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Static mechanical properties of GFRP laminates with fly ash and graphite as filler material

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A B S T R A C T

Glass fiber reinforced polymer matrix (GFRP) woven fabric composite material was tested to determine tensile, Flexural and Impact strength. In this paper a comparison study is done for Tensile, Flexural and Impact strength taking two different materials such as (i) woven glass fibre Aralide LY 556epoxy matrix laminates and (ii) woven glass fibre Vinyl Ester epoxy matrix laminates. 1% Graphite and 1% Ash clay are used as filler material as the use of fillers in the matrix, gives rise to many combinations that provide increasing load withstanding capability, reduced coefficient of friction, improved wear resistance and improved thermal properties.

1. Introduction:

Over the past decades, polymer matrix composites are made and most widely used for structural applications in the aerospace, automotive, and chemical industries, and in providing alternatives to traditional metallic materials. The features that make composites so promising as industrial and engineering materials are their high specific strength, high specific stiffness and opportunities to tailor material properties through the control of fiber and matrix compositions. Composites are developed for superior mechanical strength and this objective often conflicts with the simultaneous achievement of superior wear resistance. As a result of this, these materials are found to be used in mechanical components such as gears, cams, wheels, impellers, brakes, clutches, conveyors, transmission belts, bushes and bearings. In most of these services the components are subjected to tribological loading conditions, where the likelihood of wear failure becomes greater. Of the large number of matrices available commercially, only a small portion is in significant use for these kinds of applications. The use of fillers in the matrix, gives rise to many combinations that provide increasing load withstanding capability, reduced coefficient of friction, improved wear resistance and improved thermal properties. In addition to this, fillers in polymeric composite reduce the cost due to the less consumption of matrix material. Fibers are the principal constituents in a fiber reinforced composite materials. They occupy the largest volume fraction and share the major portion of the load acting on a composite

Circumlocution in disposing industrial wastes with no end-use has tantalized scientists to explore their potential utility as competent fillers for polymer matrices. In this scenario, fly ash is considered as one of the major industrial wastes. It is the burnt end product of pulverized coal from thermal power plants, produced in massive quantities, posing problems like air and water pollution, wastage of large tracts of agricultural land for disposal, etc. There has been a large impetus in the effective utilization of waste fly ash as filler in polymer matrix, as a result of impending stringent environmental regulations. Recently, a conspicuous attempt to elucidate successful utilization of such wastes was extensively studied, thus helping to solve specific solid waste problems, and also in providing solution to technical issues in specific areas. Saroja Devi [1],[2] and

Ramakrishna[3] have researched the mechanical properties of fly ash-filled general-purpose unsaturated polyester resin. Wong and Truss[4] reported the effect of fly ash addition and the effect of coupling agent on the tensile and impact properties of polypropylene (PP). Bose and Mahanwar[5] observed that the addition of fly ash to nylon 6 improved its rigidity, heat resistance, and dimensional stability. Chand et al.[6],[7] developed a new type of cheaper fly ash-filled PP/polymethyl methacrylate blend system and also studied the effect of temperature on electrical behavior of fly ash-filled epoxy gradient composites. Kishore et al.[8–11] investigated the compressive properties of epoxy and hybrid epoxy composites filled with fly ash under different conditions. Sombatsompop et al.,[12] Alkadasi et al.,[13] and Mahanwar et al.[14] successfully attempted in utilizing fly ash as fillers for rubbers. Ismail and Kheong[15] studied the effect of silane coupling agent, Si69, on the properties of recycled poly(vinyl chloride)/nitrile butadiene rubber/fly ash composites and found that the presence of Si69 significantly improved the tensile properties and swelling resistance of composites. In another study, Sombatsompop et al.[16] discussed the mechanical and morphological properties of microwave-cured fly ash-filled epoxy composites Studies on polyurethane and epoxy phenol cashew nut shell liquidmodified epoxy composites filled with fly ash were carried out by Wu et al.[17] and Ramakrishna et al.,[18] respectively. Also, the use of epoxy resin, being one of the most intriguing and fascinating materials, is contemplated for composite manufacture, as it is primarily used for fabricating high-performance composites with superior mechanical properties, resistance to corrosive liquids and environments, superior electrical properties, good performance at elevated temperatures, good adhesion to substrate, or a combination of these benefits. However, epoxy resins, when cured with stoichiometric amounts of polyfunctional amines, are rather brittle, being only slightly tougher than inorganic glasses. Various additives are used in epoxy formulations to mitigate this shortcoming.

2. Experimental Procedure:

2.1. Materials and Specimen Fabrication:

Two different types of laminates were fabricated; (i) woven glass fibre Aralide LY 556epoxy matrix laminates and (ii) woven glass fibre Vinyl Ester epoxy matrix laminates. The laminates were fabricated by dry hand lay-up technique at GITAM, Bhubaneswar. Hand lay-up technique was chosen as it was ideally suited to manufacture low volume with minimum tooling cost. Fabrication process involves four basic steps: lay-up, wetting/impregnation, consolidation, and solidification. E-glass plain weave roving fabric, which is compatible to epoxy resin, is used as the reinforcement. Araldite LY 556 epoxy resin mix with HY 951 grade room temperature curing hardener was employed for the matrix material for the first laminate and Vinyl Ester epoxy resin mix with HY 951 grade room temperature curing hardener was employed for the matrix material for the second laminate.The composition for each laminate is given in table-1. Graphite powder is a fine black powder that can be mixed with epoxy resin to produce low friction exterior surfaces, commonly used on boat bottoms, rudders and centerboards. Graphite powders were dispersed into araldite LY 556 and Vinyl Ester epoxy resin with a novel and simple setup. The resin consisting of 2% (1%graphite powder and 1%ash clay) fillers were agitated at 400 rpm, to ensure proper mixing. Composite laminates were formed by placing successive layers of the fiber and resin mixture. Each fabric layer was wetted with resin mixture using a squeezing plate for proper impregnation. The squeezing plates were used to remove excess resin and air, which results in compaction of the plies. During lay-up, each ply is impregnated with an epoxy resin mixture with graphite and ash clay particulate filler. The purpose of this step is to make sure that the resin flows entirely around all fibres. Consolidation is a very important step in obtaining a good quality part. During this step, intimate contact between each layer of the lamina is formed, which ensures that all the entrapped.

Table-1

Laminates	Epoxy	Filler		E-Glass
01	Aralide LY 556 + Hardener HY 951(48%)	Graphite (1%)	Ash Clay (1%)	R099 1200 P566 (50%)
02	Vinyl Ester + Hardener HY 951(48%)	Graphite (1%)	Ash Clay (1%)	R099 1200 P566 (50%)

2.2. Mechanical Tests:

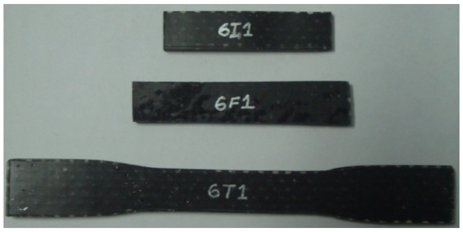

Fig-1

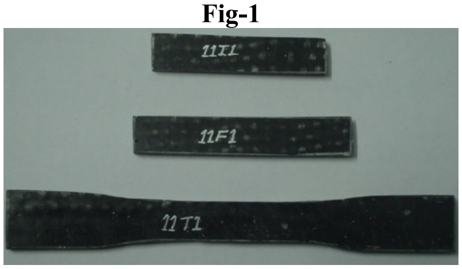

Fig-2

2.2.1. Tensile test:

Tensile specimens 167 mm long and 4 mm thick with a width of 20 mm were prepared according to ASTM D638 and the end tabs fixed to the specimens. Tensile tests were performed on a INSTRON UK made universal testing machine at a crosshead rate of 5 mm/min which corresponds to a strain rate of 0.2% per second. The strains were recorded with strain gauges. At least three tests were carried out for each case.6T1 and 11T1 in Fig. 1 shows the specimen for Aralide LY 556 Resin and Vinyl Ester resin for tensile testing.

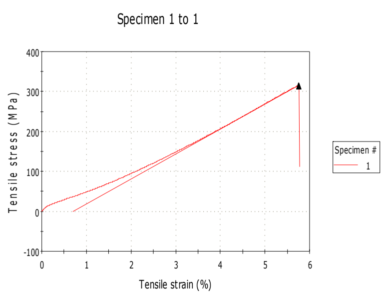

Fig-4

From the tensile test results (Table 2), it can be concluded that the tensile strength of Aralide LY 556 based GFRP laminate are higher than that of Vinyl Ester GFRP laminate. The inclusion of graphite particulate fillers in epoxy resin in both cases increases the tensile modulus and hence the stiffness. A typical stress–strain plot for both the specimens are presented in Fig.4 and Fig-5. The specimen was separated into two parts during loading at a strain as indicated. Thefailure was also observed. The strain corresponding to the particular point was 5.77 and 5.57 for Aralide LY 556 GFRP and Vinyl Ester based GFRP laminates respectively.

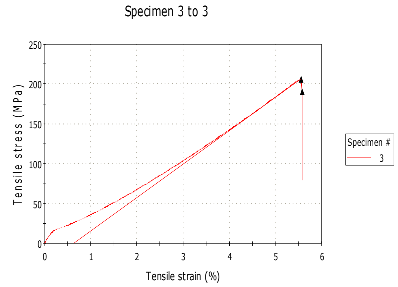

Fig-5

Table-2

Properties	Aralide LY 556 Resin	Vinyl Ester resin
Tensile stress at Maximum Load (MPa)	315.14	206.29
Tensile strain at Break (%)	5.77	5.57

It is interesting to note that the laminate perform in a similar fashion where by their behavior is almost linear before reaching the peak load. On the other hand, beyond that peak point of the load, there is no such displacement, which proved that both are not able to absorb large amounts of energy before fracture.

2.2.2 End Notch Flexure (ENF) test:

Several test methods are widely used to quantify the delamination resistance, among which End Notch Flexure (ENF) test is being adopted as an international standard for the measurement .The 3-point bending is the common mode used to induce fracture, but yet accepted as a standard. Nevertheless, the 3-point bending test on specimens with an end-notched defect, known as end notch flexure test, has been used by many researchers. INSTRON UK made universal testing machine at a crosshead rate of 5 mm/min was used for the Flexural tests. According to International standard for Flexural test the length of the specimen is taken as the 20th times of the thickness. So the length, width and thickness taken are 80 mm, 12.7 mm and 4 mm respectively. At least three specimens were tested for each condition to ensure reproducibility of the results. The sample did not break into two fragments, demonstrating a true composite ‘‘pseudo-plastic’’ behavior. 6F1 and 11F1 in Fig. 1 shows the specimen for Aralide LY 556 Resin and Vinyl Ester resin for Flexural testing. From this test the maximum load and maximum stress for Aralide LY 556 are 816.61 N and 343.43 MPa and for Vinyl Ester are 1529.92 N and 378.71MPa respectively.

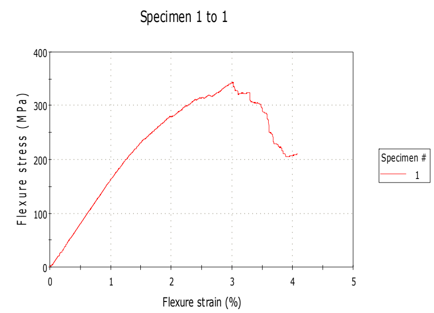

Fig-6

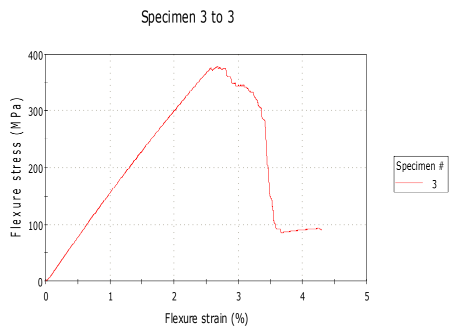

Fig-7

2.2.3 Low-velocity impact testing:

The falling weight impact test is employed for low-velocity ranges and is used to investigate the impact behavior under lower acceleration. This type of impact tests helps to understand the behavior of materials when they are subjected to impact loads. According to ASTMD 257 the length, width and thickness are taken as 63.5mm, 12.7 mm and 4 mm respectively. 6I1 and 11I1 in Fig. 1 shows the specimen for Aralide LY 556 Resin and Vinyl Ester resin for Impact testing. From the test it is found that the absolute energy for Aralide LY 556 is 6.28 J and for Vinyl Ester is 10.84 J.

3. Scanning Electron microscopy (Fractographic Study)

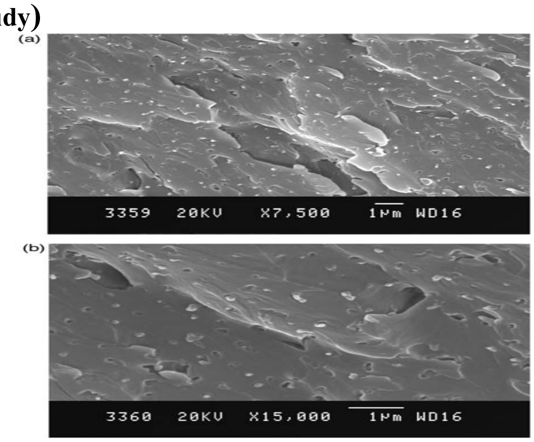

Fig-3

Figure-3 (a) and (b) shows the SEM fractographs of tensile fracture surface of Aralide LY 556 Resin and Vinyl Ester resin. Fractured surface exhibits river pattern-type morphology. Here, the thermoplastic phase is uniformly distributed as discrete spherical particles. This feature clearly shows that the domains delay the crack propagation as they are evenly distributed in the epoxy resin matrix system. Fly ash is distributed homogeneously in the form of small balls/globules in blend matrix. It is observed from fractographs that, the addition of fly ash to blend creates discontinuity in dispersion

5. Conclusion:

The present study indicates that the tensile strength is more incase of Aralidde LY 556 but the flexural and impact strength is more incase of Vinyl Ester. It is also found with comparing the previous work that addition of graphite and ash clay as filler material with epoxy gives better mechanical properties. Further studies on such polymer composites can give useful information regarding the potential commercial application of products.

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