JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

INVESTIGATION OF MECHANICAL PROPERTIES FOR BASALT FIBER COMPOSITE WITH GRAPHENE NANO PARTICLES

[1] T. Malyadri, [2] Dr. J. Suresh Kumar
[1] Research Scholar,Department Mechanical Engineering, Jawaharlal Nehru Technological University (JNTU), Hyderabad-500085, Telangana. India
[2] Professor,Department Mechanical Engineering, Jawaharlal Nehru Technological University (JNTU), Hyderabad - 500085, Telangana. India

Abstract : In this study, the effect of Graphene 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 Graphene used . By varying the layers, composites are developed and their mechanical properties like Tensile, flexural, and Impact are evaluated. The higher content of Graphene 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 Graphene, 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[17].

NANO GRAPHENE

Graphene is a single-atom-thick sheet of carbon molecules or atoms are arranged in a hexagonal lattice structure.. It is the building block of graphite, but with a number of exceptional qualities that have given it the title "wonder material" multiple times, graphene is an incredibly fascinating substance. The thinnest substance known to man is graphene. Additionally, it is incredibly strong—about 200 times stronger than steel. Additionally, graphene has exceptional light absorption qualities and is a good conductor of heat and electricity. With countless applications in virtually every industry, it is undoubtedly a material with the potential to revolutionize the world. Materials made of graphite have been in use for a very long period. Expanded graphite has been utilized as polymer filler for almost a century. More recently, graphite Nano platelets (GNPs), which are tiny forms of graphite, have also been used. Because of its good mechanical, electrical, and thermal properties, graphene has attracted the scientific community's attention in the recent decade.

Graphene is a two–dimensional material with a unique atom–thick structure that possesses remarkable electrical, optical, chemical, thermal, and mechanical properties. It's a versatile material with applications in electronics, energy systems, sensors, actuators, and composites, among others. Graphene is regularly chemically changed to meet the requirements of practical applications. To begin with, graphene in its purest form is insoluble and intractable, and it decomposes before melting. As a result, traditional material processing processes are unable to mould it into the appropriate structures. Second, only solid supports can physically stabilize graphene layers. Through – and hydrophobic interactions, free–standing graphene layers tend to form creases or stack together. Third, graphene is a substance with no bandgap. The opening of graphene's bandgap is required for its use in electronics and optoelectronics. Fourth, virgin graphene has poor catalytic activity and weak interactions with other small molecules or polymers, which limits its use in catalysis, sensors, and composites. To overcome these challenges, many chemical approaches for modifying the surfaces and electrical structures of graphene sheets have been devised.

However, graphene oxide (GO), which is made by oxidizing and exfoliating graphite, has been used in a significant number of research's. Due to its surface properties, GO is an appealing and promising filler since it can easily disperse in polar solvents and certain polymeric hosts. Because the functional groups on its surface behave as defects, as-prepared GO has lower mechanical, electrical, and thermal characteristics when compared to graphene. Nonetheless, thermal or chemical techniques can be utilized to reduce the quantity of impurities/functionalities and achieve graphene-like performance.

MECHANICAL PROPERTIES OF NANO GRAPHENE

Graphene is a very light substance with a planar density of 0.77 mg/m2. It also has the strongest and hardest crystal structure of any material ever discovered. It has a tensile strength of 125 GPa and an elastic modulus of 1.1 TPa, compared to the most common steel's elastic modulus of 200 GPa. Graphene has 100 times the mechanical strength of steel, with a breaking strength of 42 N/m

APPLICATIONS OF NANO GRAPHENE

Graphene-based nanomaterials have a wide range of potential applications in the energy sector. Here are a few recent examples: Activated graphene provides exceptional supercapacitors for energy storage; graphene electrodes may lead to a potential strategy for creating inexpensive, lightweight, and flexible solar cells; and multifunctional graphene mats are attractive substrates for catalytic systems.Graphene and other direct bandgap monolayer materials such as transition-metal dichalcogenides (TMDCs) and black phosphorus have a lot of potential to be used in low-cost, flexible, and highly efficient photovoltaic devices because of their excellent electron transport properties and extremely high carrier mobility. For improved solar cells, these are the most promising materials.

II. METHODOLOGY

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

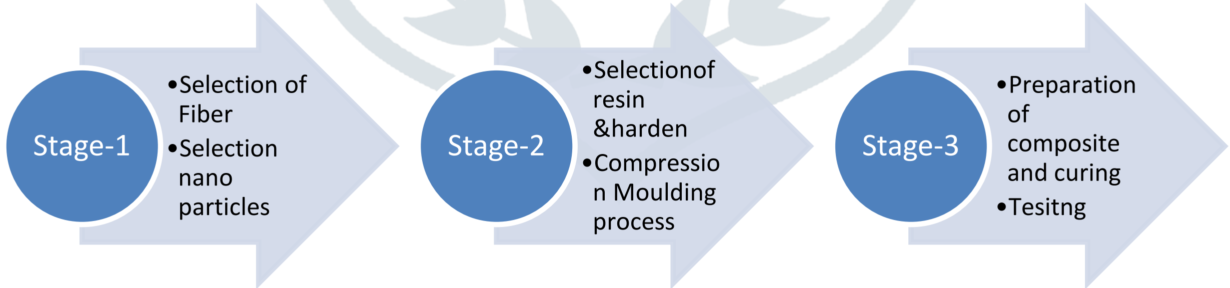

Fig 1. work flow chart

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

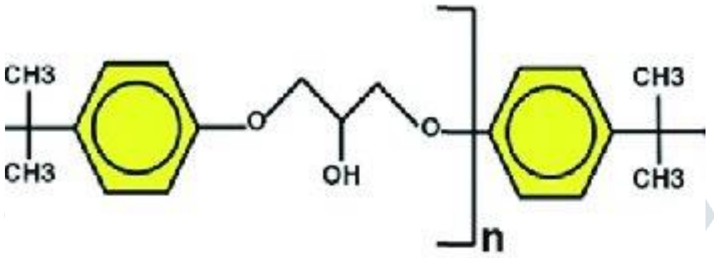

Fig.4. Epoxy resin LY556 chemical structure

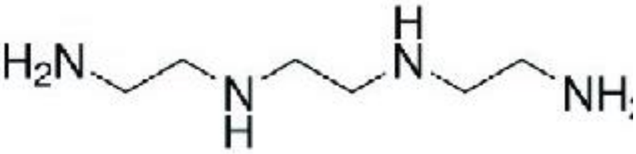

Fig. 5. Hardener – HY951 chemical structure

Fig.6.basalt fiber

Fig.7. Nano Graphene powder

III. FABRICATION PROCESS:

To fabricate the composite made up of basalt fiber and Nano Graphene. Collect the samples of basalt fiber and Nano Graphene 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 Graphene 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

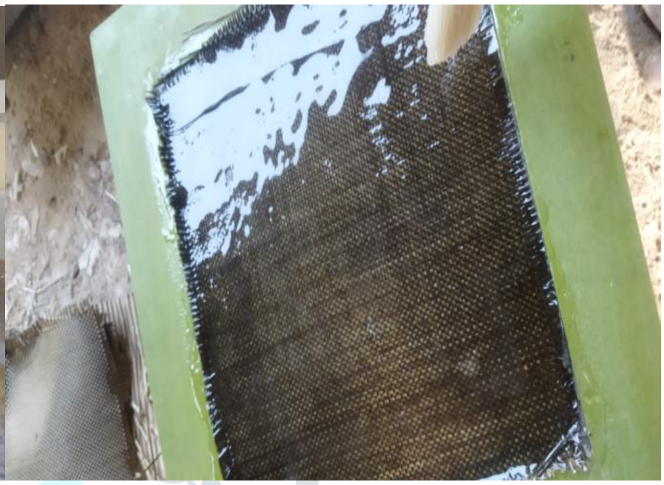

Fig.11.fabrication process step 4

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, a170 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 below table 6.1:-

Table 1. Tensile test results

Composite	Experiment No.	UTS (N/mm2)	YS (N/mm2)	% Elongation
0.2% Graphene	1.1T	444.3	423.6	23.3
	1.2T	216.1	187.9	13.7
	1.3T	366.0	320.2	20.0
0.4% Graphene	2.1T	432.9	392.4	23.0
	2.2T	272.0	203.1	17.2
	2.3T	338.7	284.7	19.4
0.6% Graphene	3.1T	365.5	338.0	22.3
	3.2T	324.9	284.6	20.1
	3.3T	271.2	229.6	23.1
0.8% Graphene	4.1T	398.4	335.9	21.3
	4.2T	422.0	351.2	21.5
	4.3T	288.8	247.8	23.8

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 below figure 16.

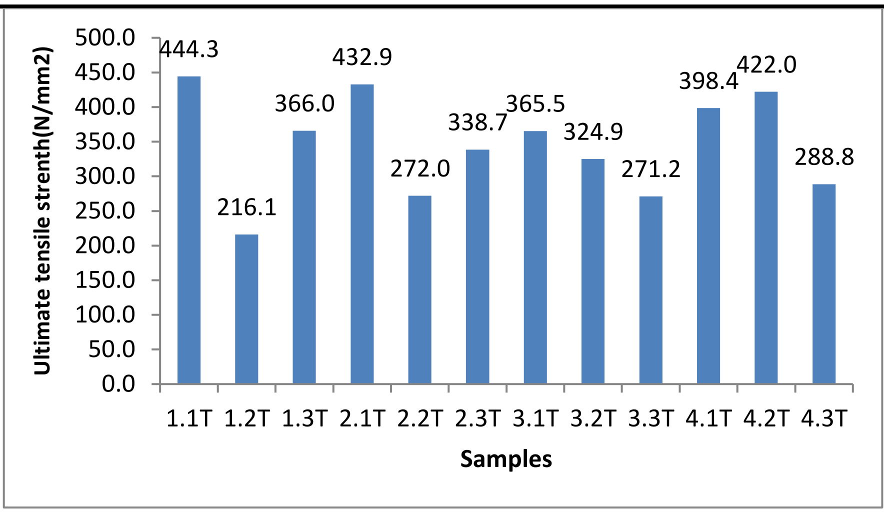

Fig.16. comparison of ultimate tensile strength values

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 below figure 17.

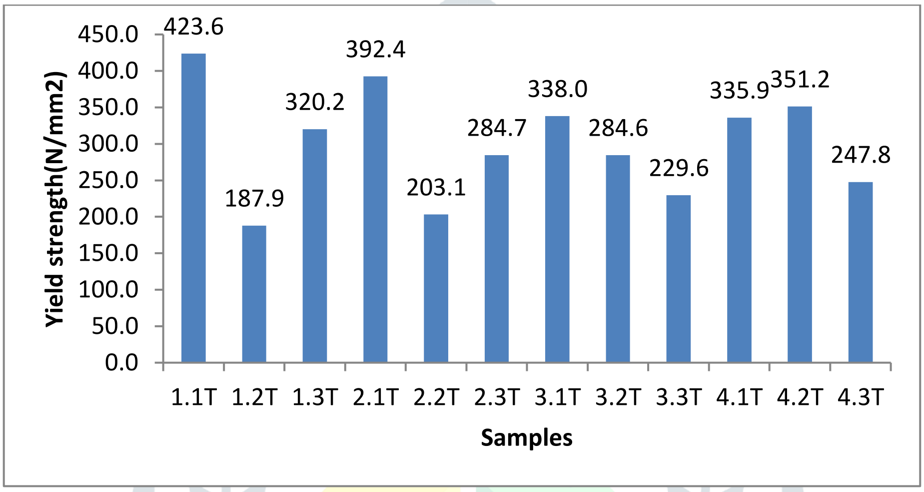

Fig.17. comparison of yield strength values

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 below figure 18.

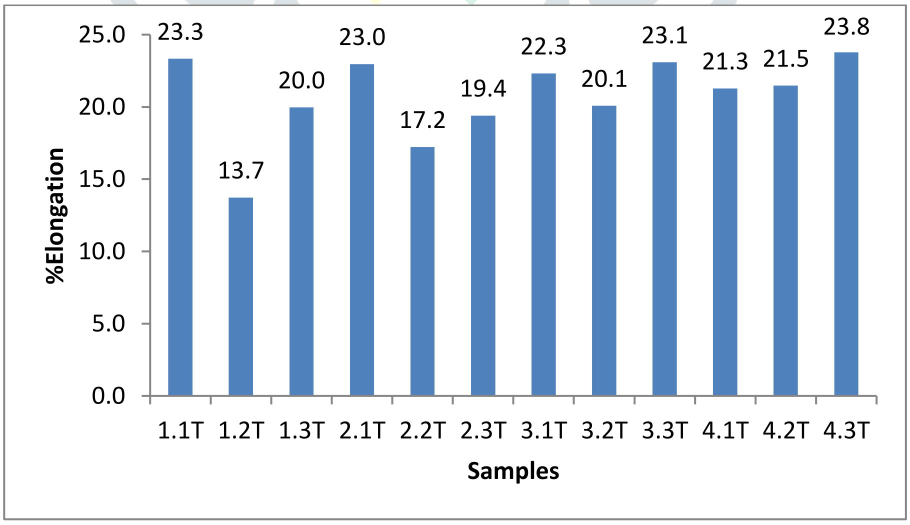

Fig.18. comparison of %elongation values

The graph 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 below 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% Graphene	1.1F	498.4	140.1	73382.4
	1.2F	296.6	88.2	43785.9
	1.3F	457.1	85.8	66734.2
0.4% Graphene	2.1F	473.5	125.1	71062.5
	2.2F	331.7	87.6	41711.0
	2.3F	439.1	98.1	64661.9
0.6% Graphene	3.1F	448.1	104.7	67410.9
	3.2F	388.7	84.9	59082.9
	3.3F	423.9	121.3	61811.2
0.8% Graphene	4.1F	436.6	93.5	63796.5
	4.2F	431.5	85.1	63425.6
	4.3F	410.0	130.2	59736.1

From the above table 2, we can get to know the values of Maximum Flexural Strength, Yield Flexural strength and Flexural modulus at 1% strain for the composites.

Firstly, 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 below figure 19.

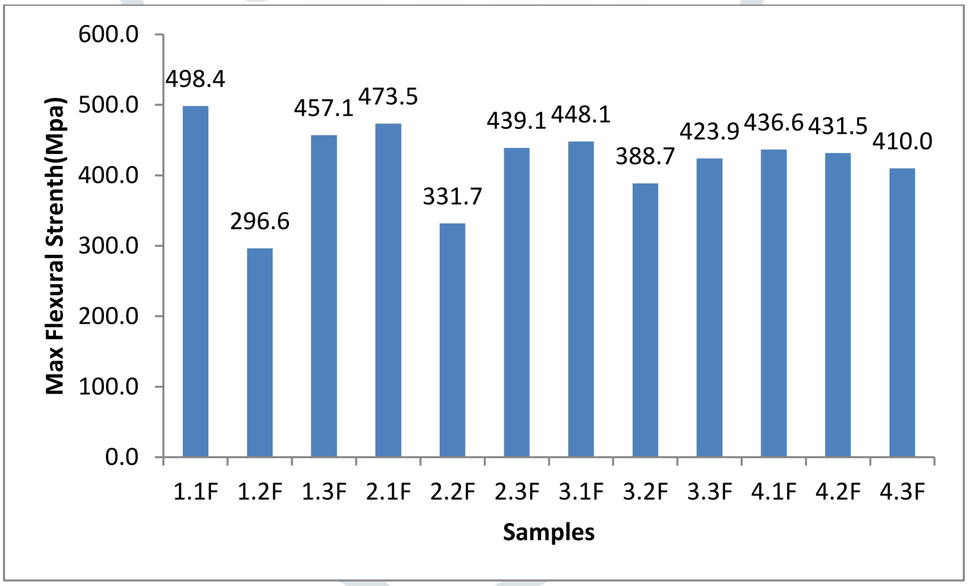

Fig.19. Comparison of maximum flexural strength

Secondly, 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 below figure 20.

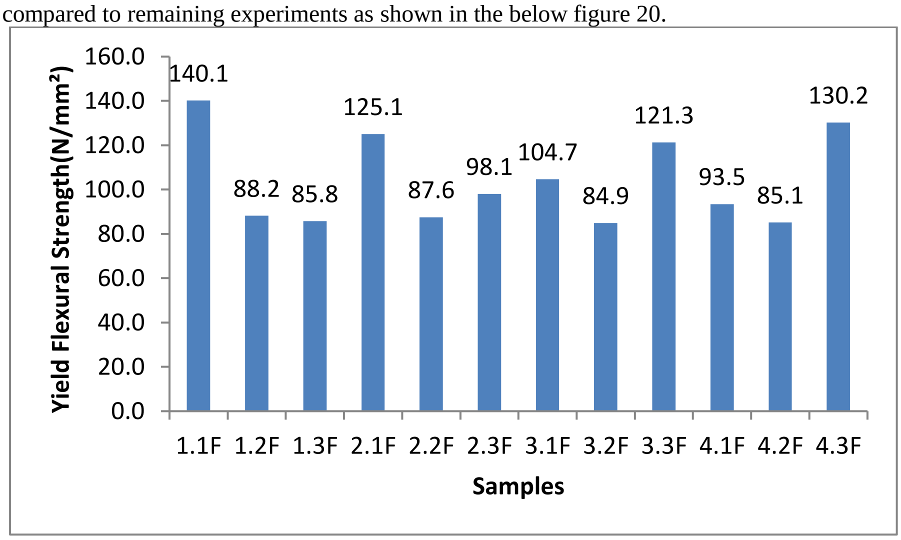

Fig.20. comparison of yield flexural strength

Thirdly, 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 below figure 21.

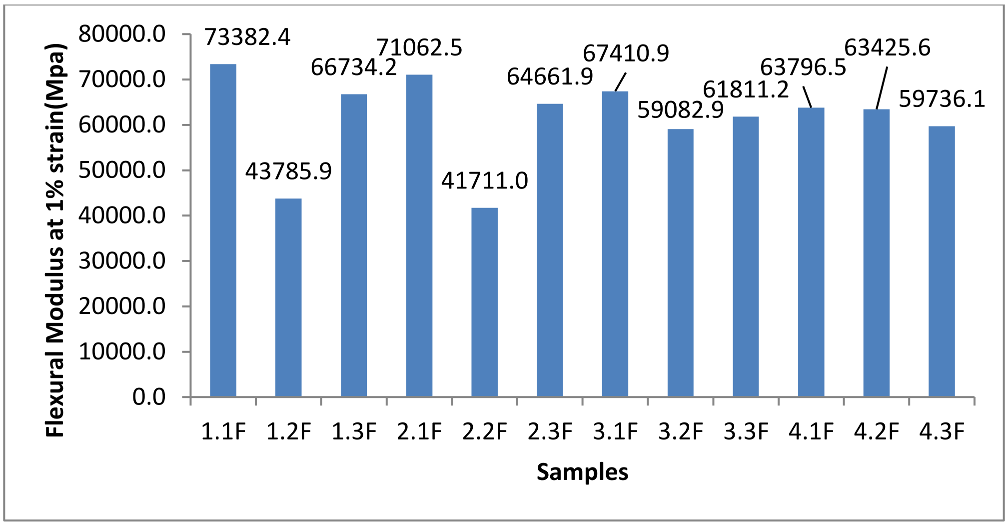

Fig.21. comparison of flexural modulus at 1% strain

The graph 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, and 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 below table 6.3:-

Table 3. Impact Test results

Composite	Experiment No.	Thickness	Width	Impact energy (J)
0.2% Graphene	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% Graphene	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% Graphene	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% Graphene	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 below figure 22.

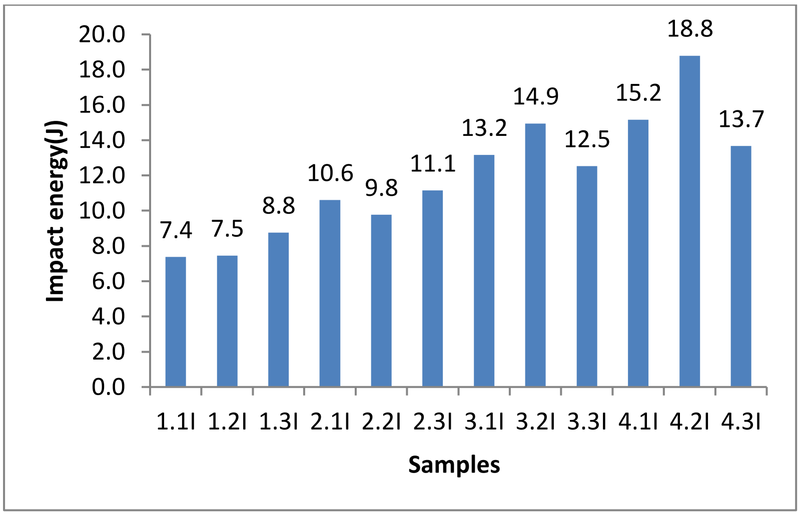

Fig.22. comparison of impact energy values

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 [11-16].

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 Graphene Nano Particles weight% increases from 0.2% to 0.8 % then% of Elongation and Impact strengths are high at 0.8% of Graphene Nano particles and Ultimate strength, Yield strength and Flexural strengths are high at 0.2% of Graphene Nano particles.

References

[1]. Smita Mohanty, Sanjay K. Nayak , Interfacial, dynamic mechanical, and thermal fiber reinforced behavior of MAPE treated sisal fiber reinforced HDPE composites, Applied Polymer ScienceVolume102, Issue4, 15 November 2006, Pages 3306-3315. https://doi.org/10.1002/app.24799.

[2]. Nagamadhu M, Jayaraj P, G C Mohan Kumar, Influence of textile properties on dynamic mechanical behavior of epoxy composite reinforced with woven sisal fabrics, Sadhana Publications, Volume 45, Issue 14, 2019, Pages 1-10. https://doi.org/10.1007/s12046-019-1249-z.

[3]. P. V. Joseph, Kuruvilla Joseph, Joseph Sabu Thomas, Short sisal fiber reinforced polypropylene composites: The role of interface modification on ultimate properties, January 2002Instrumentation Science & Technology 9(2):171-205, https://10.1163/156855402760116094.

[4]. Amaresh Gunge, S. B. Kivade, M. Nagamadhu, Praveennath G. Koppad, K.V. Shivananda Murthy, Study on mechanical properties of alkali treated plain woven banana fabric reinforced biodegradable composites, Composite Communications, Volume 13, 2019, Pages 47-51. https://doi.org/10.1016/j.coco.2019.02.006.

[5]. Amaresh Gunge, S. B. Kivade, Nagamadhu M, Sangamesh Rajole, Mechanical properties of chemical treated Woven Banana/Polyvinyl Alcohol Composites, Emerging Materials Research, Volume 8, Issue 3, 2020, Pages 638-643. https://doi.org/10.1680/jemmr.18.00028.

[6]. Sathish Kumar, S., Suresh, AV., Nagamadhu, M., Vitala, HR., Dileep, BP., Optimization of Drilling Parameters on Alkaline Treated Jute fiber Sandwich Material, International Journal of Recent Technology and Engineering, Blue Eyes Intelligence Engineering & Sciences Publication, Volume 8, Issue 3, 2020, Pages 2454-2459. https://doi:10.35940/ijrte.C4693.098319.

[7]. M. Nagamadhu, P. Jeyaraj, G. C. Mohan Kumar, Characterization and Mechanical Properties of Sisal Fabric Reinforced Polyvinyl Alcohol Green Composites: Effect of Composition and Loading Direction, Materials Research Express, Volume 6, Issue 12, 2020, Pages 125320. https://doi.org/10.1088/2053-1591/ab56b3

[8]. M. Nagamadhu, P. Jeyaraj, G. C. Mohan Kumar, Mechanical and Tribological Behavior of Woven Sisal Fabric, Tribology in Industry, Volume 41, Issue 4, 2019, Pages 622-633. https://doi.org/10.24874/ti.2019.41.04.14

[9]. Nagamadhu M, Vijay Kumar S, Rajath Upadhya, Samuel Sehgal, Basavaraj Hittinahalli, Mechanical and Drilling Process Characterization of herringbone sisal fabric reinforced vinyl ester sandwich composites, Advances in Materials and Processing Technologies, Volume 7, Issue 2, 2020, Pages 1-18. https://doi.org/10.1080/2374068X.2020.1855963

[10]. S. B. Kivade, Amaresh Gunge, Nagamadhu M, Sangamesh Rajole, Mechanical and Dynamic Mechanical Behavior of Acetylation Treated Plain Woven Banana Reinforced Biodegradable Composites, Advanced Composites and Hybrid Materials, Volume 4, Issue 2, 2020, Pages 1-15. https://doi.org/10.1007/s42114-021-00247-8

[11] G. C. Mohan Kumar, P. Jeyaraj, M. Nagamadhu. "Influence of Glutaraldehyde Crosslinker on Dynamic Properties of Polyvinyl Alcohol Polymer" Emerging Materials Research, Volume 9, Issue 1, Page number 168-179. (2020). https://doi.org/10.1680/jemmr.18.00059

[12] M. Nagamadhu, Vijay K. Shankar, Samuel Sehgal, Rajath Upadhya. "Study the Impact of Drilling Process Parameters on Natural Fiber Reinforced Herringbone Epoxy Composites" Annales de Chimie - Science des Matériaux, Volume 44, Issue 5, Page number 339-345. https://doi.org/10.18280/acsm.440506

[13] Nagamadhu M, S. B. Kivade. "Effect of multifrequency, boundary conditions of Polyvinyl Alcohol (PVA) cross-linked with Glutaraldehyde (GA) using Dynamic Mechanical Analyzer" Advances in Materials and Processing Technologies, Volume 7, Issue 1, Page number 1-12, 2021. https://doi.org/10.1080/2374068X.2021.1878698

[14] Nagamadhu M, S. B. Kivade. "Novel studies on Thermo-Mechanical Properties of Structural Glass with and without Lamination" Applied Mechanics and Materials, Volume 903, Page number 65-72, 2021. https://doi.org/10.4028/www.scientific.net/AMM.903.65

[15] M. Nagamadhu, P. Jeyaraj, G. C. Mohan Kumar "A novel approach to determine the thermal transition of gum powder/hydro-gels using dynamic mechanical analysis" Applied Mechanics and Materials, Volume 1943, Page number 020030, 2019. https://doi.org/10.1063/1.5029606

[16] G C Mohan Kumar, P Jeyaraj, M Nagamadhu "Dynamic mechanical analysis of glutaraldehyde cross linked polyvinyl alcohol under tensile mode" Applied Mechanics and Materials, Volume 2057, Page number 020017, 2019. https://doi.org/10.1063/1.5085588

[17]. T. Malyadri , Dr. J. Suresh Kumar "An Ample survey on Characterization and Analysis on Nano-Hybrid Composite Structures" JETIR July 2021, Volume 8, Issue 7, ISSN-2349-5162.