FABRICATION AND CHARACTERIZATION OF FLY ASH FILLED GLASS FIBER REINFORCED POLYMER COMPOSITES

Komal Verma[1], Ravindra Kumar[1#]

[1]Department of Chemical Engineering, Bundelkhand Institute of Engineering &Technology Jhansi, Jhansi-284128, Uttar Pradesh.

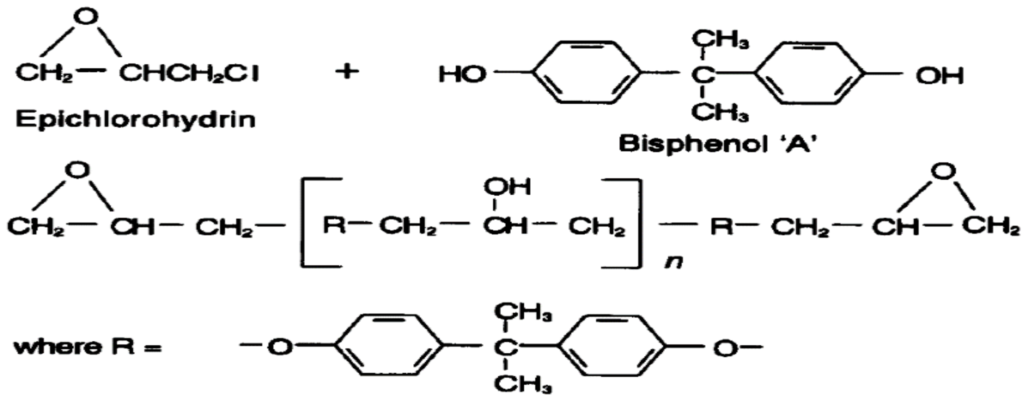
Abstract: Due to their lighter weight, greater strength and durability, the use of polymer composites for multiple applications such as automotive, aerospace, défense, marine and other industries is becoming extremely advantageous. To reduce the price of resin and/or improve its physical characteristics, inert materials added to composites, called filler. Fly ash is also commonly used as filling material now a day. The purpose of the current job was to assess the impact on the characteristics of hybrid polymer matrix composites based on epoxy resin reinforced with glass fiber by adding fly ash as filler. The composites of the hybrid polymer matrix were manufactured using the easy technique of hand lay-up followed by curing in the compression moulding machine. The percentage of fly ash particles in the epoxy matrix ranged from 5, 10 and 15 percent by adding 4 layers of woven glass fiber mat for hybrid composite manufacturing. Dynamic mechanical analysis (DMA) was then subjected to the manufactured composites. DMA is a strong method for characterizing polymers and composites viscoelastic characteristics. The results show that the fly ash-filled epoxy composites storage modulus and loss modulus increase considerably with the addition of up to 10 wt percent of fly ash. The fly ash can therefore be used as one of the low-cost reinforcing fillers for epoxy composites reinforced with glass fiber. The flexural modulus shows increasing trend but flexural stress first decreases then increases alternately. The peak flexural stress is at 20 wt percent fly ash. The tensile stress reduces up to 15 wt percent fly ash. At 20 wt percent fly ash, the value of tensile stress is maximum and then it reduces again. Tensile modulus is maximum at 20wt% of fly ash.

Key words: Epoxy composite, Fly ash, glass fiber.

Introduction-

Today's composite materials being used in several systems possess high strength, light-weight and stiffness is the output of extensive research and development. These composites are combinations of binder material or matrix and reinforcements either in particle form or fiber form. Fibers have higher structural integrity when used in tension, but is of no use in compression and shear. Proper distribution of reinforcements in matrix will give continuous distribution of load otherwise the composite will not be able to serve more than one purpose. Ideally, reinforcements carry most of the stress whilst the matrix serves the purpose of uniformly distributing the stress to all particles or fibers and alleviates their fracture or buckling. In the load transfer process, the most crucial region is the reinforcement-matrix interface and often it's poorly defined. The predominant properties delivered by composites is a function of different variables like type and amount of matrix and reinforcement, orientation of reinforcement, fabrication route implied, etc. Usually, particle reinforced composites exhibit isotropic mechanical behavior and fiber reinforced composites exhibits anisotropic behavior.

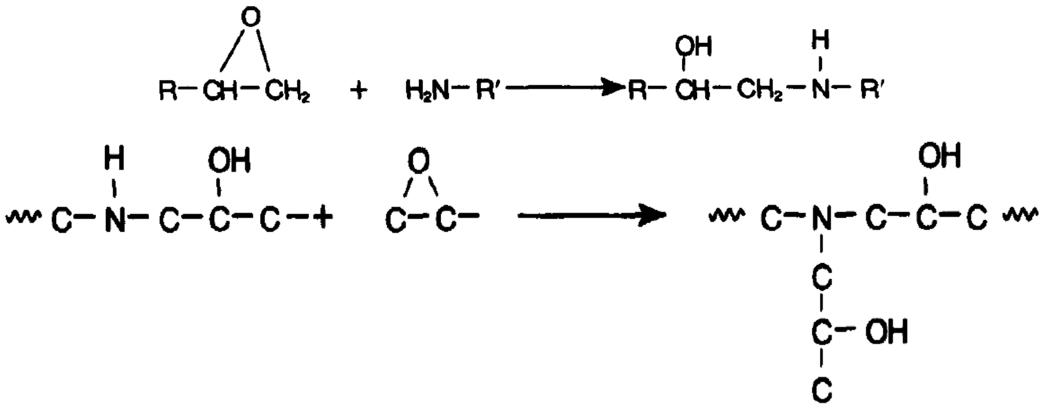
Epichlorohydrin and bisphenol A are undergoing reaction to form epoxy resins. In their thermoplastic state, they are viscous and contain no volatile monomeric element. Various proportions of epichlorohydrin and bisphenol A yields distinct resins, for instance, if portion of bisphenol A is increased, the molecular weight of resin decreases. These variations in resins give rise to their governing characteristics as viscosity, melting point, material flow index, etc. Epoxy resins are usually undergone viscosity reduction by dissolving in inert solvent to facilitate lamination at room temperature or are processed at higher temperature (50-100°C). This may lead to pre-curing of resin before evaporation of all the solvent when low temperature curing hardeners are present.



Curing agent is used to cure the epoxy resins which are also sometimes referred as activators, catalyst or hardeners. Even though these terms are used indiscriminately, they are different. Different curing agents perform differently as one may react and get adsorbed on the resin chain and other may work through catalytic action. Majorly, epoxy resins are cured by following reaction mechanisms:

1. Rearrangement of epoxy groups and formation of direct linkages among themselves.
2. Reaction of aliphatic and aromatic hydroxyl groups with epoxy groups.
3. Formation of cross links via radical groups with curing agent.

Amine curing agents often used to cure epoxy resins that may be aliphatic, aromatic or a policyclic, primary, secondary or tertiary. The optimum proportion of epoxy and hardener are taken to obtain the most suitable cured properties via following reaction:



Literature Survey-

Usually, in this sort of curing, epoxy-hydroxyl reaction does not occur and very high cross-linked structure is obtained due to poly functionalized amine and epoxy resin**.**

Fly ash is a by-product of industry generally produced due to coal combustion for producing energy and was recognized and considered as pollutant due to presence of toxic elements in flue gases**.** From power generation point of view, Fly ash is a waste while it is an unused resource from the view of coal usage**.** Concerned researchers worked in this area and found its several applications where it can be used as a major constituent as cement industry, recycling material in engineering and agricultural areas and as zeolite.

Vijaykumar H.K.et.al. [19] studied on completely different ratios of epoxy and fly ash sandwiched material for locating the flexural strength three completely different ratios of epoxy and fly ash were used for the analyses that were 65%-35% (65% fly ash and 35% epoxy by weight), 60%-40% and 55%-45%. They found that 60%-40% sample incontestable higher leads to bending and compression tests. That improvement was authorized to hollowness of fly ash particles and robust surface energy between resin and fly ash. supported the observation, they urged that this composite is used and replaced to areas wherever it wants an honest compressive strength like wood applications, ceiling, flooring, and different constructions.

Pichi Reddyet.al. [20] examined the impact of fly ash molecules on tensile and flexural strength of 10% fiber glass (by weight) epoxy composites. The quantity of fly ash was altered in measures of 2 grams from 0 to 10 grams. The greatest tensile strength was acquired for composite with 6 gram fly ash, the largest composite elasticity modulus with 8 gram fly ash and the lowest flexural strength for composite with fly ash 4 gram.

V. Pradeep et.al. [21] manufactured fiber glass strengthened polymer composites with fly ash in variable weight percentages (0 percent, 5 percent, 10 percent, and 15 percent) using hand lay-up methods. They discovered that mechanical characteristics enhanced when fly ash was strengthened with fiber glass; In addition, the sample with 15 percent (the largest fly ash percentage of all samples) had superior tensile strength, impact strength and hardness.

Nikhil Gupta et.al. [22] studied the addition of filler particles in lower volume parts resulted in reduced compressive strength of fiberglass epoxy composite filler samples. On the other hand, this combination has dramatically improved impact power. The impact of the sample aspect ratio on the material's compressive strength is significant and cannot be ignored. Sample conduct with aspect ratio modification was discovered to alter considerably; it also affected compressive strength values. Fiber length should be taken into consideration when selecting sample sizes and aspect ratio in case of brief fiber composites. It depends extremely on the interface strength of the filler and matrix material in case of fracture mode of effect.

Materials and methods-

Epoxy Resin PG100 Epoxy resins in polymer matrix composites are the most widely used thermo set plastic. Epoxy resins are a family of plastic thermo-set materials that do not yield reaction products when cured and therefore have minimum cure shrinkage. They also have excellent adhesion to other fabrics, excellent resistance to chemical and environmental effects, excellent chemical properties and excellent insulating. Epoxy resins are usually formed by responding with bisphenol to epichlorohydrin. Various resins are created by different proportions of the two as the epichlorohydrin percentage decreases the resin's molecular weight

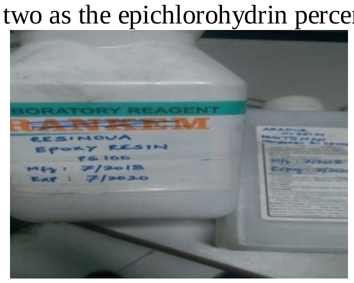


Figure 1epoxy resin

Hardener-HY951

Only when they are blended with an epoxy hardener can they cure correctly. When applied to a floor without the hardener, the resin would remain a near liquid indefinitely and could not be transformed into a durable flooring system. Mix this resin hardener carefully at room temperature (Epoxy: Hardener, 10:1). This hardener can be readily applied over the big substrate surfaces. For good resistivity against chemical & atmospheric circumstances, great mechanical strength and better electrical characteristics, the araldite HY 951 epoxy hardener is valued.

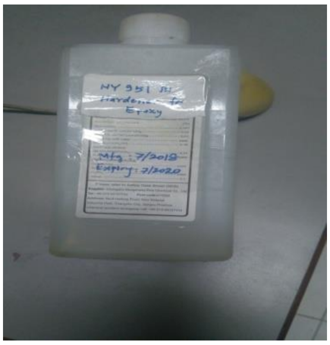


Figure 2 Hardener

Woven glass fiber

Woven glass fiber reinforced plastic (GFRP) is a form of strengthened plastic where the reinforcement fibre is specially a fiber. It’s going to be at random organized however it's ordinarily a woven sort in mat kind. Fibre it's roughly comparable mechanical properties to alternative fibres like carbon fibre and polymers. Even though it is not strong or as stiff as carbon fiber, it is cheaper and much less brittle when used in composites. E-glass or electrical glass is used as electrical wiring insulators.

Figure 3 Woven glass fiber

Filler material

Fly ash is one of the remains of carbon combustion. Fly ash is often bagged from power plant chimneys, while as the name indicates, bottom ash is separated from the lower part of the furnace. Earlier, fly ash was generally discharged through the smoke stack into the atmosphere, but pollution control machines have instructed it to be bagged before discharge in recent centuries. At most power generation plants, it is generally held on site. Fly ash usually comprises of SiO2, Al2O3, and Fe2O3 as major elements and oxides of Mg, Ca, Na, K etc. as small roles. Fly ash particles are generally spherical in form and differ from dimensions below 1µm to 100µm with a defined surface region, usually between 250 and 600m2/kg. Fly ash's specific gravity lies within the 0.6-2.8gm / cc range. Fly ash is usually used to accompany Portland cement in concrete manufacturing, where it can bring technological and financial benefits, and is gradually finding use in geo-polymer and zeolite production**.** The filler material used in the project is fly ash powder. It provides excellent strength to the composite materials and also provides excellent mechanical characteristics.

Figure 4 fly ash

Methods

Fabrication Method

Epoxy of 100 gm was heated to 30 ^{0}C and fly ash was preheated in the furnace at 70ºC for 3hrs. Preheated fly ash was added into the epoxy in 0 wt%, 5wt%, 10wt%, 15wt%, 20 wt% and 25wt% and 30wtpercent. Magnetic stirring of these samples was performed to form a homogeneous mix of fly ash and epoxy. Magnetic bead is set to rotate at 30 °C at medium rpm for 3 hours. Important point to be kept in mind maximum rpm is not set in one step but it is gradually increased from 0rpm to maximum rpm so that a proper magnetic field is set up.

Figure 5 Mixing of epoxy resin and fly ash on magnetic stirrer

Hand layup technique

The simplest methodology of composite process is that the hand lay-up technique. There's also marginal infrastructural demand for this methodology. The steps of the method are simple. First, a release gel is poured on the surface of the mold to prevent polymer from sticking to the surface. On high and bottom of the mold plate, thin plastic sheets are accustomed get sensible surface end of the product. Reinforcement within the style of plain-woven mats or cut strand mats is cut in line with the scale of the mold and placed once polymethyl methacrylate sheet on the surface of the mold. Then thermoset chemical compound in liquid type is completely mixed with a prescribed hardener (curing agent) and poured into the mat surface already placed within the mold. With the assistance of a brush, the polymer is spread equally. Second layer of paper is then placed on the polymer surface and a roller is shifted to get rid of any trapped water moreover because the surplus polymer present with a gentle pressure on the mat-polymer layer. For each layer of polymer and mat, the method is recurrent till the desired layers are stacked. The discharge gel is poured on the interior layer of the highest mold plate once putt the plastic sheet, that is then keep on the stacked layers and therefore the pressure is applied. After either solidifying at temperature or at bound specific temperature, mold is opened or therefore the composite portion created is removed and any processed.

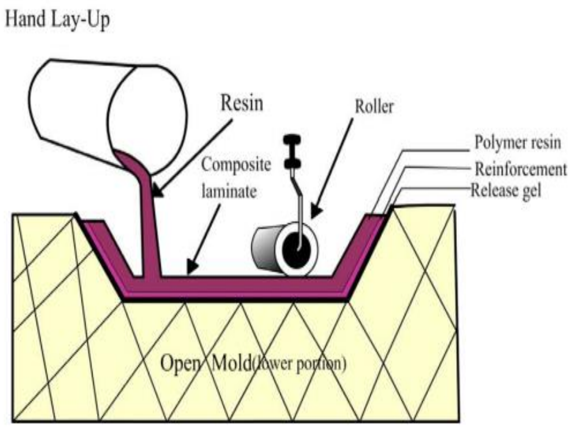


Figure 6Hand lay up method

Characterization

Tensile test samples were prepared according to ASTM D 3039.The test was performed at room temperature using a universal tensile testing machine (UTM) MTS 810 having a maximum load capacity of 100 KN. The total length, gauge length and width of the composite specimen used were 200, 100 and 12.5 mm, respectively. The thickness was taken as per the thickness of the fabricated composite laminate. The rectangular end tabs with dimensions 50 × 12.5 × 2 mm, (made of Epoxy-glass fabric composite) were bonded to the composite specimens using epoxy adhesive. The tensile test was conducted with loading speed of 1 mm/min in the displacement control mode.

Figure 7UTM MTS 810

Flexural Strength Test

The determination of flexural strength is an important feature of any structural material. It is the ability of a material to withstand the bending before reaching the break point Flexural Test samples were ready in line with ASTM D 790. The test was performed at temperature using UTM (Zwick Roell-Z010) having a most load capability of 10 KN. The test was conducted in three- purpose bending mode at the loading speed of 1 millimeter /min with the span length of 45 mm. The sample dimensions were taken as 100 × 15 × 3.5. For tensile and flexural mode, 1 sample of every composition was tested.

Figure 8UTM Zwick Roell-Z010

Dynamic Mechanical thermal analysis

Dynamic mechanical thermal analysis to study the viscoelastic behaviour of the epoxy composites, DMTA instrument (Perkin Elmer- Pyris Diamond DMA, USA) was used. The sample dimensions used were taken as 55 mm ×13 mm × 1.5 ± 0.1 mm. The test was performed in bending mode with a frequency of 1 Hz, strain amplitude of 5 mm under nitrogen atmosphere (flow rate of 200 ml min $^{-1}$) and temperature of 25–177^{0}C. The heating rate was kept at 10 ^{0}C /min. The inbuilt software in DMTA was used to collect the storage modulus, loss modulus, loss factor, etc.

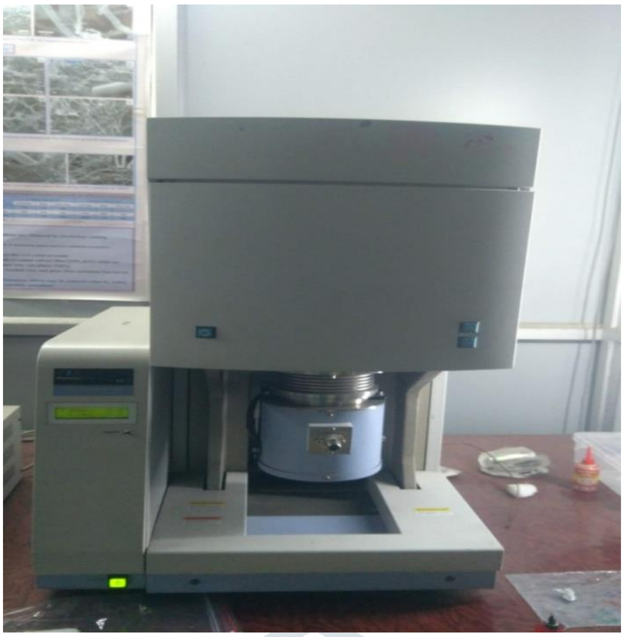


Figure 9 (Perkin Elmer- Pyris Diamond DMA, USA)

Results and discussions

Flexural Strength

The optimum bending load taken by the 0 wt percent epoxy was 169 N, which was increased when fiber glass was reinforced with fly ash as filler into the matrix. Furthermore, when fly ash filler was added to the matrix, the peak bending force improved compared to the polymer composite without fly ash filler. The flexural strength of the composite material increases from 185 MPa for unfilled epoxy to 231 MPa for fly ash filled glass fiber reinforced epoxy composites. Flexural stress first decrease then increases alternately. Flexural stress is Maximum at 20 wt% of fly ash.

Flexural Modulus

The flexural modulus of the composite material increases from 0 wt% FA to 20 wt% FA. It has been observed that the flexural modulus of the composite material increases with increase in Fly ash concentration in the pure epoxy as shown in Figure 10. The increase in the modulus for 20 wt% FA carbon fiber reinforced composite is more in magnitude as compared to unfilled epoxy composites.

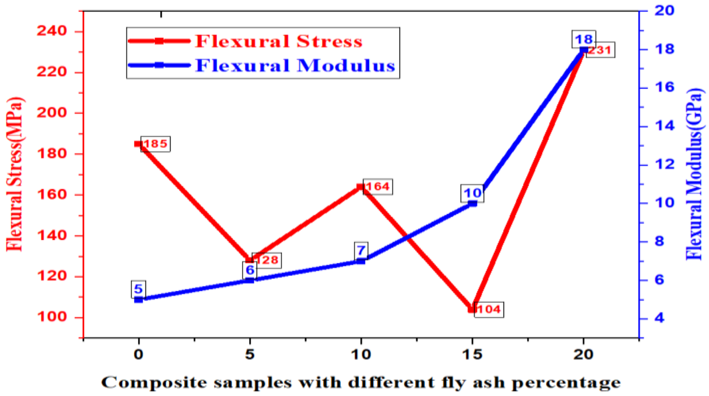


Figure 10Flexural modulus and flexural stress v/s composition of fly ash

Tensile Strength

Analyzing the outcomes of tensile testing for distinct fly ash filled epoxy-glass composites, it was noted that the tensile strength with dispersion of filler components was not significantly improved. Figure 4.3 shows the tensile strength of the composite epoxy glass with various percentages of fillers. Composite without filler can be obviously seen to have maximum tensile strength followed by fly ash at 20 wt% of fly ash. The pattern of results extremely well demonstrates that tensile load and tensile stress have a decreasing trend upto15 wt% of fly ash in epoxy composite. But from the consequence acquired, the weight proportion increases further, i.e. the characteristics begin to increase at 20 wt percent. In addition, by raising the weight proportion, it prompts bad dispersion of fly ash particles in epoxy resin, thus reducing and associating the interfacial region, resulting in reduced homogeneity in cross-link density. The presence of bidirectional glass fiber mat expands the strength of fly ash-reinforced particle epoxy resin composites.

Tensile Modulus

As the fly ash concentration increases from 0% to 30% by weight in the pure epoxy it has been observed that there is a significant increase in the tensile modulus of fly ash filled glass fiber reinforced composites as compared to pure epoxy. The increase in the tensile modulus follows almost a linear trend as shown in Figure 4.4. The increase in the modulus of the composite can be attributed due to the restriction in the movement of the polymer chains upon the incorporation of glass fiber into the polymer matrix.

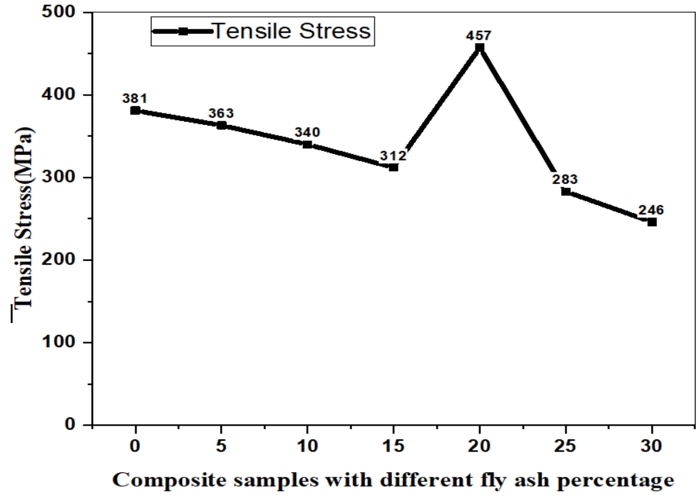


Figure 11Tensile stress v/s composition of fly ash

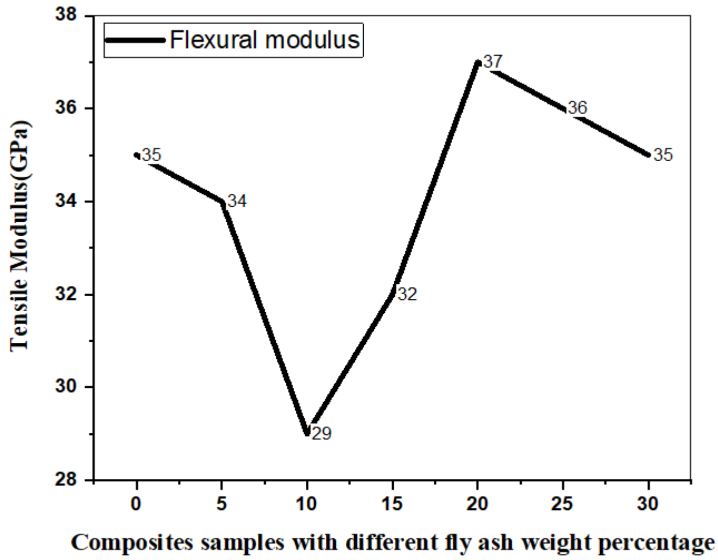


Figure 12 Tensile modulus v/s composition of samples

Dynamic Mechanical Analysis

Dynamic mechanical analysis is an outstanding instrument for characterizing the viscoelastic characteristics of polymer composites and improving knowledge of the composite's dynamic mechanical characteristics. It enables to identify relationships between structure and property and then connect these characteristics to the final performance. It is therefore essential to explore the impacts of FA loading on Epoxy -GF composites dynamic mechanical characteristics through parameters such as storage modulus, loss modulus, damping factor, etc.

Storage Modulus

The storage modulus (E') is a measure of the highest energy stored in the fabric during cyclic oscillations, representing the composite's rigidity conduct. The temperature graph of the storage modulus acquired from dynamic mechanical thermal analysis is used as a function of temperature to provide helpful data about the material's rigidity. This curve is predominantly susceptible to various types of structural parameters such as sample density, interaction of polymer material with both fiber and filler, degree of cross linking in polymer material, and interfacial bonding between fiber and matrix material. Figure 13 figure show the variation for the fly ash filled epoxy-GF composites in the E' versus the temperature for different FA loading and variation in the

E' versus FA content at different temperatures. Depending on the filler material (i.e., fly ash), the composites showed distinct E' temperature curves initial E' of epoxy-GF-FA 0, epoxy-GF-FA 5, epoxy-GF-FA 10, and epoxy-GF-FA 15 at uppermost 177^0C respectively. As it can be seen from the graph, the original E' rises by as much as 10 percent compared to the E' of unfilled composite and this trend continues to load up to 10 wt percent of Fly ash. This impact subsequently becomes less prominent, as the FA load rises to 15 wt percent. This results in adverse density and E' impacts as can be seen, the nature of the curve is nearly the same across the temperature range for all compositions. The original value of E' is comparatively large for all epoxy-GF-FA compositions; however, it reduces as the temperature increases. The epoxy-GF-FA composites are initially in a glassy condition (nearly no movement in polymer chains), where they are highly rigid and highly E' as the temperature rises up to the rubbery area , the polymer chains become smooth and flexible, resulting in more free polymer chain motion and less FA particle hindrance in the rubbery plateau area. The potential relationship between epoxy resin and FA could be weak Vander Waals, decreasing at greater temperatures. At high temperature, this eventually decreases stiffness and E' shows the variety of E' recorded for composites with variable FA content at five distinct temperatures. E' indicates a growing trend as the FA content in the epoxy-GF composite rises; however, its value slowly reduces as the temperature rises. The fact that the addition of FA allows fly ash filled epoxy-GF composites to absorb more energy up to the given deformation compared to unfilled epoxy composites. The rise in E' with filler content for the full range of test temperatures can be associated with polymer resin matrix-filler interactions that limit segmental mobility and thus boost composite stiffness or boost composite energy storage ability.

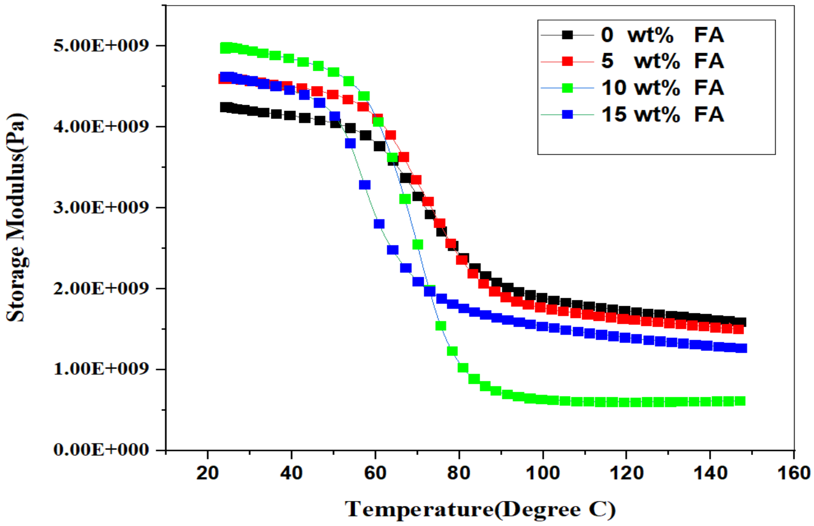


Figure 13 Storage Modulus v/s Temperature

Loss modulus

The material's loss modulus (E") is used to determine the energy consumed by the composites per unit cycles under the circumstances of oscillatory loading. It is obvious from the Fig. 14 that an increase of percent is noticed in the E" even after the addition of only 5 wt percent FA in the composites of the epoxy-GF. This can be attributed in the presence of the FA to the matrix's irregularly cross-linking network compared to the matrix's regularly cross-linking network without fillers. Due to the breakdown of soft strengthening of polymer filler relationships and frictions between the reinforcements within the composites, the energy loss rises in the form heat. As the filler content rises, the composite laminate's flexibility declines due to increasing the limitation of the polymeric molecule's segmental mobility at relaxation temperature. An obvious change in the glass transition temperature (Tg) to the greater temperature side is noted with the addition of 0 to 15wt percent FA in the epoxy-GF composites. As the temperature continues to rise, the Tg of composites can be recognized by the fall in storage modulus temperature curves and loss modulus (E") temperature or tanD temperature curves peaks. The E" is basically directly proportional to the quantity of energy produced by the composite as heat. Moreover, the mechanical damping term is the ratio of the loss modulus to the storage modulus and is related to the degree of flexibility in the organic molecules chain material. The maximum value of loss modulus is at 10 wt% of fly ash.

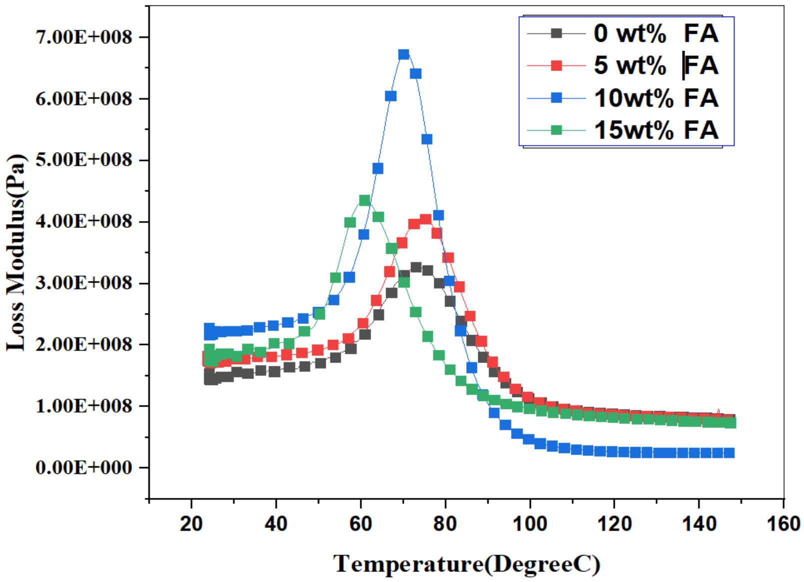


Figure 14 Loss Modulus v/s Temperature

Damping Factor (tanD)

The damping factor is the ratio of the loss modulus to the storage modulus of the polymer composites. It furnishes information about the balance between the elastic and viscous phase of polymer composites. The damping parameter of the composites can also be calculated by their areas under the tan D–temperature curves. The epoxy-GF-FA 0 composite has shown the lowest damping parameter compared to the composites with fillers. This is due to the less molecular mobility of highly cross linked network of polymer matrix. Among filler-loaded composites, the epoxy-GF-FA10, epoxy-GF-FA5 and epoxy-GF-FA0 composites have shown their damping characteristics in a decreasing order. Compared to the other epoxy-GF-FA composite, the epoxy-GF-FA10 composite showed a maximum damping characteristic. This is due to its more irregularity in its network of cross linked matrixes, owing to the charging of the filler. The energy is dissipated by frictions within the composites in the form of heat between reinforcements and reinforcement-polymer interactions. As the loading rises further to 10 and 15 wt percent, the damping features of the composites further reduce due to a more constant network of fillers in the matrix, which is also due to the small resin weight percentage. In addition, as the filler content rises, the continuity rises, the E' and E" have shown a growing trend. The increase in damping factor by adding FA indicates that the composite's loss property dominates the storage property more. In addition, the graph also shows a change to a greater temperature side in peak positions.FA's capacity to resist elevated temperatures could be the reason for the greater temperature side of Tg's change.

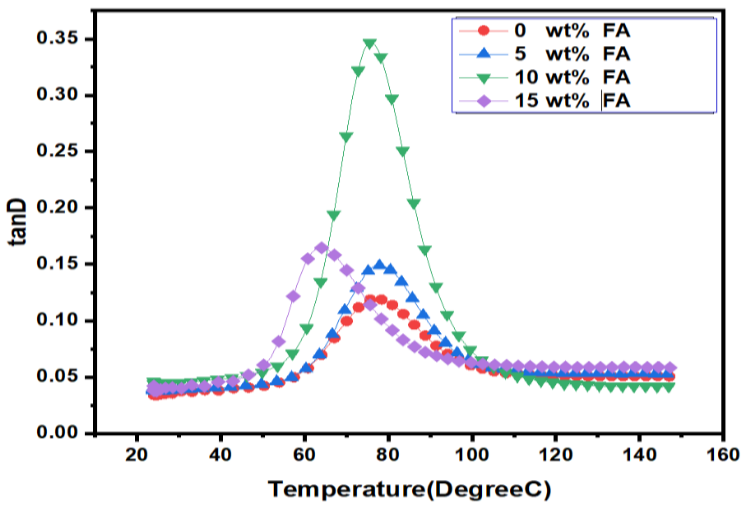


Figure 15 damping factor v/s Temperature

Conclusion

The experimental study was performed on the impact of fiber loading and filler substance on the mechanical behavior of epoxy composites. Properties such as the Tensile strength, tensile Modulus, flexural strength, flexural modulus and hardness were evaluated from various experiments. Due to their high specific strength, stiffness, low weight and inexpensive, light weighted polymer matrix composite has taken over the market in many fields. As a member of thermoset polymers, epoxy has notable characteristics and fly ash is a by-product of coal combustion systems consisting mainly of metal oxides. When these two entities are coupled in one, according to our requirements, we are enabled to tailor characteristics. Due to its ease and cost-effectiveness, fly ash / epoxy composites are manufactured via fabrication method.

Composite strength was researched for tensile strength, flexural strength and dynamic strength, and all showed satisfactory outcomes. Adding fly ash to epoxy increases not only mechanical strength but also wear resistance. It has been researched that sliding distance, sliding speed, fly ash content and ordinary loads play a crucial role in determining wear frequency and we can readily adapt our composite's wear quality to our needs.
With relatively uniform distribution of fly ash filler particles, fiberglass reinforced polymer matrix composites were effectively manufactured. Micro structural research disclosed that the particles of the fly ash filler are spread throughout the matrix but with certain agglomerations.

In DMA storage modulus, loss modulus and damping factor have maximum value at 15 wt% of fly ash. Tensile strength decreases with the addition of fly ash particles. The tensile stress reduces up to 15 wt percent fly ash. At 20 wt percent fly ash, the value of tensile stress is Maximum and then it reduces again. The flexural strength decreases for 5 % fly ash composites and then it increases for 10 % fly ash composites, but towards the 10 % fly ash composite it started increasing again, which can be attributed to the fact that addition of more fly ash particles may increase the flexural strength further. The flexural strength was Maximum for the 20% fly ash composites.

References

[1] Olson, J.M., 1970. The evolution of photosynthesis. *Science*, *168*(3930), pp.438-446.
[2] Lubin, G., 2013. *Handbook of composites*. Springer Science & Business Media..
[3] Hollaway, L.C. ed., 1994. *Handbook of polymer composites for engineers*. Elsevier.
[4] Hara, O., 1990. Curing agents for epoxy resin. *Three Bond Technical News*, *32*(20), pp.1-10.
[5] Ahmaruzzaman, M., 2010. A review on the utilization of fly ash. *Progress in energy and combustion science*, *36*(3), pp.327-363.
[6] Kikuchi, R., 1999. Application of coal ash to environmental improvement: transformation into zeolite, potassium fertilizer, and FGD absorbent. *Resources, Conservation and Recycling*, *27*(4), pp.333-346.
[7] Querol, X., Moreno, N., Umaña, J.T., Alastuey, A., Hernández, E., Lopez-Soler, A. and Plana, F., 2002. Synthesis of zeolites from coal fly ash: an overview. *International Journal of coal geology*, *50*(1-4), pp.413-423.
[9] Kelly, A., 1967, Sci. American, 217, (B), pp. 161.
[10] Priya, N.A.S., Raju, P.V. and Naveen, P.N.E., 2014. Experimental testing of polymer reinforced with coconut coir fiber composites. *International Journal of Emerging Technology and Advanced Engineering*, *4*(12), pp.453-460.
[11] Van Suchtelen, J., 1972. Product properties: a new application of composite materials. *Philips Res. Rep*, *27*(1), pp.28-37.
[12] Agarwal, B.D., Broutman, L.J. and Chandrashekhara, K., 1990. Analysis and performance of fiber composites, John Wiley & Sons. *Inc. New York: New York*, pp.1-30.
[13] Outwater, J.O., 1956. The mechanics of plastics reinforcement in tension. *Mod. Plast*, *33*(7), pp.156-162.
[14] Rohit, K. and Dixit, S., 2016. A review-future aspect of natural fiber reinforced composite. *Polymers from Renewable Resources*, *7*(2), pp.43-59.
[15] Dhakal, B., 2013. *A study on the effect of fiber loading and orientation on mechanical behaviour of jute fiber reinforced epoxy composites* (Doctoral dissertation). [16] Chigal, G. and Saini, G., 2012. Mechanical testing of Al6061/silicon carbide metal matrix composite. *IJREAS*, *2*(2), pp.221-238.
[17] Mehrabian, R.G.R.R., Riek, R.G. and Flemings, M., 1974. Preparation and casting of metal-particulate non-metal composites. *Metallurgical transactions*, *5*(8), pp.1899-1905.
[18] Shash, A.Y., Amer, A.E. and El-Saeed, M., 2015. Influence of Al 2 O 3 Nano-dispersions on Mechanical and Wear Resistance Properties of Semisolid Cast A356 Al Alloy. In *Mechanical and Materials Engineering of Modern Structure and Component Design* (pp. 13-24). Springer, Cham.
[19] Vijaykumar, H.K., Prashanth, M., Saheb, S. and Nayak, V., 2014. Experimental Investigation of the Tensile strength and Compressive strength of Fly Ash Core Sandwiched Composite Material. *J Int org Sci Res*, *4*(6), pp.1-10.