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AN COMPARATIVE STUDY OF MECHANICAL PROPERTIES ON CONVENTIONAL LAMINATED GFRP AND Al-6061 REINFORCED LAMINATED GFRP FOR THE AUTOMOBILE APPLICATION

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ABSTRACT

The project deals with the development of Aluminum reinforced GFRP (glass fiber reinforced plastic) which will serve as an effective Replacement for conventional Aluminum A360 alloy, Structural Steel A36 & comparative study on GFRP used to manufacture safety frames in automobiles. Aluminum - glass fiber reinforced plastics (GFRP) sandwich panels are hybrid laminates consisting of GFRP bonded with resin epoxy mixed aluminum powder. Such sandwich materials are increasingly used in airplane and automobile structures. Laminates with varying aluminum thickness fractions, fiber volume fractions and orientation in the layers of GFRP were fabricated by hand lay-up method and evaluated for their impact performance by conducting Tensile Test, Compression Test and Wear Test. The impact energy required for initiating a crack in the outer aluminum layer as well as the energy required for perforation was recorded. Scanning electron micrographs were taken to visualize the crack and the damage zone. The bidirectional cross-ply hybrid laminate AL-GFRP has been found to exhibit better impact performance and damage resistance than the unidirectional hybrid laminate (GFRP). Introduction of aluminum powder along with GFRP and a greater extent of thickness fraction (Al_{tf}) and fiber volume fraction (V_f) resulted in an Increase in the impact energy required for cracking and perforation. On an overall basis, the sandwich panels of Al-GFEP exhibited better impact performance than the monolithic

aluminum.

KEYWORDS: 6061 Aluminum Powder - Glass fiber sandwich panels (GFRP), Tensile, compressive test, Wear test - Resistance and Scanning electron Microscopy.

1. INTRODUCTION

In the wake of passenger safety becoming an important industry norm we propose to replace the traditional material Structural steel-A36 with Aluminum reinforced GFRP. The project focuses on the reinforcement of GFRP with Aluminum powder by Hand layup method for optimal energy absorbing properties. The latter part of the project focuses on testing the composite material laminate and The material being economical and extremely reliable against fatigue can replace carbon fiber based composites in sports cars. Thus, safety norms can become less expensive and help save the consumer money without taking chances on safety. Composite materials has seen several civil engineering applications. Glass Fiber reinforced plastic (GFRP) has been used to strengthen structures such as beams and slabs. Our project focuses on application of a suitable light weight, high energy absorbing and high strength composite material for automobile safety frames–The frontal frame. The frontal frame being the most important impact dissipation safety feature in the car has to be extremely light and also should deform adequately to absorb the impact during collision.

In this paper car bumper is selected a bumper is a shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. In existing bumper the weight is more. In the present trends the weight reduction has been the main focus of automobile manufacturers. Less fuel consumption, less weight, effective utilization of natural resources is main focus of automobile manufacturers in the present scenario. The above can be achieved by introducing better design concept, better material and effective manufacturing process. Steel bumper have many advantages such as good load carrying capacity. In spite of its advantages, it stays back in low strength to weight ratio. It is reported that weight reduction with adequate improvement of mechanical properties has made composites as a viable replacement material for conventional steel. In the present work, the steel bumper used in passenger vehicles is replaced with a composite bumper made of glass/epoxy composites. The thickness of the composite bumper is calculated by bending moment equation and other dimensions for both steel and composite bumper is considered to be the same. The objective was to compare the stress, weight, and cost savings.

2. EXPERIMENTAL DETAILS

2.1 Material selection

Material selection is done on the basis properties required to facilitate good strength to the part for automotive by the literature survey, materials ware identified which may be suitable say aluminum, glass etc. Because of their mechanical properties and availability so these materials are selected for the analysis and manufacturing the part.

Aluminum has a unique and unbeatable combination of properties that make it into a versatile, highly usable and attractive construction material.

Table 1: Properties of Al6061.

Table 1	Properties
Tensile Strength	70-700 MPa depending on alloy
Elasticity (Young‟s Modulus)	70,000 MPa
Specific weight	2.7 g/m^3
Grade	Al 6061
Corrosion	Good resistance

Glass is one of the oldest known man-made materials; the practical strength of glass, however, has always been a limiting and puzzling Factor.

Table 2: Mechanical Properties of Glass Fiber.

Table 2	Properties
Tensile Strength	430 MPa Standard Structure
Elasticity (Young‟s Modulus)	72,000 MPa
Specific weight	2.59 g/m^3
Grade	E-Glass
Corrosion	Good resistance

Table 3: Epoxy-Mixture.

Table 3	EPOXY
Resin	LY556
Hardener	HY951

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or 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 products to form a very strong and relatively lightweight Hybrid Composite.

2.2 Sample Preparation

The fabrication of Al reinforced GFRP (Glass Fiber polymer Reinforced with Aluminum) by Hand lay-up technique, it is simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. Resins are impregnated by hand into fibers which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

Advantages

Design Flexibility. Tooling cost is low. Design changes are easily effected. Sandwich construction are possible.

Disadvantages

One molded surface is obtained. Low volume process. Longer cure times required. Waste factor can be high.

Table 4: Selection of materials.

Material	Type	Thickness in mm	Dimension in mm	QTY
Glass Fiber	Woven roving	3	300x300	12 No
Aluminium	Al6061	Powder		50 gms
Resin	LY556			300 ml
Hardener	Hy951			30 ml

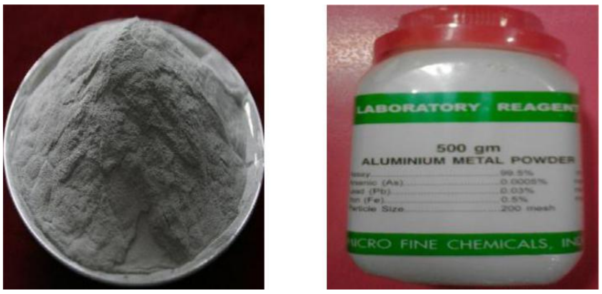


Figure 1: Aluminium Powder.

Figure 2: Glass woven roving.

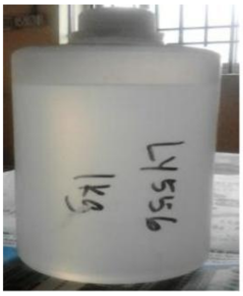


Figure 3: Resin.

Figure 4: Hardener.

Figure 5: Glass fiber reinforced Aluminum lamina.

2.2.1 Procedure

1. Glass fibers are cut with required dimension and numbers
2. Aluminum, Resin, Hardener are measured and taken as required.
3. Hand Lay-Up Process - Initially wax is applied to a plastic sheet, then the mixture of resin is applied on the sheet and a layer of glass fiber is placed, again the resin is applied by brush to the fiber, the another layer is placed and the resin is applied. This steps are repeated till 6 layers is done. Finally another sheet which is waxed is placed on the final layer, the load is kept on the laminate and it is allowed to dry at room temperature.
4. Finally the component is obtained.

2.3 Experiment

Glass fiber reinforced aluminum is fabricated using Hand lay-up method the specimen is taken for testing like Tensile Compression and impact employing testing machines like UTM (Universal Testing Machine) and Impact testing machine (Charpy) the specification of these machines are shown below:

Figure 6: UTM.

Table 5: Equipment Details.

Name of the equipment	Universal Testing machine
Sl. No	ML/MT/034
Model	WDW 100
Serial no	02 08 93
Make	TE
Range	(0-100)kN
Calibration due date	08.05.2017

Figure 7: Impact Testing Machine.

Table 6: Equipment Details.

Name of the equipment	Impact Testing machine
Sl.No	ML/MT/004
Model	IT-30
Serial no	81/993
Make	FIE
Range	0-300 J
Calibration due date	08.05.2017

2.4 SPECIMEN FOR TESTING

The fabricated specimen is cut into number of samples to carry out the testing as shown below

Figure 8: Samples.

2.4.1. Tensile Test

From the specimen two samples are chosen for conducting the tensile test with the parameters as shown below:

Table 7: Tensile Test Parameters.

Test Parameters	Sample 01	Sample 02
Gauge Thickness (mm)	3.84	3.82
Gauge Width (mm)	23.22	22.96
Original Cross Sectional Area (mm^2)	89.16	87.71
Ultimate Tensile Load (kN)	29.52	29.08
Ultimate Tensile Strength(MPa)	331.09	331.55

Figure 9: a) Sample on Machine. (b) Sample after testing.

2.4.2. Compression Test

From the specimen two samples are chosen for conducting the compression test with the parameters as shown below:

Figure 10: Sample mounted on Machine.

Figure 11: Sample after compression test.

Table 8: Compression Test Parameters.

Test Parameters	Sample 01	Sample 02
Gauge Thickness (mm)	3.91	3.96
Gauge Width (mm)	22.82	23.03
Original Cross Sectional Area (mm)	89.23	91.20
Compressive Load (kN)	1.35	1.26
Compressive Strength(MPa)	15.13	13.82

2.4.3. Impact Test

From the specimen three samples are chosen for conducting the impact test with the parameters as shown below

Figure 12: Sample after testing.

Figure 13: Sample mounting on machine.

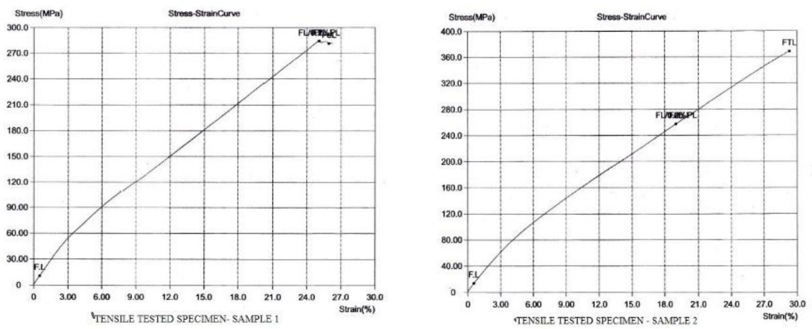
Table 9: Impact Test Parameters.

Specimen size (mm)	3.5x10x80
With out notch	
Test temperature	RT
Sample	Absorbed Energy-Joules
1	10
2	08
3	09
Average	9

3. RESULTS AND DISCUSSONS - TESTING

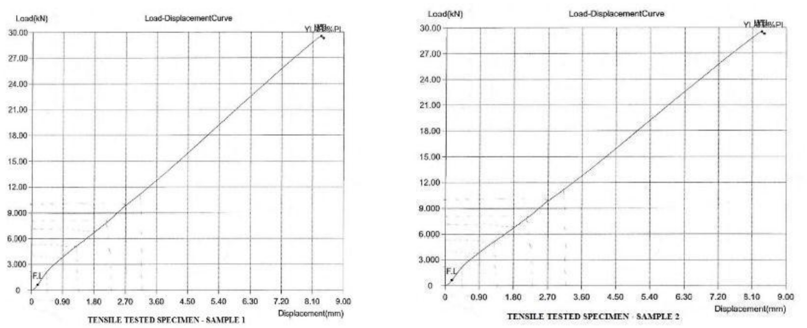
The tests are conducted as discussed above obtained results in the form of graph is plotted below and the values are compared with each other.

For Tensile Test



(a) (b)

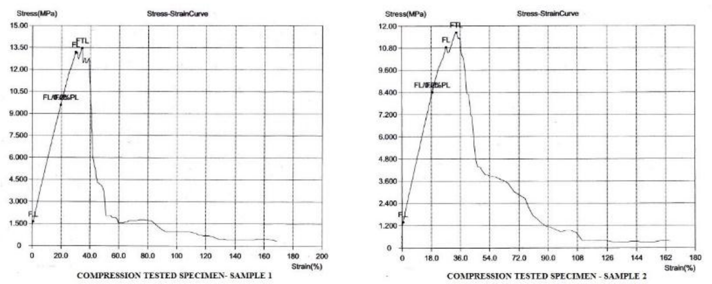
Figure 14: Stress-Strain Curve.



(a) (b)

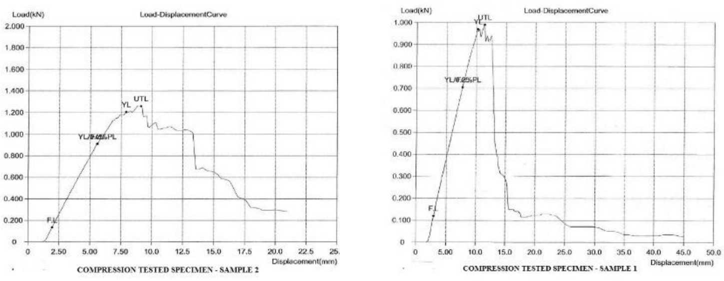
Figure 15: Load-displacement curve.

For Compression



(a) (b)

Figure 16: Stress-Strain Curve.



(a) (b)

Figure 17: Load-displacement curve.

OBSERVATIONS

Table 10.

(a)

Materials Parameters	GFRP	AL+GFRP
Ultimate tensile load (kN)	25.325	29.30
Ultimate tensile strength (Mpa)	326.34	331.32

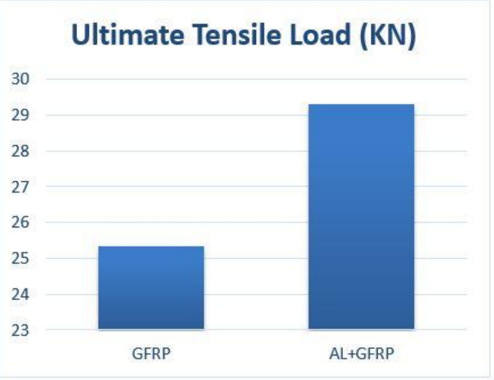
(b)

Materials Parameters	GFRP	AL+GFRP
Compressive load (kN)	0.995	1.305
Compressive strength (MPa)	12.55	14.475

(c)

Materials Parameters	GFRP	AL+GFRP
Absorbed Energy - Joules	13	09

Comparison of GFRP and AL+GFRP is done as below



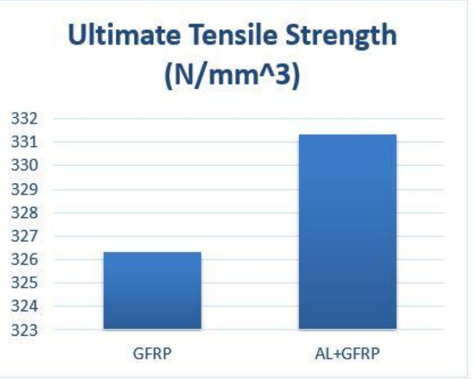
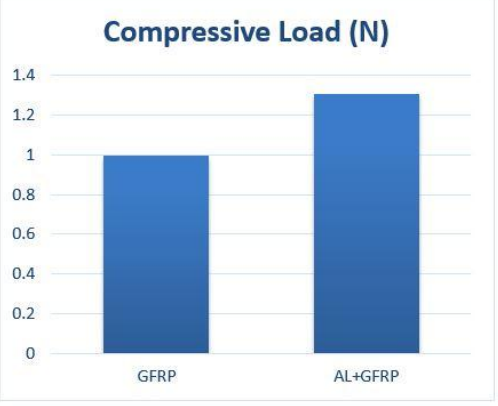


Figure 18: Ultimate Tensile Load. **Figure 19: Ultimate Tensile Strength.**



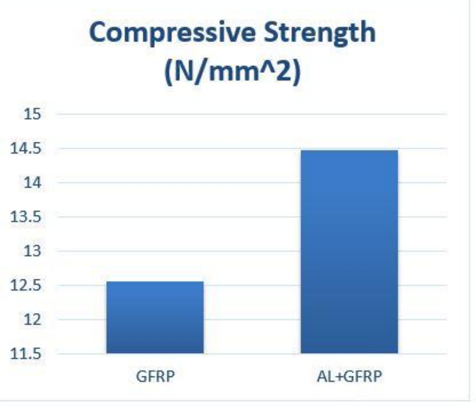


Figure 20: Compression Load. **Figure 21: Compression Strength.**

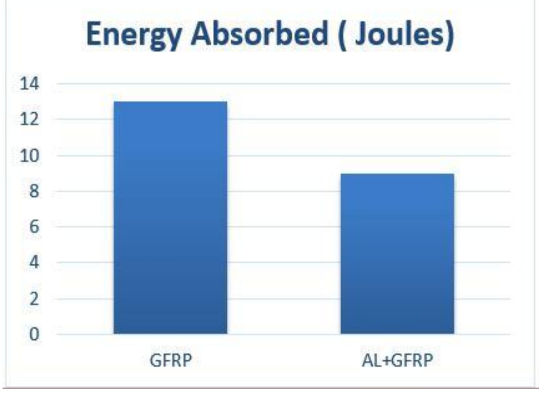


Figure 22: Absorbed Energy.

AL+GFRP exhibits superior strength in 4 aspects but due to uneven (Epoxy + E-glass) bonding the “Energy Absorbed” in AL+GFRP has been reduced.

4. WEAR TEST

The wear test was conducted using a pin-on-disc computerized wear testing machine as shown in figure in accordance with ASTM standards G99-95. The test uses the specimens of size of 3mm*3mm dimensions and machined from the cast specimens.

Figure 23: Pin on disc machine setup.

Figure 23a: Pin-on-disc arrangement.

Figure 24: Specimen Photos after wear test.

4.1 PROCEDURE

1. Immediately prior to testing, and prior to measuring or weighing, clean and dry the specimens. Take care to remove all dirt and foreign matter from the specimens. Use non – Chlorinated, non - ®lm – forming cleaning agents and solvents. Dry materials with open grains to remove all traces of the cleaning fluids that may be entrapped in the material. Steel (Ferromagnetic) specimens having residual magnetism should be demagnetized. Report the methods used for cleaning.
2. Measure appropriate specimen dimensions to the nearest 2.5µm or weigh the specimens to the nearest 0.0001g.
3. Insert the disk securely in the holding device so that the disk is fixed perpendicular (61°) to the axis of the resolution.
4. Insert the pin specimen securely in its holder and, if necessary, adjust so that the specimen is perpendicular (61°) to the disk surface when in contact, in order to maintain the necessary contact conditions.
5. Add the proper mass to the system lever or bale to develop the selected force pressing the pin against the disk.
6. Start the motor and adjust the speed to the desired value while holding the pin specimen out of contact with the disk. Stop the motor.
7. Set the revolution counter (or equivalent) to the desired number of revolutions.
8. Begin the test with the specimens in contact under load. The test is stopped when the desired number of revolutions is achieved. Tests should not be interrupted or restarted
9. Remove the specimen and clean off any loose wear debris. Note the existence of features on or near the wear scar such as: protrusions, displaced metal, discoloration, micro cracking or spotting.
10. Re-measure the specimen dimensions to the nearest 2.5µm or reweigh the specimens to the nearest 0.0001g, as appropriate.

4.2 FORMULAE

S = Sliding distance (meter)

$S= \pi*D*N*T = = 2*\pi*R*N*T$

Where,

D = Diameter of wear track in meter

R = Radius of wear track in meter

N = Speed of the wheel in rpm

T = Sliding time in minutes

4.2.1 CALCULATION

For specimen (GFRP and AL+GFRP) pin on disc wear test conducted with 3kg load, 5 minutes as sliding time and 200rpm.

OBSERVATION

Radius of the Wear Track in mm (R) = 25

Speed of the Wheel in RPM (N) = 200

Weight in Hanger in Kg = 2

Sliding Time (T) in Minute = 5

Test Dimension Specimen in mm = 3*3

Test Specimen Initial Weight in grams (W1) = 0.11

Test Specimen Final Weight in grams (W2) = 0.103

Sliding distance in Meters

(S) = π * D * N *

T = π *50*200*5

= 1500 m (Round off figure)

5. RESULTS - WEAR RATE ANALYSIS

The effect of AL6061 and E-Glass fiber on the wear characteristics of Aluminum hybrid composites for different speeds and loads as shown in Graph 5.14 to 5.16 which are the representative graphs plotted based on wear rate results.

Case 1: Wear Loss as a function of Sliding Distance at 30N, Time=5M and Speed of 200 RPM.

Figure 25: Wear rate for case 1.

As seen in above Figure.25, the wear rate decrease as the reinforcement of AL6061 and E – glass increases. An E-Glass reinforced AL6061 based hybrid MMC At 3kg load, Time-5minutes and 200rpm at track diameter of 50mm is on a pin-on-disc apparatus and under the influence of AL powder induced along with GFRP is giving steady state wear loss. But for the above graph its clearly explains that AL+GFRP tends to give steady and uniform at the same initial experimental conditions.

Case 2: Wear Loss as a function of Sliding Distance at 50N, Time=5M and at a Speed of 400 RPM.

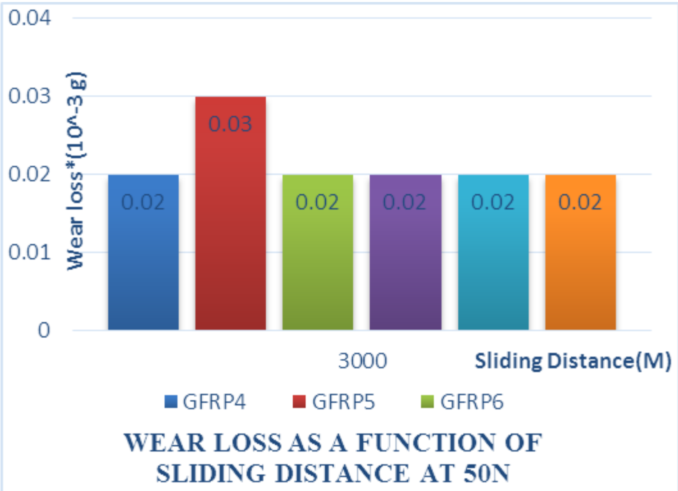


Figure 26: Wear rate for case 2.

As seen in above Figure.26 the wear rate decrease as the reinforcement of AL and E – glass increases. An E–Glass reinforced AL6061 based hybrid MMC. At 5kg load, 5 minutes time and 400rpm at track diameter of 50mm in pin on disc experiment and under the influence of AL powder induced along with GFRP is giving steady wear loss on the surface of the specimen when compared to convention laminated GFRP.

Main Intension of conducting wear test on the specimen is to determine the wear resistance of AL+GFRP. Under several different conditions such a variation in Sped, Load and Time, the wear resistance is determined. Hence during actual car crash / collision the deformation of the material will be minimum thereby safety standards will be improved.

Case 3: Wear Loss as a function of Sliding Distance at 70N, Time=5M and at a Speed of 600 RPM.

Figure 27: Wear rate for case 3.

As seen in above Figure.27, the wear rate increases as the reinforcement of AL and E – glass increases with speed and load... An E-Glass reinforced AL6061 based hybrid MMC. At 7kg load, Time-5minutes and 600rpm at track diameter of 50mm in pin on disc experiment and under the influence of AL powder induced along with GFRP is giving steady state wear loss. But for the above graph its clearly explains that AL+GFRP tends to give steady and uniform at the same initial experimental conditions but tends to lose it strength because of improper mixture of epoxy resin or Lay-up process has to be done in order to increase the impact resistance force.

This is quite clearly evident from the surface cracks found from the SEM micrograph which are discussed in the next section.

6. SCANNING ELECTRON MICROSCOPE [S.E.M] STUDIES ON WEAR TEST SAMPLES

6.1. Material/Specimen

GFRP – GLASS FIBRE REINFORCED POLYMER COMPOSITES

SEM was conducted on wear tested specimen to study the fibre orientation and bonding strength at microscopic level.

As seen below in the Fig 28, Fig 29, Fig 30 and Fig 31 under the influence of wear testing. The surface of the specimen as completely lost its fiber orientation thus causing a weakness in terms of strength and thus deformation induced will be more.

Point of improvement will be such that in order to improve the fiber orientation, the bonding properties between E-glass laminates should be improved at an extreme level of Epoxy resin mixture.

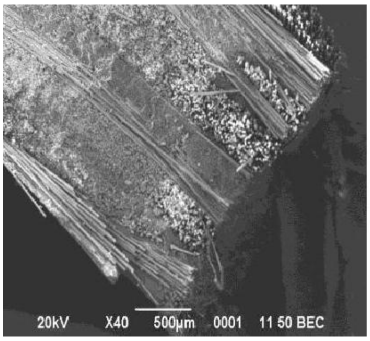


Figure 28: GFRP at X40.

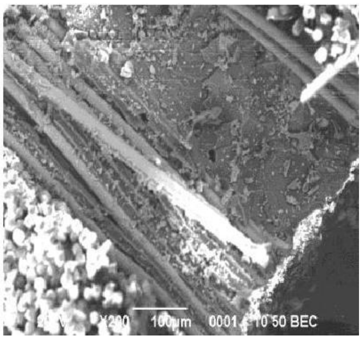


Figure 29: GFRP at X200.

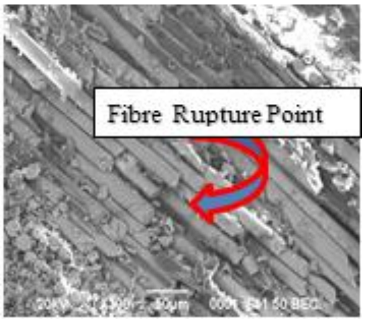


Figure 30: GFRP at X300.

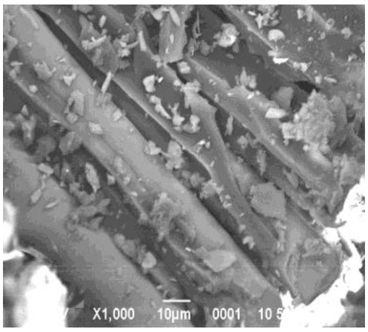


Figure 31: GFRP at X1000.

6.2. Material/Specimen

AL+GFRP (Al6061 Powder epoxy Laminated GFRP)

SEM was conducted on wear tested specimen to study the fiber orientation and bonding strength at microscopic level.

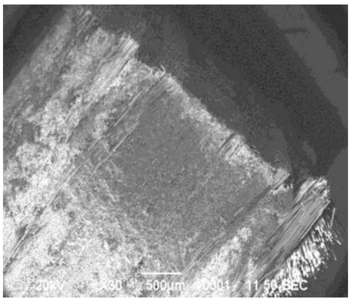


Figure 32: GFRP at X30.

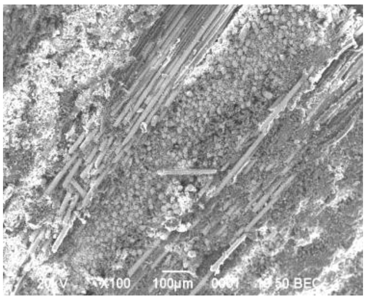


Figure 33: GFRP at X100.

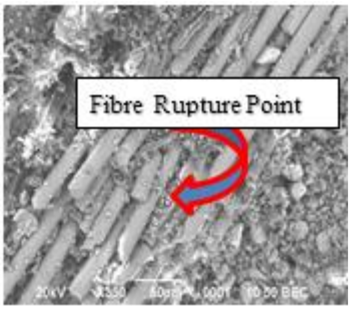


Figure 34: GFRP at X350.

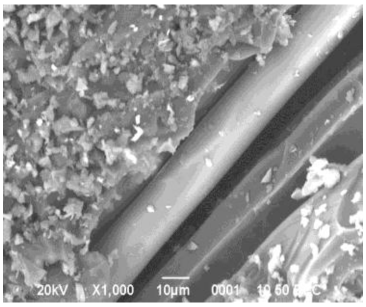


Figure 35: GFRP at X1000.

As seen in above figure the Fig.32, Fig 33, Fig 34 and Fig 35, under the influence of wear testing. The surface of the specimen as slightly less lost its fiber orientation when compared to GFRP material. Thus it's a clear evident of better bonding strength, higher Ductility properties indirectly less deformable material when compared to GFRP.

Specimen's machining process has to be carried by more non-conventional methods such as Water-jet cutting process, Laser beam cutting process etc. so that material fiber orientation will not be lost or affected by the machining process and it will not directly impact on mechanical properties too.

7. CONCLUSION

The experimentation is done for AL+GFRP which include Tensile, Compression, Impact and Wear Test in which it is evident that the AL+GFRP is much better combination of material when compared with GFRP alone, because of the addition of Aluminum and E-glass fibre which made AL+GFRP material to enhance its mechanical properties. Thus making more suitable material for the frontal bumper part for any passenger cars by withstanding greater amount of impact force during any type of head on collision /accidents.

- Ultimate tensile strength and flexural strength of the fiber glass polyester composite increased with increase in the fiber glass Vf of fiber weight fractions – **Due to the addition of E-glass fiber and AL 6061- mechanical properties has increased in the AL+GFRP material.**
- The damping properties of GRP were improved by increasing the GF content in composite and the natural frequency was measured for all conditions. – **Because of effective curing process**.
- The water absorption was analyzed for various environmental conditions with different time period. The water absorption decreased the mechanical properties of the composites.

REFERENCE

1. Tanzeem ul Hasan*, Raisuddin Ansari. Study of the Impact Response of Glass Fiber Reinforced Aluminum Laminates for Conical and Blunt Nose Projectiles, Composite Structures, 2013; 03: 580-58.
2. Jong-Yop Kim* - Optimum Blank Design of an Automobile Sub-Frame. Journal of Materials Processing Technology, 2000; 101.
3. Prajwal Kumar M. P* - Design and Analysis of A Tubular Space Frame Chassis of A High Performance Race Car. International Journal of Research in Engineering and Technology

eISSN: 2319-1163.

4. L.B.Vogelesang* & A.Vlot* – Development of Fiber Metal Laminates for Advanced Aerospace Structures. Journal of Material processing Technology, 2000; 103: 1-5.
5. VLOT.A* - Impact Loading on Fiber Metal Laminates. International Journal of Impact Engineering, 1996; 18: 291-307.
6. F.Ashenai Ghasemi* et al - Journal of Failure Analysis and Prevention.
7. Springer Link publications, August 2016; 16(4).
8. Pradeep Kumar Uddandapu*, Impact Analysis on Car Bumper by varying speeds using Materials ABS Plastic and Poly Ether Imides by Finite Element Analysis software Solid works, Modern Engineering Research, 2013; 03: 391-395.
9. Adinarayana*, Ch. Ashok Kumar, M. Ramakrishna, Design and Analysis of Bus Front Panel Using GFRP, Engineering Research and Applications, 2014; 07: 141-147.
10. American Society for Testing Materials*. Standard Test Methods for Determining the Izod Impact Resistance of Plastics. ASTM., 2004; 256-04.
11. Tanzeem UL Hasan*, RAISUDDIN ANSARI., Study of the Impact Response of Glass Fiber Reinforced Aluminum Laminates for Conical and Blunt Nose Projectiles, Composite Structures, 2013; 03.
12. PO-Ching Yeh*, Po-Yu Chang a, Justin Wangi, Jenny-Ming Yang a. Bearing strength of commingled boron/glass fiber reinforced aluminum laminates, Composite Structures, 2012; 94.
13. S. Jeyanthi* and J. Janci Rani, Improving Mechanical Properties by KENAF Natural Long Fiber Reinforced Composite for Automotive Structures, Applied Science and Engineering, 2012; 15: 275-280.
14. Pradeep Kumar Uddandapu*, Impact Analysis on Car Bumper by varying speeds using Materials ABS Plastic and Poly Ether Imides by Finite Element Analysis software Solid works, Modern Engineering Research, 2013; 03: 391-395.
15. G. Adinarayana*, Ch. Ashok Kumar, M. Ramakrishna, Design and Analysis of Bus Front Panel Using GFRP, Engineering Research and Applications, 2014; 07: 141-147.
16. American Society for Testing Materials. Standard Test Methods for Determining the Izod Impact Resistance of Plastics. ASTM, 256-04.
17. Dr. H.K. Shivanand, Shantharaja, Effect of Reinforcements on the mechanical properties of aged Al(7075) Based Hybrid Composites, Accepted for publication in Indian Foundry Journal, 1 Jan 2007; 53.
18. C. A. Rogers, in Smart Materials, Structures, and Mathematical Issues, edited by C. A.

Rogers (Techonomic, Lancaster, 1989), 221.

19. J. S. N. Paine and C. A. Rogers, in Adaptive Structures and Composite Materials: Analysis and Application, edited by E. Garcia et al., AD-Vol. 45/MD, Vol. 54 (ASME, New York, 1994), 37.