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Fabrication, Testing and Evaluation of Mechanical Properties of S-Glass Fibre Reinforced Epoxy Composites

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Abstract— Due to increasing demand and widespread application of fiber reinforced polymer composites, they have been used in a variety of application like aerospace, automotive, sports, ships and constructional work. Because of their several advantages such as relatively low cost of production light weight, easy to fabricate and superior strength to weight ratio. In the present study, Mechanical behavior of the S-glass/epoxy composites with fiber orientation [0/90°] was investigated incorporating graphite filler within the common matrix of epoxy resin. Composite specimens for tensile, hardness, impact and flexural tests were prepared and tested according to ASTM standards with graphite filler of 5 and 7 wt.%. Graphite, a particulate refractory filler (relatively coarse) was used. Finally, the properties of S-glass/epoxy composite without filler was also compared with the filler included composite.

Keywords— S-glass/epoxy composites, Mechanical Behavior, Graphite Filler, Fiber orientation Angle.

I. INTRODUCTION

Composites are made from a polymer matrix that is reinforced with an engineered, man-made or natural fiber (like glass, carbon or aramid) or other reinforcing material. The matrix protects the fibers from environmental and external damage and transfers the load between the fibers. The fibers, in turn, provide strength and stiffness to reinforce the matrix and help it resist cracks and fractures. In many of industrial products, polyester resin is the matrix and glass fiber is the reinforcement. But many combinations of resins and reinforcement are used in composite and each material contributes to the unique property of the finished product such as fiber, powerful but brittle, provides strength and stiffness, while more flexible resin provides shape and protects the fiber. Frp composites may also contain fillers, additives, core materials or surface finish designed to improve the manufacturing process, appearance and performance of the finial product. [1]

1.1 Reinforcement Material:

Glass fiber (or glass fiber) is a material consisting of numerous extremely fine fibers of glass. Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites.

Glass fibers are therefore used as a reinforcing agent for many polymer products to form a very strong and relatively lightweight fiberreinforced,polymer (frp) composite,material called glass-reinforced plastic (grp), also popularly known as "fiberglass". S-glass differs in formulation from more commonly used E-glass and features improved mechanical properties. This high strength glass fiber is used where increased performance requirements are required. These fibers are lower in density than E-glass, producing a lighter laminate with higher stiffness. S-glass produces enhanced mechanical properties compared to e-glass and with lower cost than aramid or carbon fiber. [1]

1.2 Matrix Material:

The primary function of the resin is to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. Resins used in reinforced polymer composites are either thermoplastic or thermoset. Epoxy resins have a well-established record in a wide range of composites parts, structures and concrete repair. The structure of the resins can be engineered to yield several different products with varying level of performance. A major benefit of epoxy formulated with different material or blended with other epoxy resins to achieve specific performance features. Epoxy are used primarily for fabricating high performance composites with superior mechanical properties such as resistance to corrosive liquids and environments, superior electrical properties, good performance at elevated temperature, good adhesion to a substance, or a combination of this benefits. [1]

1.3 Filler Material:

Graphite is pure carbon in a crystal form much like that of mica–sheets of strongly linked atoms, with very weak bonds between the sheets. This structure makes graphite an excellent dry lubricant wherever temperatures do not get too high. Graphite fibers reinforced composites have exceptional mechanical properties which are un-equaled by other materials. The material is strong, stiff, and lightweight. Polymeric graphite fibers composite is the material of choice for applications where lightweight & superior performance is paramount, such as components for spacecrafts, fighter aircrafts, and race cars. This study investigated the effect of filler on mechanical behavior of epoxy composites. [1]

II. RELATED WORK

Effect of Graphite Filler on Mechanical Behaviour of Epoxy Composites

Graphite reinforced epoxy composites with different particulate fractions of graphite were investigated for mechanical properties such as tensile, impact and flexural. The graphite content was varied from 2% to 8% by weight of total matrix in the composites. The results showed that the mechanical properties of the composites mainly depend on dispersion condition of the filler particles, particle size and aggregate structure. The composites showed improved tensile modulus, flexural modulus and impact strength in bending properties with increase filler Content as the functional group tends to decrease in composites with increasing filler content as gelation occurs vigorously in the composite.

Strength Characterization of E-glass Fiber Reinforced Epoxy Composites with Filler Materials:

In this research work, an investigation was made on the mechanical properties of E-glass fibre reinforced epoxy composites filled by various filler materials. Composites filled with varying concentrations of fly ash, aluminium oxide, magnesium hydroxide and hematite powder were fabricated by standard method and the mechanical properties such as ultimate tensile strength, impact strength and hardness of the fabricated composites were studied. The test results show that composites filled by 10% volume magnesium hydroxide exhibited maximum ultimate tensile strength and hardness. Fly ash filled composites exhibited maximum impact strength

Axial and Lateral Buckling Analysis of Fiber Reinforced S-Glass/Epoxy Composites Containing Nano-clay Particles.

In the present study, lateral and axial buckling characteristics of the S-glass/epoxy composites were investigated incorporating Nano-clay (NC) particles within the common matrix of epoxy resin. Critical axial and lateral buckling loads of the composite samples were experimentally determined for different weight contents of NC particles (1, 1.5, 2 and 3 wt. %). The effects of fibre orientation angles on critical buckling loads were investigated for both of axial and lateral buckling analyses, and it was shown that maximum axial and lateral buckling loads were obtained with fibre orientation angle of [0/90°] & [15/-75°], respectively. In addition, influence of NC particles on tensile and flexural properties were examined only for NC content of 1 wt. %. It is concluded that incorporation of NC particles by 1 wt. % in the composites resulted in 8.6 % improvement axial buckling load, and further increasing NC content did not significantly effects on axial and lateral buckling values implying poor interfacial stress between NC particles and epoxy resin.

Mechanical and Sliding Wear Behaviour of E-Glass Fiber Reinforced with Epoxy Composites

Due to increasing demand and widespread application of Fibre reinforced polymer (FRPs) composites, they have been used in a variety of application like aerospace, automotive, sports, ships and constructional work. Because of their several advantages such as relatively low cost of production light weight, easy to fabricate and superior strength to weight ratio. In the present work E-glass fibre is used as reinforcing agent with and without alumina filler. The objective of the present research work is to study the mechanical and abrasive wear behavior of E-glass fibre reinforced epoxy-based composites. The effects of fibre loading and filler content on mechanical properties like tensile strength, flexural strength of composites is studied. A robust design technique called Taguchi method is also used to determine the optimal condition for specific wear rate of the composites by considering different parameters.

Enhanced Mechanical and Wear Performance of Epoxy/glass Composites with PTW/Graphite Hybrid Fillers

Epoxy/glass composite containing two different micro-fillers was developed by vacuum bagging technique. The effect of ceramic whisker (7.5 wt. %) and solid lubricant filler (2.5 wt. %) on mechanical and dry sliding wear behavior of epoxy/glass composites was studied. The mechanical property characterization included evaluations of tensile, flexural and impact properties as per ASTM standards. The dry sliding wear tests were conducted on pin-on-disc arrangement with steel disc as counter face. Experimental results indicated that single incorporation of ceramic whisker can improve stiffness, friction coefficient and antiwear abilities of epoxy/glass composites significantly. The strength properties of composites were slightly reduced after whisker addition. However, incorporation of solid lubricant as secondary filler resulted in improvement of both mechanical and tribological properties of composites. It was also found that tribological properties of filled epoxy/glass composites were closely related with sliding conditions such as applied load and sliding velocity.

Effect of Perlite Particle Contents on Delamination Toughness of S-glass Fiber Reinforced Epoxy Matrix Composites

The effects of perlite particulate-filler on the mode I and mode II inter laminar fracture and mechanical behavior of glass fabric/epoxy composites was studied. Composite specimens for double-cantilever beam (DCB), end-notched flexure (ENF) tensile and flexural tests were prepared and tested according to ASTM standards with perlite contents of 1, 3, 5 and 10 wt.%. The optical and scanning electron microscopes images were described the mechanisms of mode I and II inter laminar fracture. The results indicated that the mode I and mode II inter laminar fracture toughness were optimum at perlite content of 3 wt.% with increment of 39.9% and 72.3%, respectively. The tensile strength and flexural properties reached maximum values at perlite content of 1 and 5 wt%, respectively.

Experimental Investigation on Mechanical Behaviour of E-Glass and S-Glass Fiber Reinforced with Polyester Resin

Glass fibre reinforced polyester composites have played a dominant role for a long-time in a variety of applications for their high specific strength, stiffness and modulus. In this research work, an E-glass and S-Glass fibre with random oriented reinforced polymer composite was developed by hand lay-up technique with varying fibre percentages. In this particular investigation, E Glass-Polyester (E-P) and S-Glass Polyester (S-P) composite is compared with that of combination of E Glass and S Glass-Polyester (ES-P) composites for mechanical properties. The influence of glass fibre percentage on the mechanical properties such as tensile strength, flexural strength and impact strength was investigated. Hardness of composites was evaluated by using Brinell hardness tester. The results showed remarkable improvement in the mechanical properties of the fabricated composite with an increasing in the glass fibre contents. The results show the best suitable fibre resin ratio with respect to strength.

III. METHODOLOGY

3.1 Materials Used:

For the present study, a commercially available epoxy resin L-12 procured from Atul India Ltd was used as the polymer matrix. Hardener K-6 was used for epoxy resin. The graphite Powder with a particle size (max. 5% >100-micron meter) with carbon content 70-99.5% was obtained from Graphite India Limited, Bengaluru-560048.

3.2 Matrix Preparation:

Polyester resin is an unsaturated, thermosetting resin produced by a reaction between several organic acids and polyhydric alcohols. It is most commonly used in the construction of molded reinforced fibre and composite products. The polyester resin used in most molding applications is a viscous liquid requiring the addition of catalysts and accelerators to complete the curing process. Polyester resins are contact products which require no pressure to cure and can be cured from a fluid or solid state. Although these products have several distinct disadvantages when compared to other commonly used composite resins, they still offer an attractive balance of ease of use, low cost and positive physical characteristics.

Fig.1: Epoxy Resin(L-12)

Fig.2: Hardener (k-6)

3.3 Fabrication Method and Preparation of Composite Sheets

A weighted amount of epoxy resin and graphite powder was mixed in varying proportions and then the hardener, (K-6) was added to initiate the reaction. The mixture was then poured into the mould of dimension 200*200*3 mm and cured at room temperature under pressure molding and hand lay-up method. Different sheets of epoxy resin reinforced with varying amounts of graphite filler i.e. 5%, 7% (by weight of resin) were prepared and tested. Filler amount was limited to 7% in composite sheet because as the filler concentration increased to 7%, the gelation occurred rapidly, and mixture became thick and losing fluidity.

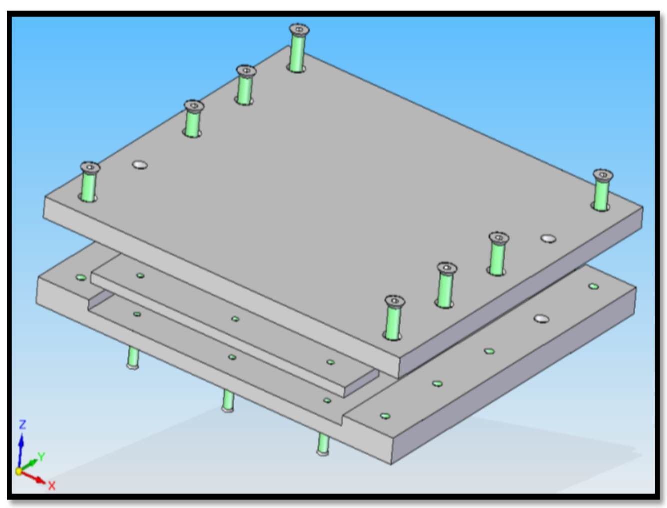

Fig.3. 3-Dimensional View of Mould Box

Fig.4. S-glass fibre

3.4 CHARACTERIZATION OF THE SAMPLES:

The composite samples were tested for their mechanical strength as:

Sample for Tensile Testing.

The samples for tensile testing were prepared according to the ASTM D-638. These samples were cut into a dumb-bell shape with the help of water jet machining, and tests were performed in universal testing machine as shown in fig 5.0.

Fig 5.0 Sample of Tensile Testing

Sample for Izod Impact Testing.

The specimen used in Izod test must be notched according to the ASTM D-256 as shown in fig 6.0. The reason for notching the specimen is to provide a stress concentration area that promotes a brittle rather than a ductile failure.

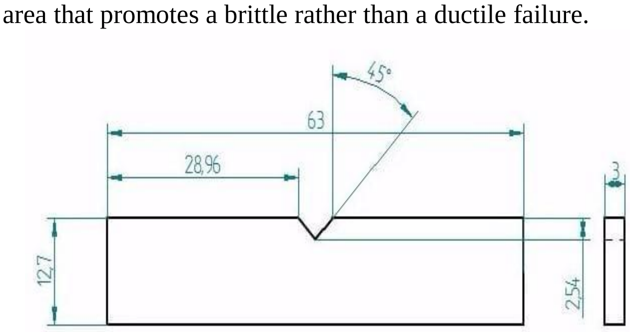

Fig 6.0 ASTM dimension for Izod Impact Testing

Sample for Flexural Testing.

The test sample of specified size 127mm x12.7mm x 3mm were cut with water jet machining according to ASTM D790 as shown in fig 7.0.

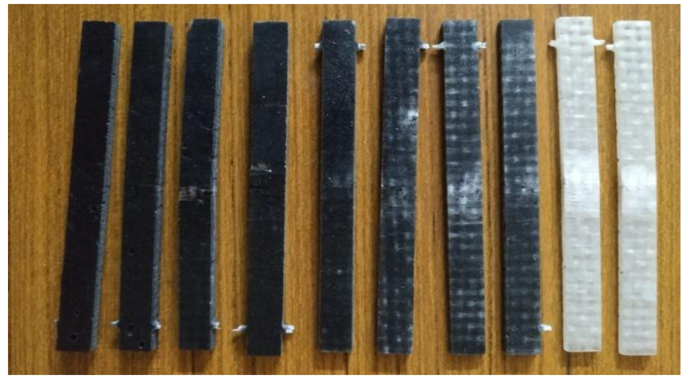

Fig 7.0 Sample of Flexural Testing

Sample for Hardness Testing.

The samples for hardness testing were prepared with specified size 25mm x 25mm and cut with water jet machining as shown in fig 8.0.

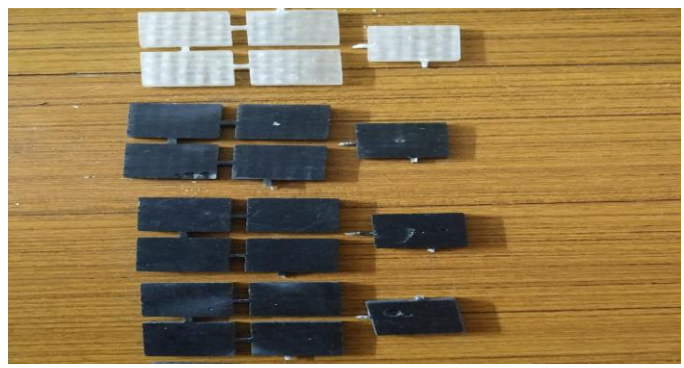

Fig 8.0 Sample of Hardness Testing

IV. RESULTS AND DISCUSSION

The mechanical properties of composite made of high modulus filler and relatively low modulus polymeric matrix are sensitive to loading rate and temperature.

Tensile elongation and tensile modulus measurements are among the most important indications of strength in a material and are the most widely specified properties of plastic materials. Tensile properties are temperature sensitive. The structure and properties of the filler matrix interface play a major role in the mechanical and physical properties of composite materials.

4.1 Tensile Test:

The variation in tensile strength of S-Glass composites with hand layup and pressure molding process with varying graphite filler percentage are shown in Figure 6.

In study it was observed that the elongation at break decreases slowly as filler concentration increases due stiffness increases with filler content. These results proved that graphite flakes have the synergistic effect on improving mechanical properties of epoxy resin.

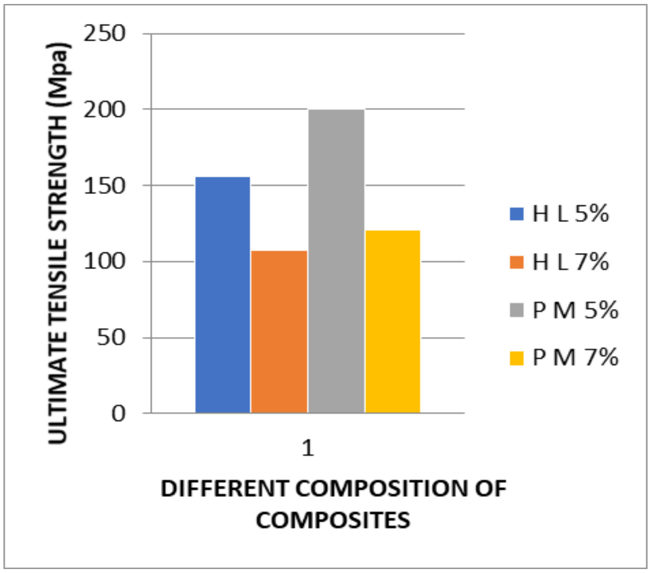

Fig 9.0 showing ultimate tensile strength of S-Glass fiber reinforced epoxy composite with graphite filler.

The results of tensile strength test with are listed in the below

Table 1. Readings of tensile testing

MOULDING PROCESS	MAX LOAD (F_{max}) KN	ULTIMATE TENSILE STRENGTH (Mpa)
Hand lay- up (5%)	8.103	155.822
Hand lay-up (7%)	5.563	106.972
Pressure Molding (5%)	10.398	199.956
Pressure Molding (7%)	6.268	120.54

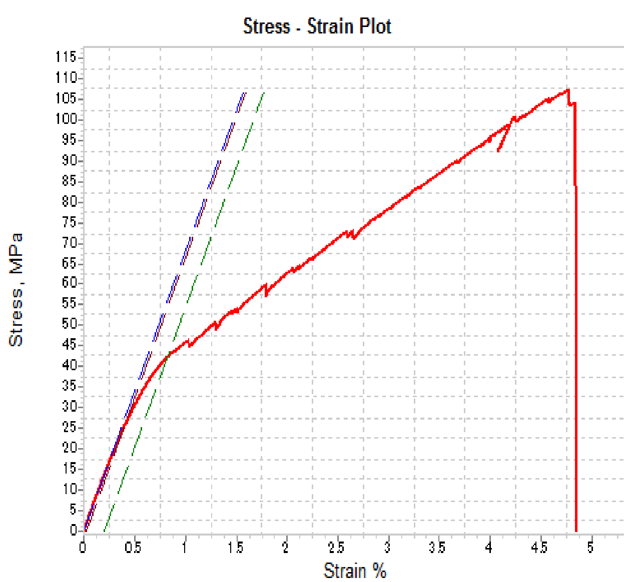

Fig 10.0 showing stress vs strain variation for tensile testing

4.2 Impact Test:

The variation of impact strength with the glass fiber in case of room temperature was presented in Figure 7.0

It was observed from figure 7 that impact strength and toughness is increased with an increase in filler content. The decrease in impact strength at hand lay-up (5%) in the figure is due to decreased availability of epoxy material to bond all the graphite particles in the matrix. It is examined that the impact property of polymeric material is directly related to the over toughness of the material. The impact energy is a measure of toughness. The higher the impact energy of material, the higher the toughness of material vice versa. The study revealed that this type of behavior is common for polymers filled with particulate system.

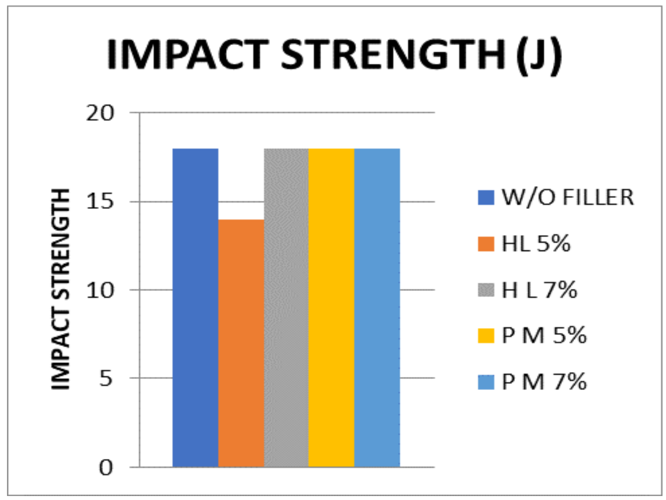

Fig 11.0 showing impact strength of S-Glass fiber reinforced epoxy composite with graphite filler.

Table 2. Properties of Fiber Compared

Materials	Density (g/cm^3)	Tensile strength (Mpa)	Young modulus (Gpa)
E-Glass	2.55	2000	80
S-Glass	2.49	4750	89

4.3 Flexural Test:

The flexural properties of composites depend critically on the microstructure of the composite and the interfacial bonding between the filler and matrix. In this study flexural strength of the graphite filled polymer composite was measured with respect to filler content.

The study reveals that the flexural strength decreases with the increase of graphite content as shown in figure 8 due to interfacial bonding and additional load bearing capacity of the matrix, which can be due to poor filler matrix adhesion.

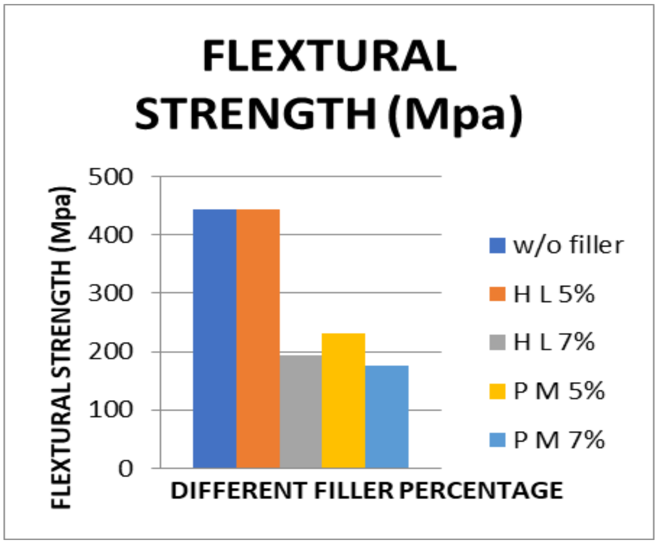

Fig 12.0 showing flextural strength of S-Glass fiber reinforced epoxy composite with graphite filler.

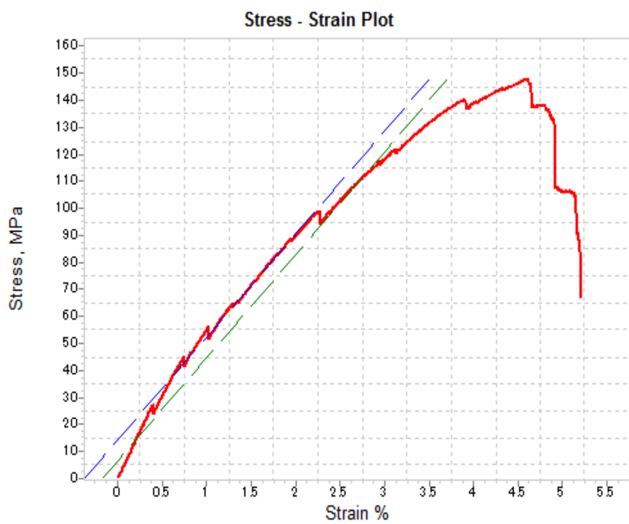

Fig 13.0 showing stress vs strain diagram for flextural test

Resin Properties:

Table 3. Comparison of properties for various resins available

Property	Polyester	Vinyl ester	Epoxy
Stiffness [GPa]	2.4 - 4.6	3 - 3.5	3.5
Ultimate strength [MPa]	40 - 85	50 - 80	60 – 80
Ultimate strain [%]	1.2 - 4.5	5	5 – 3
Density [kg/m3]	1150 - 1250	1150 - 1250	1150 – 1200
Curing shrinkage [%]	6 - 8	5 - 7	<2

4.4 Hardness Test:

The study revealed that hardness is increased with decrease in filler content using hand-layup molding process from 33.47 BHN to 52.573BHN.

The experiment was conducted on a standard Brinell hardness testing machine with 60Kgf.The study also revealed that the hardness increased with increase in filler material using pressure molding process which may be due to good filler matrix adhesion.

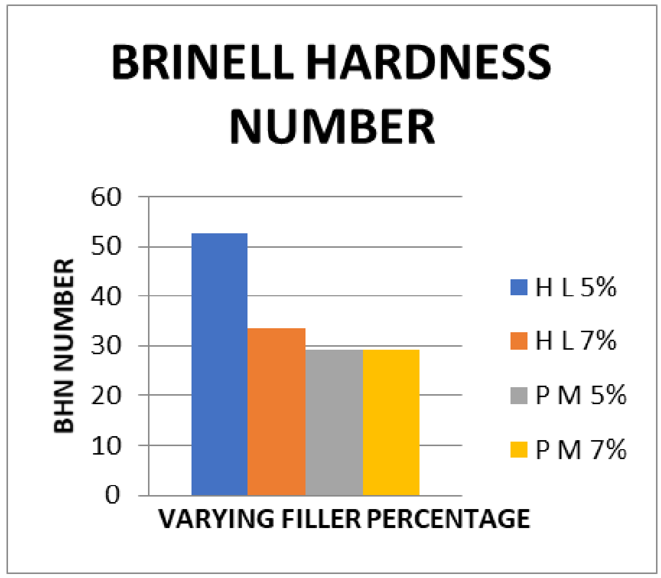

Fig 14.0 showing ultimate BHN of S-Glass fiber reinforced epoxy composite with graphite filler.

V. CONCLUSION AND FUTURE SCOPE

The S-Glass fibre reinforced epoxy composites were manufactured with inclusion of graphite filler. A sample of composite without filler was also manufactured. The tensile, flexural, impact and hardness test were carried according to ASTM standards.

The project consists of two phases:

1. Comparing the properties of composites containing filler with composites without filler[w/o].
2. Comparing the Hand lay-up [HL] process results with Pressure molding process

- The addition of graphite filler with two different varying percent increased the tensile strength from 150 Mpa to 200 Mpa. These are also due to the different techniques used to prepare composites. Here pressure molding process has played its role.
- There is a lot of difference between w/o filler and with filler composites, tensile strength from 100 Mpa to 150 Mpa.

- The graph of flexural test indicates that flexural strength decreases with increase in filler percentage from 443 Mpa to 180 Mpa.
- From the graph it is observed that the impact strength almost remains same with varying composition and process that is 20J.
- The test carried for hardness test with Brinell hardness testing machine (1/4-inch ball indenter) shows that hardness of composites with filler is greater than composites without filler.
- The hardness of varying filler composites doesn't show much increase in hardness from BHN 33.4726 to 52.5. Here the pressure molding [PM] technique exhibits poor property.

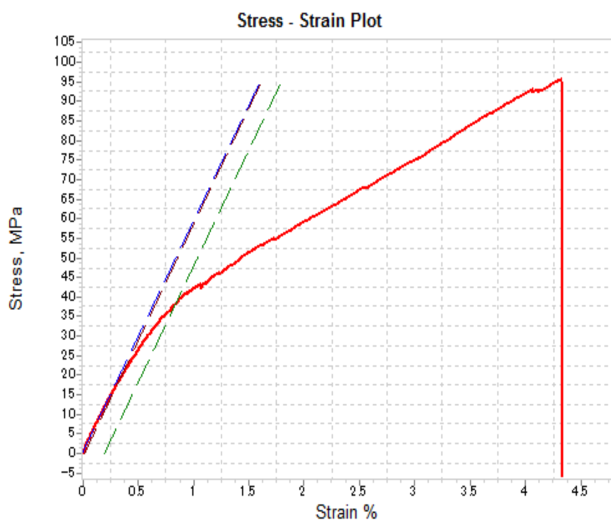

Fig 15.0 showing stress vs strain graph of tensile testing without graphite filler.

Fig 15.0 showing stress vs strain graph of flextural testing without graphite filler.

3. The above graphs indicates that composites without filler exhibits poor properties then composites with filler.Hence more properties can be determined in future for furthur advancement of composites with varities of filler materials to reduce the cost of composites.

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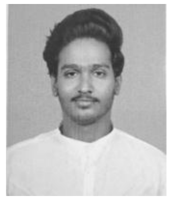

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