Effect of Filler Material on Mechanical and Thermogravimetric Analysis of GFRP Composite

G MurthujaHussain, and N Karunagaran*
Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai 602105, Tamilnadu, India
Email: *karunagarann.sse@saveetha.com

Abstract: In this project the types of laminates (EFGS-I and EFGS-II) were fabricated. The mechanical properties of tensile, flexural, inter laminar shear stress, impact test and TGA are conducted. The test specimens were prepared as per ASTM standards. From the test results the tensile strength and impact strength of EFGS-II laminates exhibits higher values than compared to EFGS-I laminates. The flexural and inter laminar shear stress and slightly less for EFGS-II when compared to EFGS-I laminate. In TGA Analysis sample 2 has higher temperature when compared to sample 1. The reasons for these values discussed. These types of laminates are useful in the fabrication for automobile parts and aircraft parts.

Keywords: EFGS, Tensile, Flexural, Inter laminar, Impact, TGA.

1. Introduction
Since 1960 with the advent of polymer composites, composite materials have been used to address engineering problems [1]. Since then, composite material has become traditional engineering materials, developed and produced for a range of applications including automotive components, sports equipment [2], aerospace parts, etc., [3] as well as growing knowledge about product efficiency and the need for lightweight components, composite development was also a significant consequence of composite use [4]. Amongst all the ingredients, the ability is to replace the widespread efficiency of the steel and aluminum parts. The key explanation for their increased use is the high strength to weight ratio [5].

The most engineers prefer composites now. Composites are particularly appealing to their high strength (stress / density), modular strength (stress / stiffness) and low density (size / volumes or m / v) [6]. This has led to considerable interest in their research and development in recent decades, particularly for aviation applications in which additional payload capability and engine efficiency are crucial [7]. More recently, the automotive industry has shown interest in composite structural material (primary load bearing components) for similar purposes, while the environmental implications of exhalation emissions have stimulated the lightweight vehicle of the future [8]. Furthermore, composites have a range of advantages over certain conventional materials such as plastics, including low density and increased capacities for corrosion and temperature [9].

2. Specification f Selected Materials
1. Glass fiber woven cloth
1. Material
   i. 360GSM
   ii. Bidirectional E-glass fiber
   iii. 3.2mm thickness

2. Matrix
   i. EPOXY - LY 556
   ii. HARDNER – HY 956.

3. Result And Discussion
   Tests conducted as per ASTM Standards
   - Tensile test (ASTM D 3039)
   - Flexural test (ASTM D 790)
   - Inter laminar test (ASTM D 2344)
   - Impact test (ASTM D 256)
   - Thermogravimetric Analysis(ASTM E1131)

3.1 Tensile Strength (Astm D3039)
The tensile strength for EFGS-I and EFGS-II, laminates is evaluated separately. It is found that in seven layered particulate reinforced glass fiber laminate the tensile strength is EFGS-II in 22% from that of the EFGS-I [10]. The reason for the reduction of strength in EFGS-I laminate could be due to the improper bonding between the resin and particulate reinforced glass fiber woven cloth and volume fraction variations [11].

3.1.1 Tensile Strength and fracture load in laminates
The tensile strength of the laminates is shown in Table 1.

| LAMINATE | LOAD (F) KN | WIDTH (B)mm | THICKNESS (t) mm | AREA OF CROSS SECTION mm² | TENSILE STRENGTH N/mm² |
|----------|-------------|--------------|------------------|--------------------------|------------------------|
| EFGS-I   | 11.53       | 25           | 3.24             | 81                       | 142.35                 |
|          | 12          | 25           | 3.24             | 81                       | 148.15                 |
| EFGS-II  | 15.11       | 25           | 3.26             | 81.5                     | 185.38                 |
|          | 13.81       | 25           | 3.26             | 81.5                     | 169.51                 |

3.1.2 EFGS-I Laminate(7 Layers)

Figure 1: Stress Vs Strain graph for EFGS-I, Sample-1

Figure 1 shows the stress vs strain graph for EFGS laminates. Here the graph is plotted between stress and strain for a laminate.
Figure 2: Stress vs Strain graph for EFGS-1, Sample-2

Figure 2 shows the stress vs strain graph for EFGS laminates of Second sample. Here the graph is plotted between stress and strain for a laminate.

3.1.3 EFGS-II laminate (7 layers)

Figure 3: Stress Vs Strain graph for EFGS-II, sample-1

Figure 3 shows the stress vs strain graph for EFGS-II laminates of first sample. Here the graph is plotted between stress and strain for a laminate.
Figure 4 shows the stress vs strain graph for GFKF-II laminates of second sample. Here the graph is plotted between stress and strain for a laminate.

Figure 5 shows the stress vs strain graph for GFKF-II laminates of second sample. Here the graph is plotted between stress and strain for a laminate.

3.2 Flexural Strength (Astm D790)

The flexural strength for EFGS-I and EFGS-II laminates are evaluated separately. It is found that in seven layered EFGS-I fiber laminate the flexural strength is increased by 20.22% from that of the laminate EFGS-II. The load value EFGS-I laminate is also increased by 20.22% when compared to EFGS-II laminate.

3.2.1 Flexural strength data observation

Observed flexural strength is listed in Table 2.

| Laminates  | Thickness (t) | Width (w) | Load(N) | Stress(S) |
|------------|---------------|-----------|---------|-----------|
| EFGS-I     |               |           |         |           |
| I          | 3.24          | 12.7      | 50      | 56.26     | 53.44     |
| II         | 3.24          | 12.7      | 45      | 50.63     |           |
| EFGS-II    |               |           |         |           |
| I          | 3.26          | 12.7      | 35      | 38.89     | 44.45     |
| II         | 3.26          | 12.7      | 45      | 50.01     |           |
In both flexural and inter laminar shear test load vs displacement curve shows that periodical increase in displacement values load value increases and sudden decrease. The reason is during load distribution each and every layer of glass fiber and particulate reinforced receives more load and then get fracture [12]. This fracture extends up to find failure of the specimens.

3.2.2 EFGS-I Laminate (7 Layers)

Figure 6: Load Vs displacement graph for EFGS-I and sample-1

Figure 6 shows the load vs displacement graph for EFGS-I laminate for first sample. Here the graph is plotted between load and displacement for a laminate.

Figure 7: load vs displacement graph for EFGS-I and sample-2

Figure 7 shows the load vs displacement graph for EFGS-I laminate for second sample. Here the graph is plotted between load and displacement for a laminate.
3.2.3 EFGS-II Laminate (7 Layers)

Figure 8: load vs displacement graph for EFGS-II and sample-1

Figure 8 shows the load vs displacement graph for EFGS-II laminates for first sample. Here the graph is plotted between load and displacement for a laminate.

Figure 9: load vs displacement graph for EFGS-II and sample-2

Figure 9 shows the load vs displacement graph for EFGS-II laminates for second sample. Here the graph is plotted between load and displacement for a laminate.
Figure 10: Flexural strength comparison

Figure 10 shows the flexural strength comparison for sample. Here the graph is plotted between stress and flexural strength for a laminate.

Figure 11: Flexural strength comparison
Figure 11 shows the flexural strength comparison for sample. Here the graph is plotted between stress and flexural strength for a laminate.

3.3 Inter-Laminar Shear Stress (Astm D2344)

The Inter laminar shear stress value for the all laminates is evaluated. It is found that in seven layered EFGS-I laminate have 13.04% higher values than that of laminate [13]. While in EFGS-II laminate. Inter Laminar Shear stress data Observations are listed in Table 3.

### Table 3: Inter Laminar Shear stress data Observations

| Laminates | Ultimate load(N) | Width(mm) | Thickness(mm) | ILSS(N/mm²) |
|-----------|------------------|-----------|---------------|-------------|
| EFGS-I    |                  |           |               |             |
| I         | 50               | 5         | 3.24          | 2.315       |
| II        | 40               | 5         | 3.24          | 1.85        |
| EFGS-II   |                  |           |               |             |
| I         | 45               | 5         | 3.26          | 2.07        |
| II        | 35               | 5         | 3.26          | 1.61        |

3.3.1 EFGS-1 Laminate

Figure 12: Load vs Displacement for EFGS-1, sample-1

Figure 12 shows the load vs displacement graph for EFGS-I laminate for first sample. Here the graph is plotted between load and displacement for a laminate.
Figure 13: Load vs Displacement for EFGS-1, sample-2

Figure 13 shows the load vs displacement graph for EFGS-I laminate for second sample. Here the graph is plotted between load and displacement for a laminate.

3.3.2 EFGS-II Laminate

Figure 14: Load vs Displacement for EFGS-II, sample-1

Figure 14 shows the load vs displacement graph for EFGS-II laminates for first sample. Here the graph is plotted between load and displacement for a laminate.
Figure 15 shows the load vs displacement graph for EFGS-II laminates for second sample. Here the graph is plotted between load and displacement for a laminate.
Figure 16 shows the comparison of ILSS between laminates. Here the graph is plotted between stress and EFGS sample 1 and sample 2 for a laminate.

3.4 Impact Strength (Astm D256)
Effect test used to assess energy recurrent to split both the laminate specimen of hybrid and non-hybrid composite. A V-sample with a measurement of 66x13x3 mm was made. The ASTM D256 specimens have been examined [14]. The specimens were held upright, whilst a 5 kg mass pendulum from a height of 15 cm had been swung to smash the specimen. The energy effect was observed by the machine's dial gauge. Five samples were tested and findings were combined for each form of composite laminate. In Table 4 impact test data observed are listed.

| LAMINATE | THICKNESS(t) | WIDTH(w) | IMPACT STRENGTH (Joules) |
|----------|--------------|----------|--------------------------|
| EFGS-1   | 3.24         | 12.7     | 4.0                      |
| I        |              |          |                          |
| II       | 3.24         | 12.7     | 5.0                      |
| EFGS-2   | 3.26         | 12.7     | 8.9                      |
| I        |              |          |                          |
| II       | 3.26         | 12.7     | 7.3                      |

Table 4: Impact test data observation
Figure 17: Comparison for impact test between laminate

Figure 17 shows the comparison impact test between laminates. Here the graph is plotted between impact strength and GFKF sample 1 and sample 2 for a laminate.

Figure 18: Overall flow chart for comparison strength in EFGS-I
Figure 18 shows the overall flow chart for comparison strength in EFGS. Here the graph is plotted between stress and tensile test, flexural test ILSS test, Izod test.

![Flow chart](image)

**Figure 19:** Overall flow chart for comparison strength in EFGS-II

Figure 19 shows the overall flow chart for comparison strength in EFGS. Here the graph is plotted between stress and tensile test, flexural test ILSS test, Izod test [15]. The properties of sample filler materials are shown in Table 5 and Table 6.

| S.NO | SAMPLE DETAILS | TEST PARAMETER | UNIT | TEST METHOD | TEST RESULT |
|------|----------------|----------------|------|-------------|-------------|
| 1    | FILLER-MATERIAL GFRP-MATERIAL (SAMPLE 1) | TGA ANALYSIS (RT to 900°C) |       |             |             |
| 1.1  | Total Polymer Content | % | ASTM E1131:2014 | 56.36 |
| 1.2  | Ash Content | % | ASTM E1131:2014 | 43.64 |

**Table 5:** Filler material sample 1

| S.NO | SAMPLE DETAILS | TEST PARAMETER | UNIT | TEST METHOD | TEST RESULT |
|------|----------------|----------------|------|-------------|-------------|
| 1    | FILLER-MATERIAL GFRP-MATERIAL (SAMPLE 2) | TGA ANALYSIS (RT to 900°C) |       |             |             |
| 1.1  | Total Polymer Content | % | ASTM E1131:2014 | 43.44 |
| 1.2  | Ash Content | % | ASTM E1131:2014 | 56.57 |

**Table 6:** Filler material sample 2
Figure 20: Graph 1

Figure 20 shows the overall graph for a sample. Here the graph is plotted between weight and temperature.
Figure 21 shows the overall graph for a sample. Here the graph is plotted between weight and temperature.

4. Conclusion and Future works
Based on the investigation of the test results, the following inference were made
   i. Tensile test comparison with EFGS-II is 22% increased than compared to EFGS-I.
   ii. Flexural test comparison with the EFGS-I is 20.22% higher exhibits compared to EFGS-II.
   iii. Inter laminar shear stress is result showed that the EFGS-I IS 13.04% increased when compared when compared the EFGS-II.
   iv. Impact test shows a EFGS-II is 80% increased when compared to EFGS-I.
   v. So it can be highly withstand the impact load.
   vi. It is also found that the changing the stacking sequence, way of cross pilling in laminate yielded good properties than unidirectional way of stacking the layers in laminates.
   vii. In TGA we also found that EFGS I withstand upto 372.50Celsius temperature and EFGS 2 can withstand upto 378.18 Celsius.
References

[1] Liu, Ying-Ling, Chih-Yuan Hsu, Wen-Lung Wei, and Ru-Jong Jeng. "Preparation and thermal properties of epoxy-silica nanocomposites from nanoscale colloidal silica." *Polymer*, Vol. 44, no. 18, pp. 5159-5167, 2003.

[2] Lee, H. S., H. J. Kim, S. G. Kim, and S. H. Ahn. "Evaluation of graphite composite bipolar plate for PEM (proton exchange membrane) fuel cell: Electrical, mechanical, and molding properties." *Journal of materials processing technology*, Vol. 187, pp. 425-428, 2007.

[3] Loos, Marcio R., Luiz Antonio F. Coelho, Sérgio H. Pezzin, and Sandro C. Amico. "The effect of acetone addition on the properties of epoxy." *Polímeros*, Vol. 18, no. 1, pp. 76-80, 2008.

[4] Du, Ling. "Highly conductive epoxy/graphite polymer composite bipolar plates in proton exchange membrane (PEM) fuel cells." PhD diss., University of Akron, 2008.

[5] Du, Ling, and Sadhan C. Jana. "Highly conductive epoxy/graphite composites for bipolar plates in proton exchange membrane fuel cells." *Journal of Power Sources*, Vol. 172, no. 2, pp. 734-741, 2007.

[6] Gupta, Nikhil, Balraj Singh Brar, and Eyassu Woldesenbet. "Effect of filler addition on the compressive and impact properties of glass fibre reinforced epoxy." *Bulletin of Materials Science*, Vol. 24, no. 2, pp. 219-223, 2001.

[7] Chaowasakoo, T., and N. Sombatsompop. "Mechanical and morphological properties of fly ash/epoxy composites using conventional thermal and microwave curing methods." *Composites Science and Technology*, Vol. 67, no. 11-12, pp. 2282-2291, 2007.

[8] Baccaro, S., B. Bianchilli, C. Casadio, and G. Rinaldi. "Radiation induced effects on particulate composites from epoxy resin and fly-ash." *Radiation Physics and Chemistry*, Vol. 52, no. 1-6, pp. 187-191, 1998.

[9] Li, Yadong, David J. White, and R. Lee Peyton. "Composite material from fly ash and post-consumer PET." *Resources, conservation and recycling*, Vol. 24, no. 2, pp. 87-93, 1998.

[10] Gu, Jian, Gaohui Wu, and Qiang Zhang. "Effect of porosity on the damping properties of modified epoxy composites filled with fly ash." *Scripta materialia*, Vol. 57, no. 6, pp. 529-532, 2007.

[11] Sagar, L. "Performance Analysis of Fuzzy Based Sliding Mode and Self-Tuning Controls of Vector Controlled Induction Motor Drive." *International Journal of MC Square Scientific Research*, Vol. 9, no. 1, pp. 311-323, 2017.

[12] Çakır, M. V., Erkilğ, A., & Ahmed, B. F. (2021). Graphene nanoparticle effect on flexural and shear behaviors of adhesively bonded single lap joints of GFRP composites. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 43(4), 1-11.

[13] Aveen, K. P., Londe, N. V., Amin, G. G., & Shaikh, I. S. (2021). A review on the effects of input parameters & filler composition on delamination during machining of FRP composites. Materials Today: Proceedings.

[14] Thakur, R. K., & Singh, K. K. (2021). Influence of fillers on polymeric composite during conventional machining processes: a review. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 43(2), 1-20.

[15] Parida, A., Nayak, A., Pattnaik, S. K., & Bhuyan, R. (2021). Study of Tribological Behavior of GFRP Hybrid Composite Using Fly-Ash and Graphite as Filler Material. Available at SSRN 3768678.