the incorporation of Nano clay has a significant effect on the mechanical behaviour of composites.

Ravi Kumar et al. [4] analysed the influence of Aluminium Oxide filler on Fracture Toughness properties of Chopped Strand Mat (CSM) E-Glass Fibre reinforced Epoxy Resin Matrix. They considered ASTM D5045 standard for the specimen preparation. They have conducted fracture toughness tests with six different compositions of composites. Three samples were tested for each composition of the composites. They have fabricated composites by hand-lay method Epoxy resin and hardener was mixed with the weight ratio of 10:1. They have shown the tensile strength for 4wt% of aluminium oxide filled composite is higher compared with 2wt%, 6wt%, 8wt%, 10wt% and neat composite. They concluded that by the addition of small percentage of aluminium oxide filler there is marginal improvement in fracture toughness of glass fabric reinforced epoxy matrix up to 4wt%.

Martin James et al. [5] contributed on nanofillers where as VB Gupta et al. [6] made a complete comprehensive review article on fibre reinforced composites. The successful uses of Kaolin and Polyurethane in epoxy based composites are explained by Mohamed Bakar et al. [7]. The impact of using thin crystal engineered Kaolin’s to enhance the mechanical properties of coatings is presented by J C Husband et al. [8].

Taraghi et al. [9] studied on Kelvar/Epoxy laminated composites with multiwall carbon nanotubes, R P Singh et al. [10] analysing effects of reinforcement particle size .Marco A. Perez et al. [11] stressed on impact damage prediction on carbon fiber-reinforced laminated composite and Investigation on effect of low velocity impact damage on buckling properties was presented by Ahmet Yapici et al. [12] standard test methods were followed for tensile test [13] flexural properties [14] and for impact properties [15].

III. METHODOLOGY

The problem stated in this paper is defined by three stages, which are:

The methodology for specimen preparation in terms of materials used in fabrication, way of for specimen preparation and different mechanical tests conducted are marked in Fig. 1. All the samples were prepared by following procedure:

Stage1: Fabrication, Stage 2: Preparation and Stage 3: Testing.

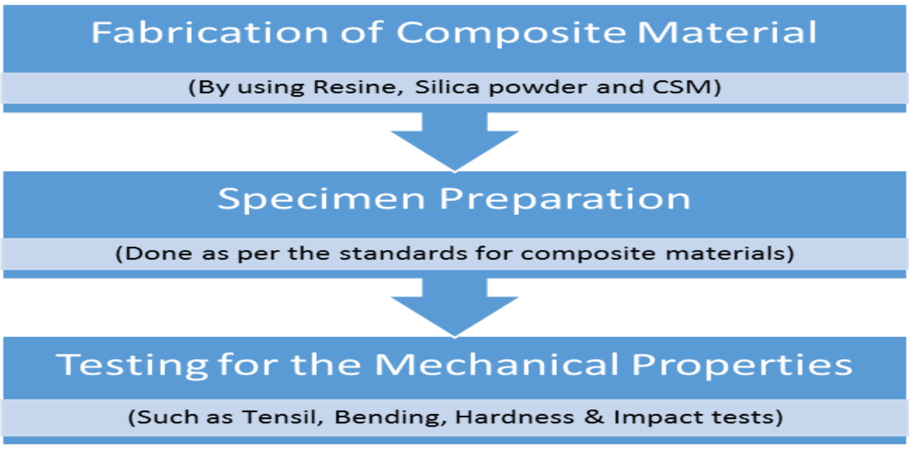


Fig. 1 Methodology for preparation of specimens

To prepare the test specimen, the 450CSM-450 glass fiber layer is cut to the defined shape as shown in Fig. 2 and placed in a position on the table. The samples are prepared by chopped strand mat E glass 450gm with mixture of polyester resin in the ratio 1:2 and mixture with the silica powder (0%, 5%, 10%, 15%, 20%) as shown in Fig. 3. The polyester resin, catalyst and accelerator are mixed in 50:1:1 weight ratio in polyester matrix with silica powder. Polyester resin is applied to the glass fiber using brush since hand-lay method is used and the process which enables the polyester resin to firmly occupy the layer. The next layer of same size and shape is then placed on another layer of CSM-450 cut pieces. The same procedure is carried out for six layers till it gets required thickness. This action enables the resin to impregnate the glass mat and dissolve the binder which holds the fibers together. Fig. 4 shows the hand-lay process for sample specimen preparation. The reinforcement is developed after curing by giving sufficient time for complete drying. The layers are impregnated in the same order of the previous layer. No air bubbles are presented during the addition of polyester resins. In sequence layer by layer is followed with same orientation of the matrix material with resin and silica powder (0%, 5%, 10%, 15%, and 20%). Also the number of layers prevents the buildup of excessive exothermic property and dried composite samples are shown in Fig. 5. The heat generation during curing with high exothermic temperatures can lead to the cracking, pre-release, distortion or scorching of the laminated and the problem of high exothermic reaction happens if there is an uneven thickness of the laminates mostly when thick laminates are used. The cooling is done after complete impregnation of the all the layers. The delay between the layers is strongly minimized while doing the hand-lay process with brush. During the process, the laminate can be easily trimmed to the dimensions of the mould and trim edges can be built into the mould to facilitate this operation. For samples prepared with silica powder (0%, 5%, 10%, 15%, 20%) with chopped strand mat E-glass fiber 450 GM the above procedure was used and the specimen is marked as - 01 for purely chopped strand mat E-glass fiber 450 GM and polyester resin. The specimen marked as 02, 03, 04 and 05) consist of silica powder at 5%, 10%, 15%, 20% along with chopped strand mat e-glass fiber 450 GM and polyester resin. Before the next process layer by layer the chopped strand mat E-glass fiber 450GM of the material is checked for any defect in the lamina such as gaps, holes, irregular orientation of mat etc.. The resins, catalyst, and accelerator should be mixed and applied in the time of 20 to 30 minutes in hand-lay process.

Fig. 2 Cut- pieces of chopped strand mat 450 gm glass fiber

Fig. 3 Mixing of resin

Fig. 4 Hand-lay process for sample specimen preparation

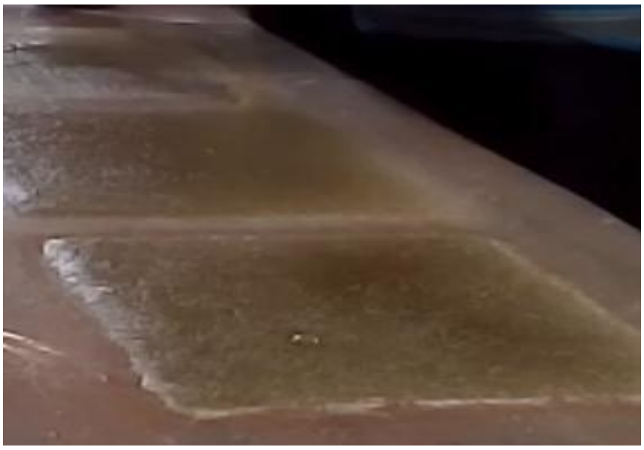


Fig. 5 Dried composite material samples

The solution is neatly applied onto the glass fiber sheets before laying them down into the mould. Putty blades are used to remove excessive spread of the material so that the solution is uniform over the glass fibers. After placing six glass fibers in roughly equal intervals, the remaining solution is used to top up the mould and obtain a smooth finish. Different mechanical tests are conducted on test specimens with sequences specified in Fig. 6.

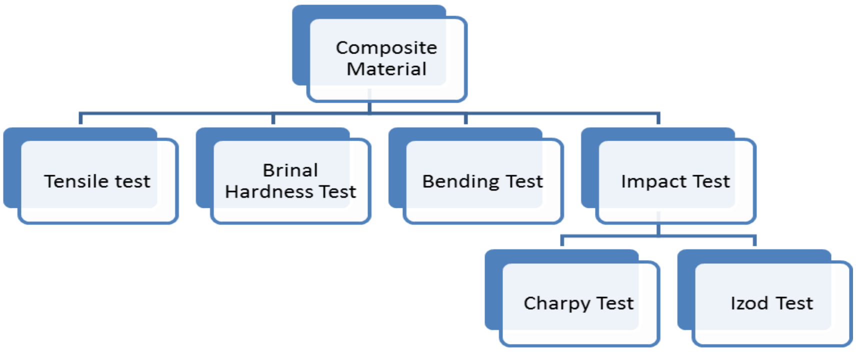


Fig. 6 Different mechanical tests conducted on specimens

A. Tensile Test (ASTM D-638)

Tensile test confirms the ability to resist deformation under tensile load. This test consists in straining a test piece by tensile stress, generally to fracture, in order to determine one or more of the mechanical properties. The cross-section of the test pieces may be circular, square, and rectangular or any other form in special cases. But for polymer matrix composite test pieces of rectangular section are used. Plain ends are used for holding the specimen during testing. The test piece is fitted to the testing machine in such a manner that the pull is applied axially. The accuracy and sensitivity of the testing machine shall be within 5% of the maximum load applied to the specimen. The extensometer is used to correct to 0.005% of the gauge length and the instrument shall possess a sensitivity of 0.001mm. The rate of loading, when approaching the yield stress, should not be more than 7.5 MPa per second. The arrangement of test specimen and its details are shown in Fig. 7.

The following procedure may be adopted in the tensile test: Prepare a test piece as per the standards. Measure the dimensions of the test piece by means of a micrometer and vernier caliper at least at three places and determine the mean value. Also mark the gauge length. Insert suitable jaws in the grips and select a suitable load scale on the testing machine. Insert the test piece in the grips by adjusting the cross heads of the machine. Fix the extensometer on the test piece and set its scale dials to zero positions (Fig. 8). Also set the vertical column of the machine to zero position to take readings in the plastic range. The automatic graph recording system may be set if desired. Start the machine and take the reading of the dials on the extensometer for a particular value of load. The rate of loading should be maintained at 7.5 MPa per second. Continue applying the load till the specimen break and then stop the machine. Plot load versus extension diagram. Determine the various mechanical tensile properties. The arrangement for tensile test is shown in Fig. 9.

Fig. 7 Tensile test specimens

Fig. 8 Impact test specimen

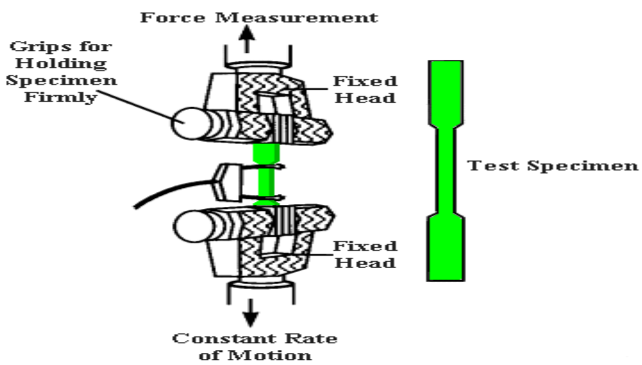


Fig. 9 Tensile testing

B. Brinell Hardness Test

Brinell hardness determines the penetration under plastic state of the material, which is important for deciding the scratching, abrasion or penetration properties of the material. Intension of hardness test is to calibrate machines to force a hard steel ball under specified conditions of load and time, into the surface of the material under test and to measure the diameter of the resulting impression after release of the load. This test consists of indenting the surface of the metal by a hardened steel ball of specified diameter D mm under a given load F in Newtons and measuring the average diameter d in mm of the impression by a Brinell microscope used in separate. The Brinell hardness HB is defined as the quotient of the applied force F divided by the spherical area of the impression for a ball of given diameter. It has been found that the Brinell hardness number varies with the load in order to obtain comparative results and the relationship between the load F (N) and ball diameter D (mm). Fig. 10 shows the samples used for hardness test.

For given test specimen material, thickness and hardness range, the ball diameter and load are to be selected. The load should be applied slowly and progressively to the specimen at right angles to the surface and the full load should maintain for period of 15 seconds. When thin specimens are subjected to the Brinell test, the nature of the plastic flow is appreciably different from that obtained on thick parts, so that unreliable hardness numbers are given. To eliminate this error the thickness of the test specimen should be 10 times the depth of impression and never less than 8 times the depth of impression. The distance of the centre of indentation from the edge of the test specimen should not be less than 2.5 times the diameter of indentation, and the distance between the centres of two indentations should be 4 times the diameter of indentation. The surfaces of the specimen should be smooth and free of oil and dirt. The Brinell hardness is represented as 75 HB/2.5/187.5/15 which means the Brinell hardness of 75 is obtained when a load of 187.5 kg is applied with a steel ball of 2.5mm diameter in 30 seconds. The BHN is calculated by dividing the area of indentation with load applied. The use of Brinell hardness tester for experimentation is shown in Fig. 11.

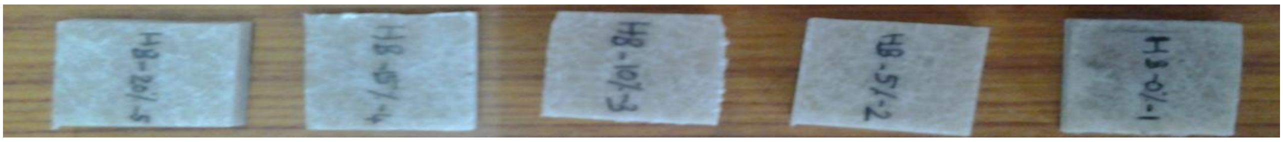


Fig. 10 Hardness test specimens

Fig. 11 Brinell hardness testing

C. Impact Test

Impact test is to determine the behaviour of materials when subjected to high rates of (sudden) loading. It measures the energy absorbed in breaking the specimen by a single blow or impact. Charpy and Izod impact tests are conducted for the composite. The test specimens of Izod and Charpy with different weight percentages of silica powder are shown in Fig. 8. Izod impact test (ASTM D 256) it is a pendulum type single blow impact test. In this, the specimen is usually notched and is fixed at one end and broken by a falling pendulum weight. The energy absorbed as measured by the subsequent rise of pendulum is a measure of impact strength or toughness of the material. The impact strength is expressed in Joules. Cantilever orientation to specimen is used in Izod impact test.

Charpy Impact test (ASTM D 256) a pendulum type single blow impact test is used in the charpy impact test. During this test, the notched specimen is supported at both ends, as a simple beam in simply supported orientation, and is broken by a falling pendulum on the face opposite to and immediately behind the notch. The energy absorbed as determined by the subsequent rise of pendulum, is a measure of impact strength or material toughness and is expressed in terms of Joules. The test pieces should be 55 mm long square section. The notch is made at the centre of the test specimen. The plane of symmetry of the notch should be perpendicular to the longitudinal axis of the test piece. The distance of the plane of symmetry of the notch from ends of test piece shall be 27.5+/-0.42 mm and the angle between the plane of symmetry of the notch and the longitudinal axis of the test piece shall be 90+/-2 degrees. The test piece is placed in the work holding supports with the plane of symmetry of the notch within 0.5 mm of the plane midway between them. It should be struck by the hammer in the plane of symmetry of the notch and on the side opposite to the notch. The speed of striking should be 5m/s to 5.5m/s. The accuracy of graduations on the scale should be +/-0.5% of the maximum capacity of the machine. The following procedure may be adopted to determine the impact strength. Lift the hammer to an appropriate inclination and positioned the knife edge and release the hammer. For the standard test, locate the test piece on the machine supports, release the hammer. The hammer will break the test piece and shoot up to the other side of the machine. The arrangement for impact test is detailed in Fig. 12.

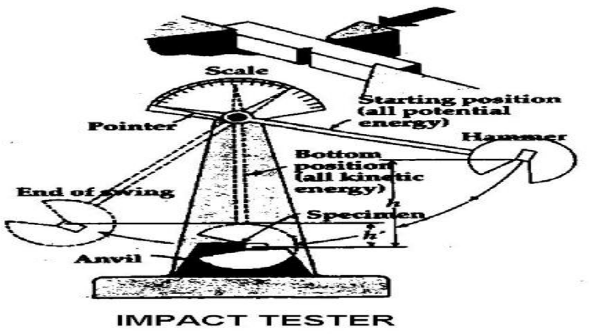


Fig. 12 Impact testing machine

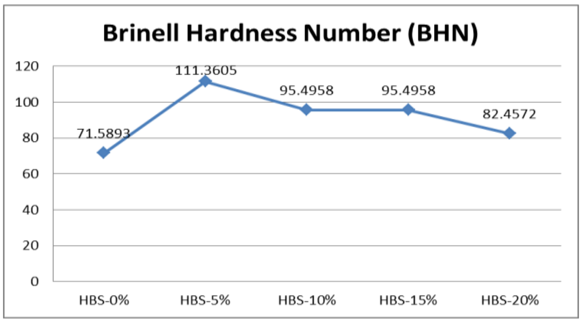
D. Flexural Strength (ASTM D-790)

Flexural strength determines the ability of the composite under vertical loading. A bending test is performed on actual beam cross section by using the three points loading systems as Fig. 13. The bending fixture is supported on the platform. The loading is held in the middle of the specimen when specimen under test is supported with knife edge points. At a particular load the deflection at the centre of the beam is determined by using a dial gauge. The deflection at the beam centre is given by: δ=Wl3/48EI.Knowing W, l, δ and I, can determine the modulus of elasticity E of the beam material. It is more advisable to plot the load deflection curve and determine the value of w/ δ from the linear part of the curve, which should be used to determine E and stiffness. The failure of beam may take place due to yielding, buckling. Excessive local high stress due to concentrated loads and the distribution of progressive bending stresses in a beam material have linear stress strain curve. Flexural test gives modulus of elasticity of the composite material.

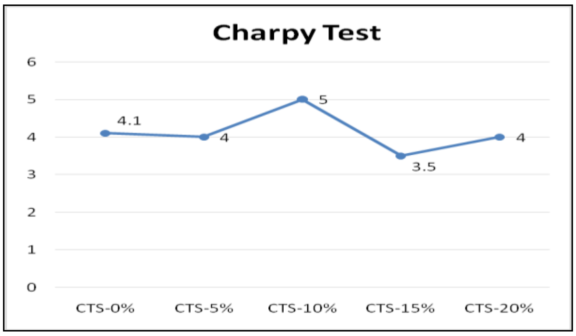
Fig. 13 Bending test

IV. RESULTS

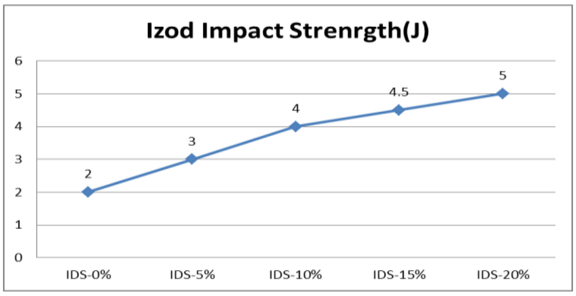
The Brinell hardness number is varied with the change in weight percentage of silica powder with matrix material. The mixed behaviour is shown from the graph 4.1 and maximum hardness is attained at 5% weight of composite material and later state gradually decreases. The impact strength is shown with the change of different weight percentages. In Izod test the Chapy impact strength is almost linearly increased not as in the case of Charpy test as shown in graphs 4.2 and 4.3. Modulus of elasticity and bending strength decrease when at 5% and again gradually increases as shown in graph 4.3 and 4.4.



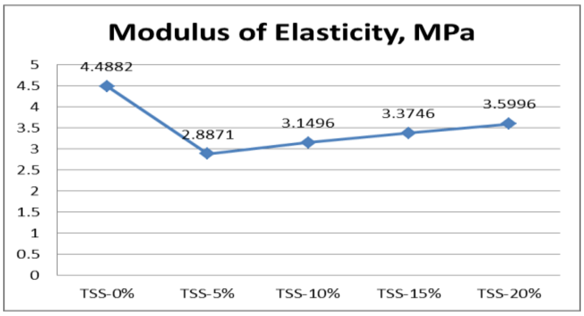
Graph. 4.1 BHN variations at different wt% of silica powder



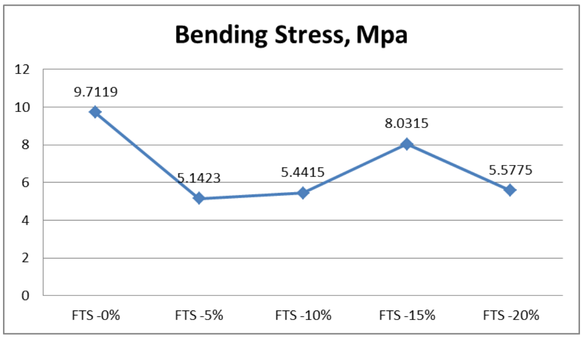
Graph. 4.2 Impact Strength variations at different wt% of silica powder in Charpy test



Graph. 4.3 Impact Strength variations at different wt% of silica powder under Izod test



Graph. 4.4 Modulus of Elasticity variations at different wt% of silica under Tensile test



Graph. 4.5 Bending stress variations at different wt% of silica under bending test

V. CONCLUSIONS & FUTURE SCOPE OF WORK

The following conclusions are drawn from the present experimental work:

- Chopped Strand Mat 450 polyester composite with silica powder was successfully prepared as a composite material with five different wt.%, viz 0%wt, 5%wt, 10%wt, 15%wt and 20%wt.
- The tensile strength and flexural strength with 0wt% silica powder composite is maximum compared with 5wt%, 10wt%, 15wt%, and 20wt%. The hardness at 5wt% silica composite is maximum compared with 0wt%, 10wt%, 15wt%, and 20wt% silica composite.
- The increase of silica powder lead to the increase of the Izod impact strength of the composite.

Image analysis can also be performed to observe the changes in the micro structure of composite, which will be the future scope of the work.

REFERENCES

[1] Naidu, G. Ramachandra Reddy, M. Ashok Kumar, M. Mohan Reddy, P. Noorunnisha Khanam, and S. Venkata Naidu, "Compressive & impact properties of sisal/glass fiber reinforced hybrid composites," *International Journal of Fiber and Textile Research, Universal Research Publications*, vol. 12, pp. 265-269, Nov. 2007.

[2] R. Sakthivela and D. Rajendranb, "Experimental Investigation and Analysis a Mechanical Properties of Hybrid Polymer Composite Plates," *International Journal of Research in Engineering and Science*, vol. 2, iss. 3, pp. 46-57, Mar. 2014.

[3] Dr. P.K. Palani and M. Nanda Kumar, "Analysis of Mechanical Properties of Chopped Strand Mat E-Glass Fiber Epoxy Resin Nanoclay Composites," *The International Journal of Engineering and Science*, vol. 2, iss. 2, pp. 185-189, June 2013.

[4] Ravikumar and M.S. Sham Prasad, "Fracture Toughness and Mechanical Properties of Aluminium Oxide Filled Chopped Strand Mat E-Glass Fiber Reinforced–Epoxy Composites," *International Journal of Scientific and Research Publications*, vol. 4, iss. 7, July 2014.

[5] Martin James, Manoj George K., Cijo Mathew, Dr. K. E. George, and Reji Mathew, "Modification of Fibre-Reinforced Plastic by Nanofillers," *ISO 9001:2008 Certified International Journal of Engineering and Innovative Technology*, vol. 3, iss. 4, pp. 125-129, Oct. 2013.

[6] VB Gupta, "Review article on fiber reinforced composites: Their fabrication, properties and applications," *Indian journal of fibbers& Textiles*, vol. 26, pp. 327-340, Sept. 2001.

[7] Mohamed Bakar and Katarzyna Skrzypek, "Effect of Kaolin and Polyurethane on the fracture and thermal properties of epoxy based composition," *Material Science*, vol. 12, pp. 39-42, Nov. 2007.

[8] J C Husband, L F Gate, N Norouzi, and D Blair, "Using thin crystal engineered Kaolin's to enhance the mechanical properties of coatings," *TAPPI International Conference on Nanotechnology for the Forest Products Industry*, vol. 2, pp. 125-129, Nov. 2010.

[9] Iman Taraghi, Abdolhossein Fereidoon, and Fathollah Taheri-Behrooz, "Low-velocity impact response of woven Kevlar/Epoxy laminated composites reinforced with multi-walled carbon nanotubes at ambient and low temperatures," *Materials and Design*, vol. 2, pp. 152-158, Apr. 2014.

[10] R P Singh, M Zhang, and D Chan, "Toughening of a brittle thermosetting polymer: Effects of reinforcement particle size and volume fraction," *Journal of Material Science*, vol. 19, pp. 781-788, Nov. 2002.

[11] Marco A. Perez, Xavier Martinez, Sergio Oller, Lluis Gil, Fernando Rastellini, and Fernando Flores, "Impact damage prediction in carbon fiber-reinforced laminated composite using the matrix-reinforced mixing theory," *Composite Structures*, vol. 15, pp. 239-248, Nov. 2013.

[12] Ahmet Yapici and Mehmet Metin, "Effect of low velocity impact damage on buckling properties," *Engineering*, vol. 20, pp. 161-166, Oct. 2009.

[13] ASTM standard (D 638-03), "standard test method for tensile properties of polymer matrix composite materials."

[14] ASTM standard (D790), "standard test method for flexural properties of polymer matrix composite materials."

[15] ASTM standard (D256), "standard test method for impact properties of polymer matrix composite materials."

Mr. NARENDRA KUMAR ATTILI is born in Visakhapatnam, Andhra Pradesh, India. He received B.Tech Degree in Mechanical Engineering from JNT University, Hyderabad, Andhra Pradesh, India. He is currently Pursuing M.Tech (Machine Design) Post Graduation from Vignan's Institute of Information Technology, Visakhapatnam, Andhra Pradesh, India. He has two years of Industrial Experience in construction and maintenance of Mechanical equipment.

Mr. Ch. Siva RamaKrishna is currently an Associate Professor in Department of Mechanical Engineering, Vignan's Institute of Information Technology, Visakhapatnam, Andhra Pradesh, India. In 1991, he received his B.Tech Degree in Mechanical Engineering from JNT University, Hyderabad, Andhra Pradesh, India. He completed his M.Tech Degree from the same University. He has a total of 23 years of professional experience with 19 years of teaching experience in engineering colleges. He published many research papers in international journals. His research interests include Intelligent Expert Systems, optimization, Powder Metallurgy, Composite Materials, Machining and Welding Technology.