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INVESTIGATION OF MECHANICAL PROPERTIES FOR BASALT FIBER COMPOITE WITH SILICA NANO PARTICLES

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Abstract: In this study, the effect of silica nanoparticles as the reinforcing filler on the mechanical properties of basalt fibre reinforced polymer (BFRP) composite was investigated. Fiber Nano composites are a popular structural material due to its numerous benefits. There has been a recent spike in interest in common composites, which are made up of specific fiber reinforcement. As the Nano particles are showing similar properties with metals and other Non-metallic materials, working on this can help us to check the properties of the composites. The objective of the work is to develop a composite using a basalt fiber and Nano particle. A series of nanocomposites with 0.2 wt.%, 0.4 wt.%,0.6 wt.%, and 0.8 wt.% nano silica used . By varying the layers, composites are developed and their mechanical properties like Tensile, flexural, and Impact are evaluated. The higher content of silica nanoparticles in the matrix increased the stiffness of the material as well as the strength of the basalt fibre reinforced polymer composite without reducing the failure strain.

Keywords: BFRP, Nano silica, Tensile, Flexural, Impact

I. INTRODUCTION

The use of Fibre Reinforced Polymer (FRP) composites has been expanded from time to time for numerous strengthening applications in various industries. The fibre reinforcement in polymer composites include materials either from synthetic fibres (carbon, glass, aramid), renewable sources or natural fibres (jute, basalt, kenaf) and by-products from food crops and recycle wastes (paper, wood), which could provide stiffness and strength of the final materials to be used in a structure for different applications. Fibres are generally categorised into two main types; natural and synthetic fibres where are then further subcategorised based on their origin. Currently, the demand for the use of natural fibres has been explored as an alternative replacement for synthetic fibres to give benefits to the environment and to enhance sustainability. Although natural fibres have a relatively lower strength compared to synthetic fibres, certain modifications by chemical treatments, as well as the development of the system, if proven could prevail in their limitations.

Issues and solutions in the use of Natural fiber

The interfacial bonding and its strength is a challenging issue in the use of natural fibers, particularly applications that demand high performance. That can be overcome by including suitable pre-treatment and appropriate nanofillers (which improves the interfacial bonding significantly). Some cases are: Different **%** of NaOH treatments have been applied to sisal fibers in order to enhance their adhesion in composites materials [1-10] preferred maleated polyethylene, and maleated polypropylene used for treating the sisal fibers. The use of natural fibers increases biodegradability. The use of natural fibers and synthetic fibers with nanofillers offers the best, strong, and durable material. The nanofillers and natural fibers help to alter the properties suitably for the appropriate use[19].

NANO SILICA

Silica nanoparticles are biocompatible, thermally stable, low-cost, toxicity-free, and their surfaces are easily modifiable. Silica nanoparticles are normally spherical in shape with a very consistent size and shape, but they can also be made in a range of forms and sizes or used as surface coatings on other nanomaterials. Silica nanoparticles can be carefully manipulated in terms of size, porosity, crystallinity, and form, allowing silica-based nanomaterial's to be optimized for a wide range of applications. Silica surfaces can be easily changed with a variety of silanes to adjust surface chemistry, drug loading, solvent compatibility, stability, and biological site targeting. Silica can be used to nanometer-level accuracy encapsulate practically any sort of nanoparticle. The surface of silica is tough, and silica-coated nanoparticles can be concentrated to extremely high levels.

Silica nanoparticles are made through condensation of silanes, which results in nanoparticles with an amorphous silicon-oxygen network. The Strober method, which was invented over 50 years ago, is still the most widely used method for synthesizing colloidal silica nanoparticles. An alkyl silicate reacts with water in an alcoholic solution in this reaction. Small silicate molecules aggregate to form bigger clusters of molecules in the presence of ammonia as a catalyst. This process can be used to make silica particles with a diameter of up to 2 m and enclose a wide range of metal and metal-oxide nanoparticles.

Melt compounding and other physical mixing techniques have been utilized to make polymer/silica nanocomposites using SiO2 nanoparticles. However, silica possesses a large number of hydroxyl groups on its surface, resulting in significant filler-filler or particle–particle interactions as well as hydrogen bonding adsorption of polar compounds. As a result, SiO2 possesses a significant self-aggregation property. The fumed SiO2 nanoparticles tend to form loosely agglomerates with an average size in the range of 300–400 nm in such conditions, and the shear forces during melt compounding cannot break down these aggregated particles.

MECHANICAL PROPERTIES OF NANO SILICA

Silicon dioxide is a crystalline material that is solid and colorless. Silicon dioxide is acid resistant and does not react with water. The substance's chemical formula is SiO2. Silicon oxide, an acidic glass-forming oxide that interacts with alkalis and basic oxides soluble in hydrofluoric acid as temperature rises, tends to produce a supersonic fusion, making glass an excellent dielectric.

APPLICATIONS OF NANO SILICA

Silica nanoparticles have a wide range of characteristics and, as a result, a large range of uses. They're abrasive and powerful compounds for polishing silicon wafers. They are used to coat waxed floors and even train tracks since they are good at minimizing friction. Because of their absorptive qualities, they can be used as a drainage aid in papermaking. They can act as a binding agent in the manufacture of rubber, plastics, and concrete. They are particularly stable and non-toxic materials with several biomedical applications.

II. METHODOLOGY

The sequence of operations was followed to achieve the desired result as shown in the figure.

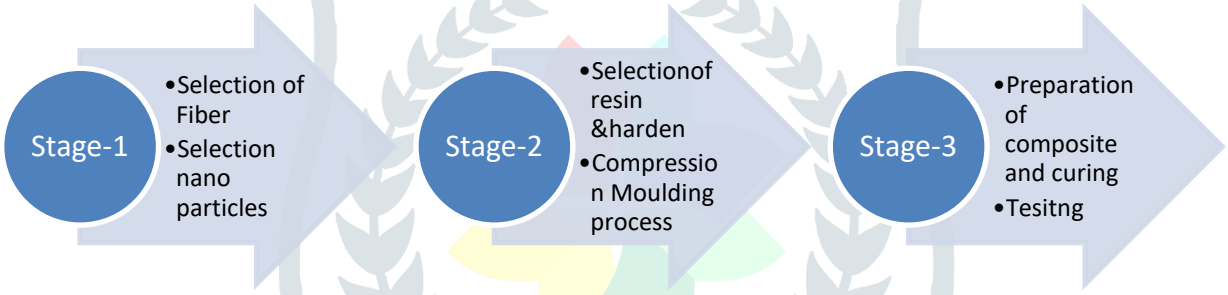

Fig 1. work flow chart

For preparing of composite, the fiber is selected along with the Nano particles required for the composite. The composite is made using the resin (EPOXY RESIN LY556) and hardener (HY951) with 10:1 ratio respectively. The composite is prepared using the compression molding process. The composite is prepared using the fiber and Nano particles in geometric shape. The test samples are taken from the composite with suitable lengths according to ASMI standards used for testing of the material. Then, the test samples are undergone through testing process.

Fig.2. Epoxy resin LY556 and Hardener – HY951

Fig.3. Hand Gloves, Scissors, Roller and transparent sheet

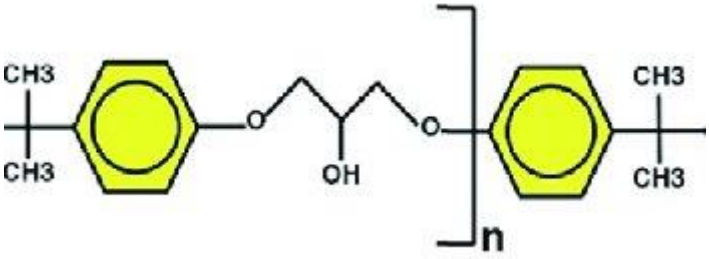

Fig. 4. Epoxy resin LY556 chemical structure

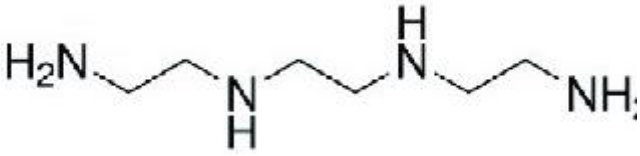

Fig. 5. Hardener – HY951 chemical structure

Fig. 6. Basalt fiber

Fig. 7. Nano silica powder

III. FABRICATION PROCESS:

To fabricate the composite made up of basalt fiber and Nano silica. Collect the samples of basalt fiber and Nano silica according to the weight percentage required for the composite. Initially, apply the grease on the Lower part of the mold and place the transparent sheet on it. Apply gentle pressure on the transparent sheet to remove air bubbles. Epoxy resin is mixed with Hardener in the ratio of 10:1 in a glass jar. Pour the matrix material on the plastic sheet and spread evenly.

Place the basalt fiber on the resin and pour some more, so that fiber gets soaked in rein and add the Nano silica fillets accordingly. Follow the same for upper mold also, Leave the mold for 24 hours for curing.

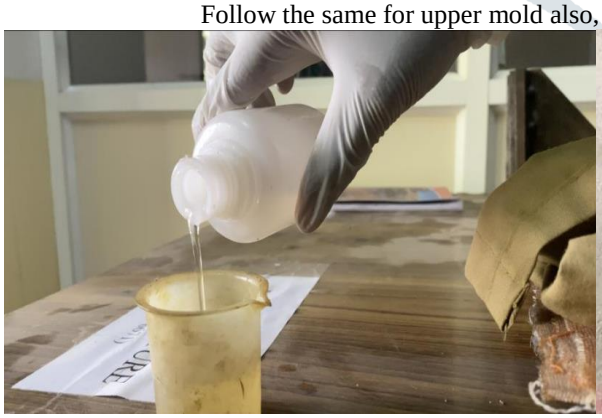

Fig.8. Fabrication process Step 1

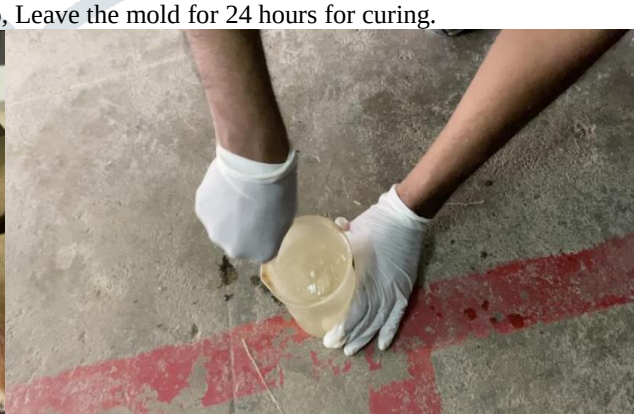

Fig.9. Fabrication process Step 2

Fig.10. Fabrication process Step 3

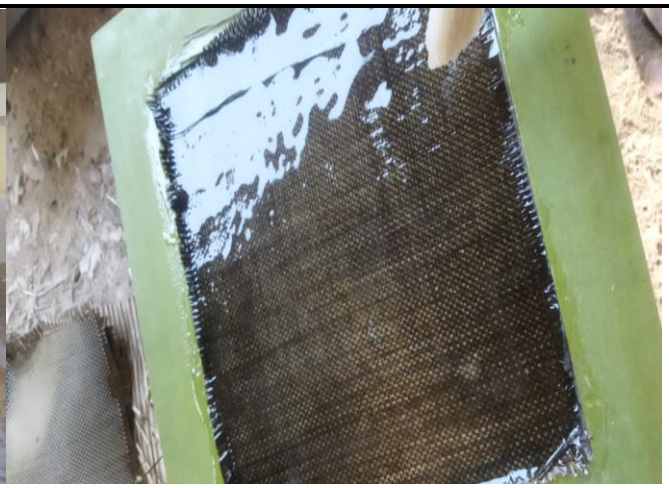

Fig.11.fabrication process step 4

Fig.12. fabrication process step 5

IV. EXPERIMENTATION

Tensile Test The tensile test was performed on the FRP nanocomposites specimen following ASTM D3039. The rectangular specimens with a dimension of 250 mm length × 15 mm width × 3 mm thickness were tested using the INSTRON 3382 Universal Testing Machine 100 kN load cell (Instron, Norwood, MA, USA). A clip-on extensometer of 25 mm gauge length was attached to the tested specimen to record the elongation data at the crosshead speed of 2 mm/min. These data were logged into computer software for analysis. Five specimens were tested for each FRP composites system.

Compression Test A static uniaxial compression test was conducted on the FRP nanocomposite specimens according to ASTM D3410. A rectangular specimen with a dimension of 110 mm length × 10 mm width × 3 mm thickness was prepared for this test. The compression test was conducted using an Universal Testing Machine INSTRON 3382 100 kN load cell (Instron, Norwood, MA, USA) with a special rig designed and fabricated according to the standard to suit the requirements of the testing machine. Five specimens for each FRP system were tested at a suggested crosshead speed of 1 mm/min.

Flexural Test The flexural test for basalt and glass FRP nanocomposites were conducted using ASTM D790 with specimen dimensions of 80 mm length × 15 mm width × 3 mm thickness and support spans of 48 mm. An INSTRON Universal Testing Machine 100 kN load cell (Instron, Norwood, MA, USA) with the three-point bending fixtures was used to apply force at midspan at the crosshead speed of mm/min. Five specimens were tested for each FRP composites system

Drop Weight Impact Test The drop weight impact test was conducted according to ASTM D7136 using an INSTRON Dynatup 8250 Drop Weight Impact Tester, Instron, Norwood, MA, USA. Specimens with dimensions of 50 mm length × 50 mm width × 5 mm thickness were used in this test. A drop tower with a 16 mm hemispherical tip impactor was used with a weight of 5.5 kg, a150 Nanomaterials 2021, 11, 1468 7 of 17 drop height of 0.8 m, and a gravity acceleration of 9.81 m/s2 , resulting in kinetic energy of 43.164 J. Five specimens were tested for each composite system.

Fig.13.Universal tensile testing machine

Fig. 14. Flexural testing machine

Fig.15. Impact testing machine

V. RESULTS AND DISCUSSION

TENSILE TEST

The results obtained when tensile test is done on composites are shown in the table 6.1:-

Table 1. Tensile test results

Composite	Experiment No.	UTS (N/mm2)	YS (N/mm2)	% Elongation
0.2% silica	1.1T	329.12	313.77	17.28
	1.2T	160.11	139.16	10.17
	1.3T	271.10	237.20	14.79
0.4% silica	2.1T	320.64	290.70	17.01
	2.2T	201.51	150.45	12.76
	2.3T	250.89	210.86	14.37
0.6% silica	3.1T	270.73	250.35	16.53
	3.2T	240.69	210.82	14.87
	3.3T	200.90	170.11	17.10
0.8% silica	4.1T	295.13	248.84	15.76
	4.2T	312.57	260.13	15.90
	4.3T	213.93	183.57	17.62

From the above table 1, we can get to know the values of Ultimate tensile strength (UTS), Yield strength (YS) and %Elongation for the composites. Firstly, when we compare the values of the Ultimate tensile strength (UTS) of the composites then we can observe that 1.1T is having the highest ultimate tensile strength when compared to remaining experiments as shown in the figure 16.

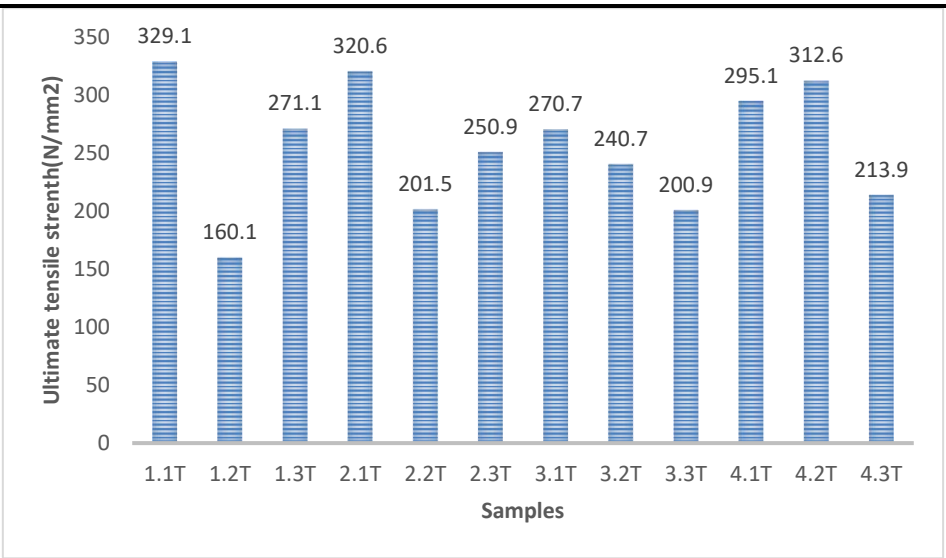

Fig.16. comparison of ultimate tensile strength values

Secondly, when we compare the values of the Yield Strength (YS) of the composites then we can observe that 1.1T is having the highest Yield Strength when compared to remaining experiments as shown in the figure 17.

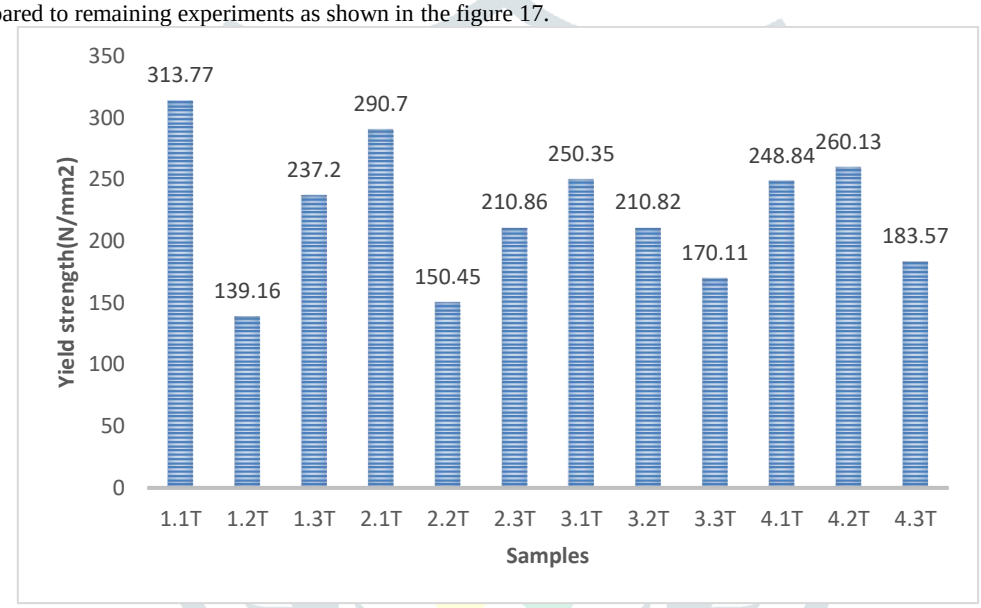

Fig.17. comparison of yield strength values

Thirdly, when we compare the values of the %Elongation of the composites then we can observe that 2.3T is having the highest %elongation when compared to remaining experiments as shown in the figure 18.

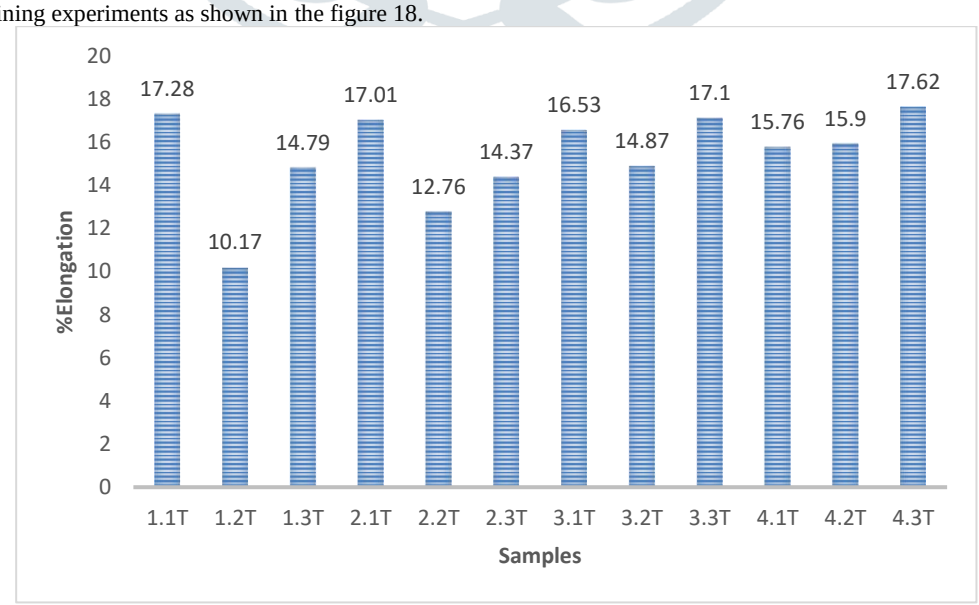

Fig.18. comparison of %elongation values

The graph 18 represents the stress strain curve of the composite 1.1T and indicates the UTS, YS and modulus values for sample composite having grip length of 90mm, gauge length of 90mm, sample width of the composite is 23.54mm and having the sample thickness of 3.55mm.

FLEXURAL TEST

The results obtained when flexural test is done on composites are shown in the table 2:-

Table 2 Flexural Test results

Composite	Experiment No.	Max Flexural Strength (Mpa)	Yield Flexural Strength (N/mm²)	Flexural Modulus at 1% Strain (Mpa)
0.2% silica	1.1F	369.2002451	103.81	54357.37
	1.2F	219.6740041	65.31	32433.98
	1.3F	338.5891364	63.52	49432.75
0.4% silica	2.1F	350.7483292	92.64	52638.92
	2.2F	245.7215489	64.86	30897.04
	2.3F	325.2678543	72.63	47897.72
0.6% silica	3.1F	331.8905432	77.53	49934.01
	3.2F	287.9605423	62.89	43765.11
	3.3F	313.9870654	89.82	45786.09
0.8% silica	4.1F	323.3762533	69.25	47256.67
	4.2F	319.6325287	63.06	46981.94
	4.3F	303.6723723	96.48	44248.98

From the above table 6.2, we can get to know the values of Maximum Flexural Strength, Yield Flexural strength and Flexural modulus at 1% strain for the composites.

When we compare the values of the Maximum Flexural Strength of the composites then we can observe that 1.1F is having the highest Maximum Flexural Strength when compared to remaining experiments as shown in the figure 18.

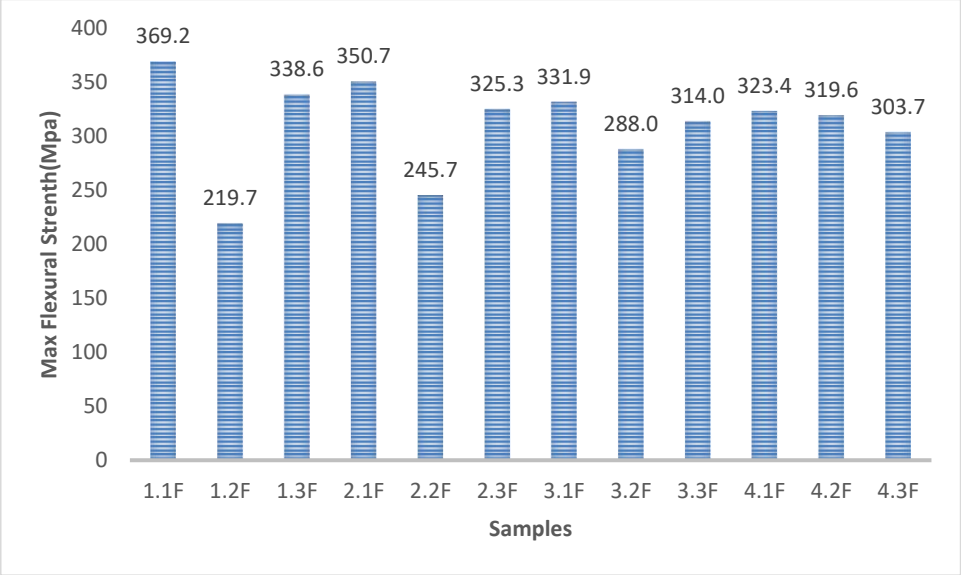

Fig.19. Comparison of maximum flexural strength

When we compare the values of the Yield Flexural Strength of the composites then we can observe that 1.1F is having the highest Yield Flexural Strength when compared to remaining experiments as shown in the figure 19.

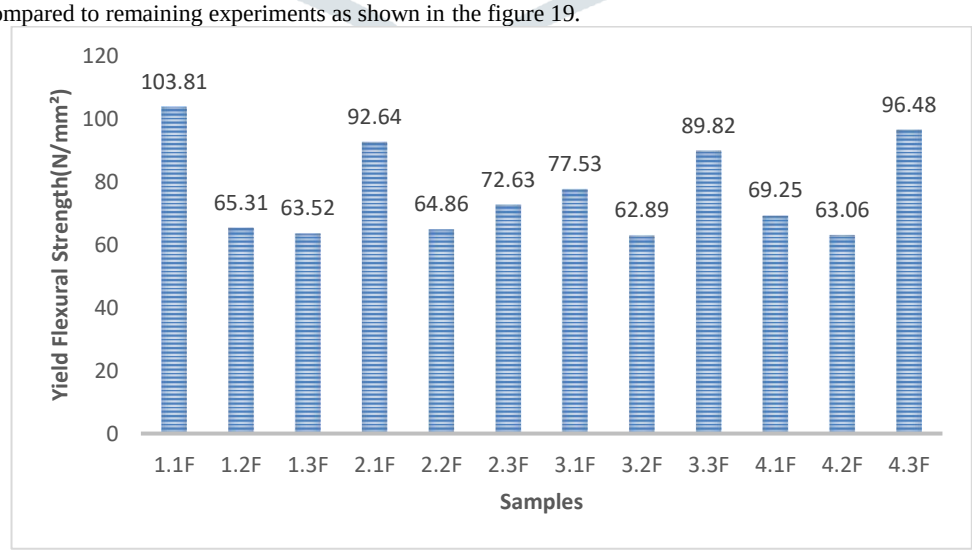

Fig.20. comparison of yield flexural strength

When we compare the values of the Flexural modulus at 1% strain of the composites then we can observe that 1.1F is having the highest Flexural modulus at 1% strain when compared to remaining experiments as shown in the figure 20.

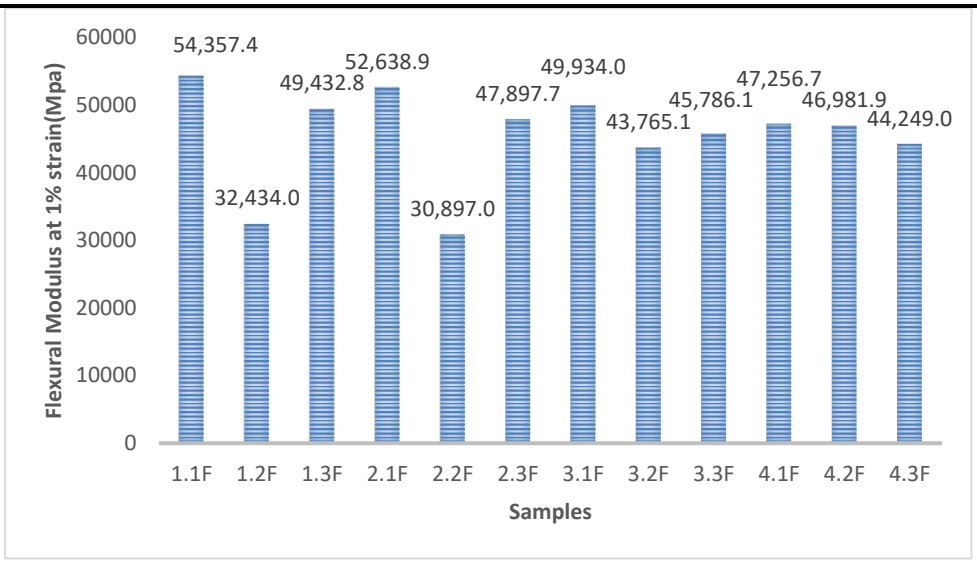

Fig.21. comparison of flexural modulus at 1% strain

The graph 21. represents the load and deflection curve of the composite 1.1F and indicates the Maximum Flexural Strength, Yield Flexural strength and Flexural modulus values for sample composite having span length of 56mm, Test speed of 5mm/min, sample width of the composite is 11.26mm and having the sample thickness of 3.55mm.

IMPACT TEST

The results obtained when Impact test is done on composites are shown in the table 3:-

Table 3 Impact Test results

Composite	Experiment No.	Thickness	Width	Impact energy (J)
0.2% silica	1.1I	3.57	11.82	5.459
	1.2I	3.59	12.52	5.522
	1.3I	3.62	13.42	6.486
0.4% silica	2.1I	3.52	12.34	7.857
	2.2I	3.57	13.11	7.234
	2.3I	3.58	13.39	8.253
0.6% silica	3.1I	3.49	12.76	9.753
	3.2I	3.55	13.67	11.071
	3.3I	3.49	13.35	9.278
0.8% silica	4.1I	3.48	12.83	11.231
	4.2I	3.54	13.99	13.921
	4.3I	3.48	13.34	10.120

From the above table 3, we can get to know the values of Thickness, Width and Impact energy for the composites.
Firstly, when we compare the values of the Impact Energy of the composites then we can observe that 2.2I is having the highest Impact Energy when compared to remaining experiments as shown in the figure 22

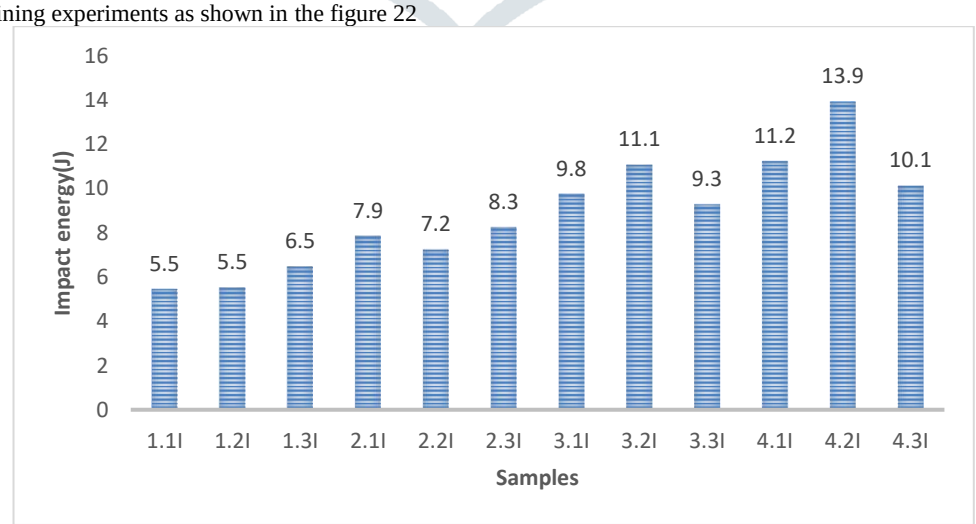

Fig.22. comparison of impact energy values

VI. CHALLENGES AND FUTURE OPPORTUNITIES

In the case of nanocomposites, the homogeneous distribution of nanofiller in matric composites plays an important role. It also includes mixing methods, mixing agents, time, temperature etc. The major challenge is the prepration of nanoparticle composites uniformly in the entire area of the polymer. Secondly, the measuring method is vital in studying nanofiller reinforced nanocomposites' mechanical and thermomechanical properties [12-18].

VII. CONCLUSION AND FUTURE SCOPE

In the realm of advanced composite materials, Nano particles are extremely important and have a great deal of room for progress and discovery. Superior characterization of the final composite can be achieved with significantly more cost-effective applications if fiber orientation is made systematic rather than random, and size is controlled, as well as the fiber-matrix mixing process during casting. Variation in composition of Nano particle in the composite affects the mechanical properties. In the later stages. The composites are developed with multiple Nano particle reinforced epoxy and perform a comparative analysis of the mechanical properties. It is concluded that as the %of Silica Nano Particles weight% increases from 0.2% to 0.8 % then% of Elongation and Impact strengths are high at 0.8% of Silica Nano particles and Ultimate strength, Yield strength and Flexural strengths are high at 0.2% of Silica Nano particles.

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