Effect of epoxy modifiers (Al2O3/SiC/TiO2) on the Tensile Strength of epoxy/glass fibre hybrid composites

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Abstract- In this work, the mechanical behaviour of Hybrid GFRP composites is improved by the addition of filler abrasive particles and the aim is to investigate the effect of epoxy modifier particles on the hybrid GFRP composite. The tensile strength of the hybrid GFRP composites was improved with the increase in concentration of abrasive content. Composites of different compositions with three different abrasive particles i.e. Al_2O_3, SiC, and TiO_2 are made with varying weight percentage from 2, 4 and 6gm each. The maximum Tensile strength i.e. 77.14 MPa is observed for composites reinforced with 2 gm of Al_2O_3, 4 gm of SiC and 4 gm of TiO_2 in epoxy. The optimum value is composites reinforced with 2 gm of Al_2O_3, 6 gm of SiC and 6 gm of TiO_2 in epoxy for maximum value of Tensile strength.

Keywords: Hybrid GFRP composites, Abrasive Concentration, Epoxy Modifier, Tensile Strength

I. INTRODUCTION

During the last decades, there has been a tremendous growth in the use of composite materials in various fields of application, ranging from sporting goods to structural components for the automotive and aerospace industries, where the long-term properties are of primary importance. High-performance polymer composite materials are being used increasingly for engineering applications under hard working conditions. The materials must provide unique mechanical and tribological properties combined with a low specific weight and a high resistance to degradation in order to ensure safety and economic efficiency. Glass Fibre Reinforcement Plastics (GFRP) is composites, which are invariably used in many applications in the fields of aerospace and traffic engineering, machine and plant construction, as well as leisure industries. The Glass fibre reinforced plastics (GFRP) is characterized by high strength and rigidity at simultaneously low weight, thus, as a light construction material in many ways superior to metal materials. Engineering polymer matrix composite materials generally consist of continuous glass or carbon fibers embedded in a thermosetting epoxy polymer. The highly cross-linked material is relatively brittle and exhibits a relatively poor resistance to crack initiation and growth. The objectives of present research are improve the strength in all directions or axis, Enhanced the resistance to crack initiation and growth, Overall improve the mechanical properties of hybrid GFRP as compared to GFRP.

Amar Patnaik (2008) has reported the effect of different ceramic fillers on the solid particle erosion characteristics of glass-polyester composites. Two industrial wastes (flyash and cement by-pass dust) rich in metal oxides and two conventional ceramic powders (Al_2O_3 and SiC) have been used as the filler materials. Among the four fillers taken in this study, the inclusion of alumina causes maximum reduction in the composite strength. P. Asokan et al. (2010) conducted the experiments to improve the mechanical properties of glass fibre reinforced plastic (GRP) waste powder filled concrete using superplasticiser for widening the scope for GRP waste recycling for different applications. The tensile splitting strength of the concrete showed 4.12 ± 0.05–4.22 ± 0.03 N/mm^2 with 5–15% GRP waste powder which is also higher than that of the control concrete (3.85 ± 0.02 N/mm^2). Manjunatha et al. (2013) fabricated two types of glass fibre reinforced plastic (GFRP) composites viz., GFRP with neat epoxy matrix (GFRP-neat) and GFRP with hybrid modified epoxy matrix (GFRP-hybrid) containing 9 wt. % of rubber micro particles and 10 wt. % of silica nanoparticles. The fatigue life of the GFRP-hybrid composite was about 4–5 times higher than that of GFRP-neat composite. Yongli Zhang et al (2013) studied the mechanical behaviors of unidirectional flax and glass fiber reinforced hybrid composites with the aim of investigation on the hybrid effects of the composites made by natural and synthetic fibers. The tensile properties of the hybrid composites were improved with the increasing of glass fiber content. Rohan Muni Bajracharya et al (2014) presented the recent developments and applications of composite materials made from recycled mixed plastics and glass fibre. With its inherent resistance to rot and insect attack, these composites can in fact be used as a replacement for chemically treated woods in various larger-scale outdoor applications such as railroad crossties and bridges.

II. FABRICATION TECHNIQUE

In the experiment, commercially available Al_2O_3, SiC and TiO_2 particles (size 200 microns) are used to modify the epoxy resin. Commercially available E-glass fibres with fiber thickness of 8 microns are used as reinforcement. The epoxy used was Araldite(LY-556) an unmodified epoxy resin based on bisphenol-A-diglycidyl-ether and belongs to 'epoxide' family. The hardener used was aliphatic 951 (HY-951), aliphatic primary amine.

For low temperature curing, epoxy resin and hardener are mixed in a ratio of 10:1 by weight percentage. The E glass fibre is used as reinforcement with varying percentages of Al_2O_3, SiC and TiO_2 which is 70% by weight and the rest 30% is resin. Total 09 sheets are to be manufactured as per Table 1. Composites of different compositions with three different filler particles i.e. SiC, Al_2O_3 and TiO_2 are made with varying weight percentage as per design of experiments. Initially the micro powders are dried at 60°C for 2 hours before mixing with epoxy. The fillers are mixed with neat epoxy and stirred manually using glass rod before hardener addition. The fibre piles were cut to size from the woven fibre cloth. The appropriate numbers of fiber plies were taken: eight for each. Then the fibers were weighed and accordingly the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a mild steel container.

The subsequent fabrication process consisted of first putting a releasing film on the mould surface. Next a polymer coating was applied on the sheets. Then fibre ply of one kind was put and proper rolling was done. Then resin was again applied, next to it fiber ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until eight alternating fibers have been laid.

On the top of the last ply a polymer coating is done which serves to ensure a god surface finish. Finally a releasing sheet was put on the top; a light rolling was carried out. Then a 20 kgf weight was applied on the composite. It was left for 24 hrs to allow sufficient time for curing and subsequent hardening.

Fig 1: Fabricated of Hybrid GFRP Sheets

Table 1: Designation of Composites

Composites	Al_2O_3 (gm)	SiC (gm)	TiO_2 (gm)
1	2	2	2
2	2	4	4
3	2	6	6
4	4	2	4
5	4	4	6
6	4	6	2
7	6	2	6
8	6	4	2
9	6	6	4

III. RESULTS & DISCUSSIONS

The experiments are designed according to number of variables and responses to be measured for that variable. Based on the preliminary experiments, three important variables are identified i.e. concentration of Al_2O_3, concentration of SiC, and concentration of TiO_2. Experiments will be conducted based on Taguchi's method with three factors at three levels each.

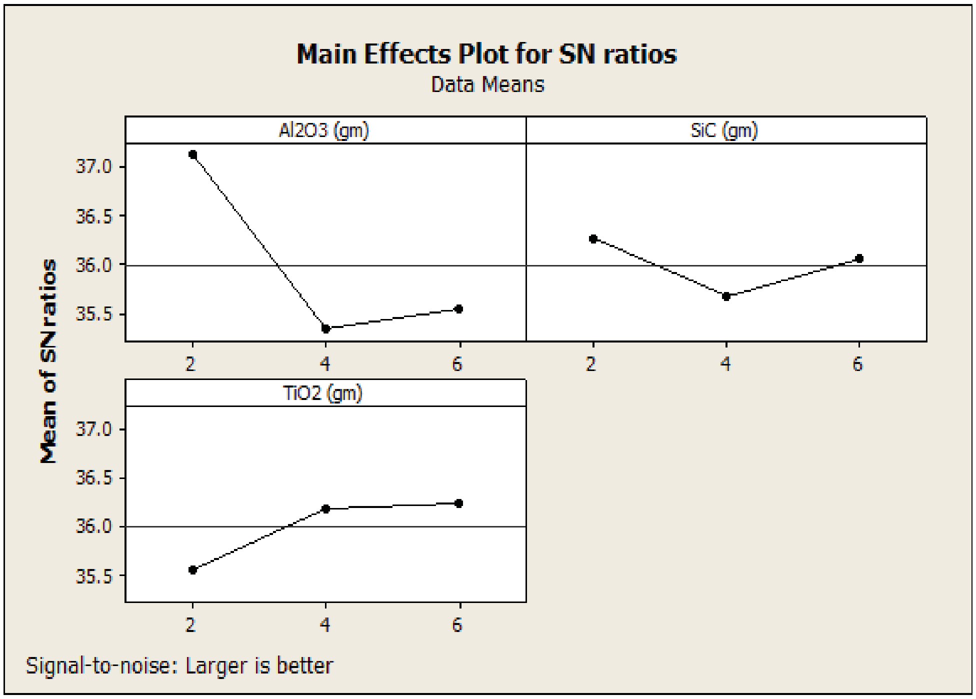

Fig 2: Mean of SN ratio of Tensile strength

Figure 2 (a) shows the effect of concentration of Al_2O_3 on Mean of SN Ratios of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained at variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is decrease in Tensile strength with the increase of concentration of Al_2O_3 abrasives from level-1 to level-2 i.e. 2 to 4gm and than slightly increases from level-2 to level-3 i.e. 4 to 6gm. Figure 2 (b) shows the effect of concentration of Sic abrasives on Mean of SN Ratios of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained at variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is decrease in Tensile strength with the increase of concentration of SiC abrasives from level-1 to level-2 i.e. 2 to 4gm and than increases from level-2 to level-3 i.e. 4 to 6gm. Figure 2 (c) shows the effect of concentration of TiO_2 on Mean of SN Ratios of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained at variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is increase in Tensile strength with the increase of concentration of TiO_2 abrasives from level-1 to level-2 i.e. 2 to 4gm and than increases further from level-2 to level-3 i.e. 4 to 6gm.

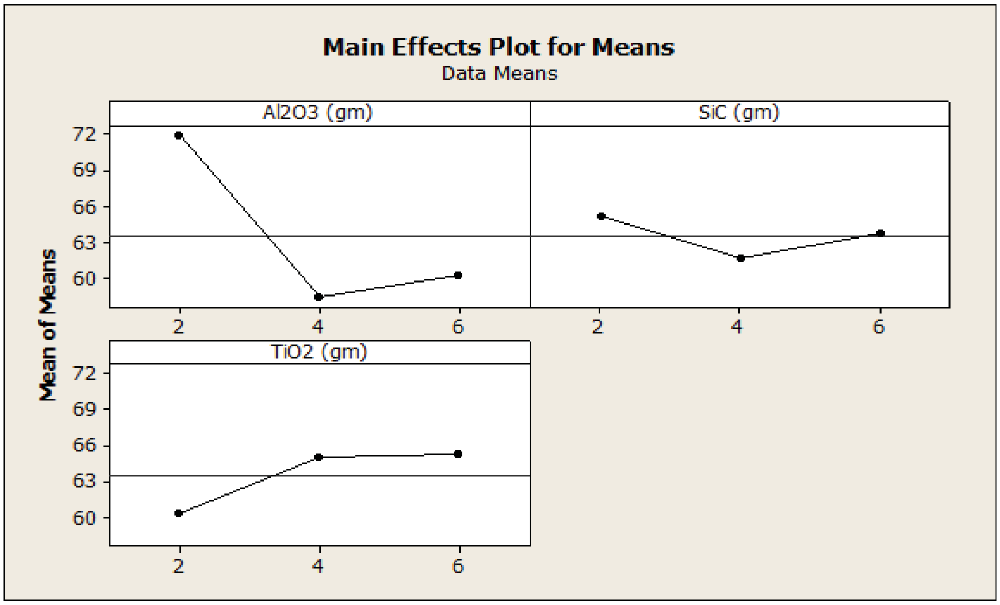

Fig 3: Mean of means of Tensile strength

Figure 3 (a) shows the effect of concentration of Al_2O_3 on Mean of Means of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained by variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is decrease in Tensile strength with the increase of concentration of Al_2O_3 abrasives from level-1 to level-2 i.e. 2 to 4gm and than increases from level-2 to level-3 i.e. 4 to 6gm. Figure 3 (b) shows the effect of concentration of SiC on Mean of Means of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained by variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is decrease in Tensile strength with the increase of concentration of SiC abrasives from level-1 to level-2 i.e. 2 to 4gm and than increases from level-2 to level-3 i.e. 4 to 6gm. Figure 3 (c) shows the effect of concentration of TiO_2 on Mean of Means of Tensile strength. Graph plotted by utilizing the Tensile strength results obtained by variation of concentration of SiC abrasives 2 to 6gm, concentration of Al_2O_3 abrasives 2 to 6gm, concentration of TiO_2 abrasives 2 to 6 gm. It is clear that there is increase in Tensile strength with the increase of concentration of TiO_2 abrasives from level-1 to level-2 i.e. 2 to 4gm and than increases further from level-2 to level-3 i.e. 4 to 6gm.

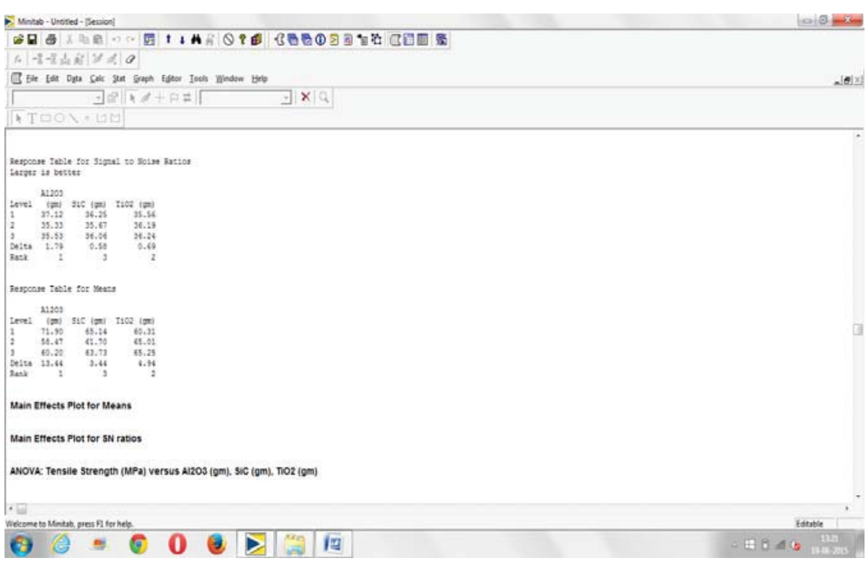

Fig 4: Ranking of GFRP parameters as per Tensile strength

Figure 4 shows the ranking of Tensile strength of GFRP, the parameters for optimizing the Tensile strength. It can be observed that concentration of Al_2O_3 abrasives has the largest effect on Tensile strength of GFRP. The concentration of SiC has the smallest effect on means of SN ratio of Tensile strength of GFRP.

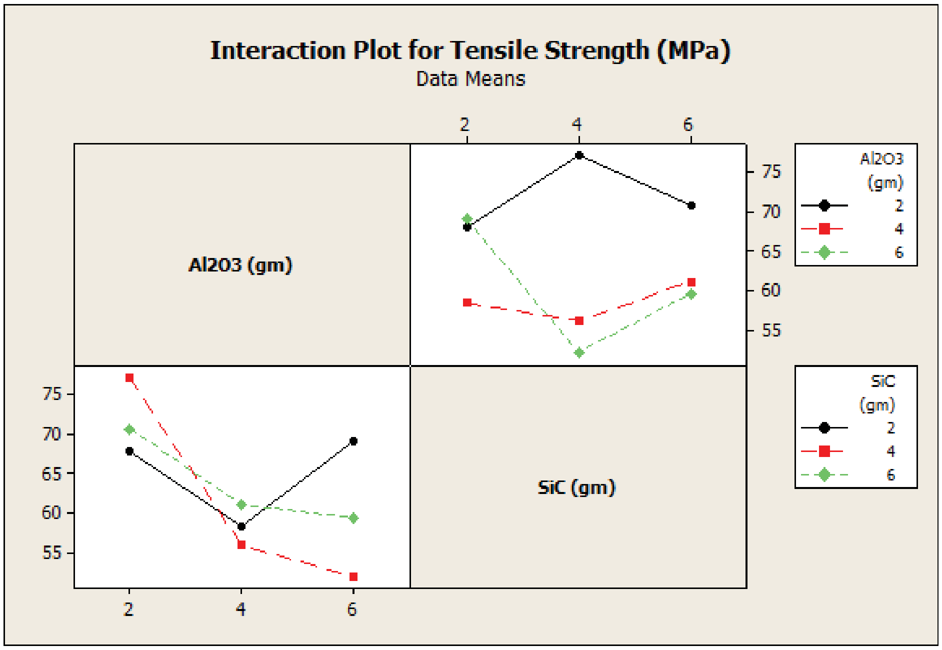

Fig 5: Interaction plot for Al2O3 abrasives and SiC abrasives for Tensile Strength

The Figure 5 shows interaction effect of concentration of Al_2O_3 abrasives and SiC abrasives on Tensile strength of GFRP. It is clear that at level 1 of concentration of Al_2O_3 abrasives i.e. 2gm; the Tensile strength increases by increasing concentration of SiC abrasives from level 1 to level 2 i.e. 2 to 4gm. By further increasing the concentration of SiC abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength decreases. At level 2 of concentration of Al_2O_3 abrasives i.e.. 4gm; the Tensile strength decreases by increasing concentration of SiC abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of SiC abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength increases. At level 3 concentration of Al_2O_3 abrasives i.e.. 6gm; the Tensile strength decreases by increasing concentration of SiC abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of SiC abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength increases.

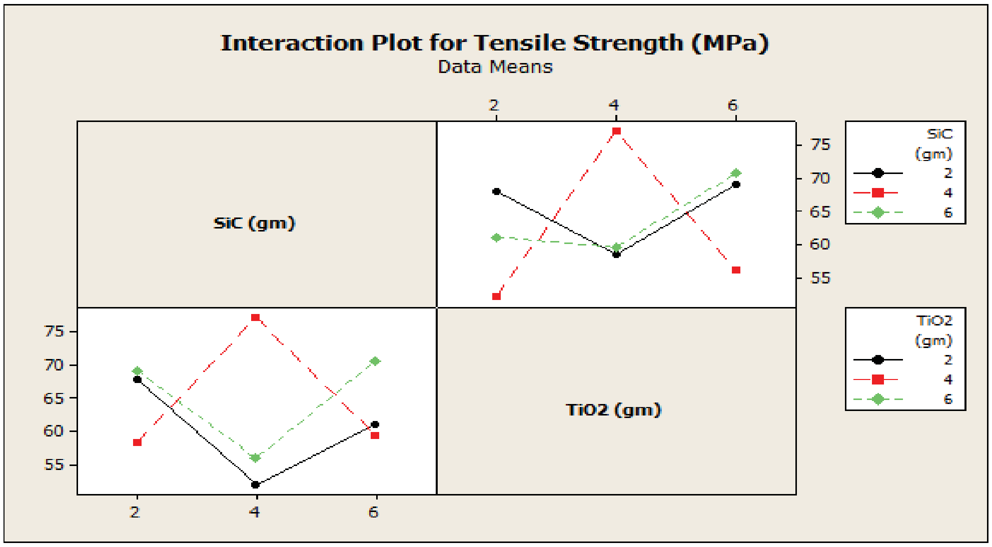

Fig 6: Interaction plot for SiC abrasives and TiO2 abrasives for Tensile Strength

The Figure 6 shows interaction effect of concentration of SiC abrasives and TiO_2 abrasives on Tensile strength of GFRP. It is clear that at level 1 of concentration of SiC abrasives i.e.. 2gm; the Tensile strength decreases by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of TiO_2 abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength increases. At level 2 of concentration of SiC abrasives i.e. 4gm; the Tensile strength increases by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e. 2 to 4gm. By further increasing the concentration of TiO_2 abrasives from level 2 to level 3 i.e. 4 to 6gm the Tensile strength decreases. At level 3 concentration of SiC abrasives i.e. 6gm; the Tensile strength decreases by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e. 2 to 4gm. By further increasing the concentration of TiO_2 abrasives from level 2 to level 3 i.e. 4 to 6gm the Tensile strength decreases.

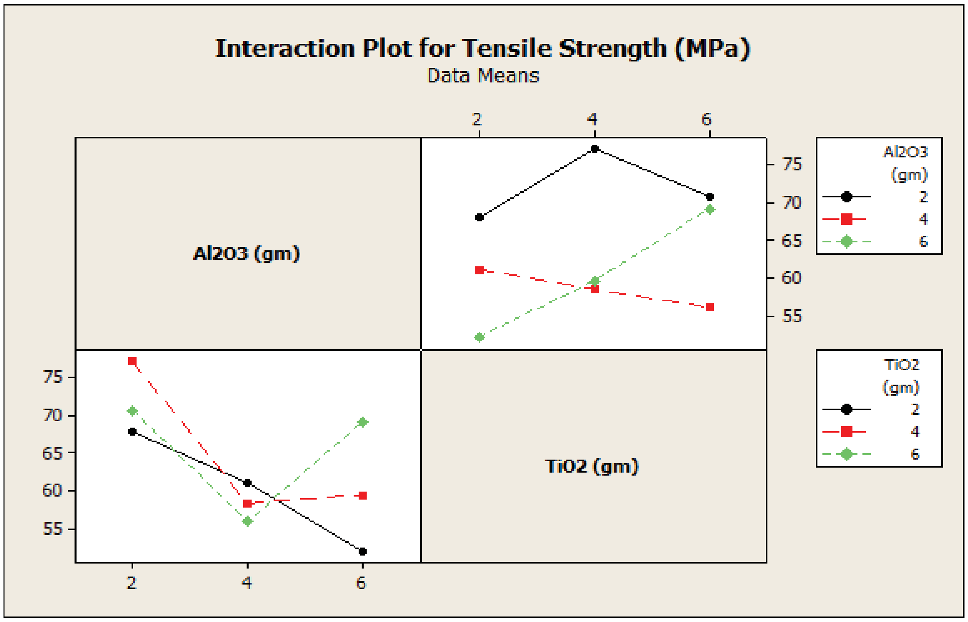

Fig 7: Interaction plot for Al2O3 abrasives and TiO2 abrasives for Tensile Strength

The Figure 7 shows interaction effect of concentration of Al_2O_3 abrasives and TiO_2 abrasives on Tensile strength of GFRP. It is clear that at level 1 of concentration of Al_2O_3 abrasives i.e.. 2gm; the Tensile strength increase by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of TiO_2 abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength decreases. At level 2 of concentration of Al_2O_3 abrasives i.e.. 4gm; the Tensile strength decreases by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of TiO_{23} abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength again decreases. At level 3 concentration of Al_2O_3 abrasives i.e. 6gm; the Tensile strength increases by increasing concentration of TiO_2 abrasives from level 1 to level 2 i.e.. 2 to 4gm. By further increasing the concentration of TiO_2 abrasives from level 2 to level 3 i.e.. 4 to 6gm the Tensile strength again increases.

IV. CONCLUSION

The following conclusions can be made from our experimental results:

1) The successful fabrication of a new class of epoxy based hybrid composites reinforced with glass fibre has been done. The present investigation revealed that epoxy modifier significantly influences the different properties of composites.

2) The maximum Tensile strength i.e. 77.14 MPa is observed for composites reinforced with 2 gm of Al_2O_3, 4 gm of SiC and 4 gm of TiO_2 in epoxy.

3) For maximum value of Tensile strength of composite the optimum value is composite reinforced with 2 gm of Al_2O_3, 6 gm of SiC and 6 gm of TiO_2 in epoxy.

REFERENCES

[1] Rohan Muni Bajracharya, Allan C. Manalo, Warna Karunasena , Kin-tak Lau, "An overview of mechanical properties and durability of glass-fibre reinforced recycled mixed plastic waste composites'', Materials and Design 62 (2014) 98–112.

[2] P. Asokan, Mohamed Osmanib, ADF Price " Improvement of the mechanical properties of glass fibre reinforced plastic waste powder filled concrete'', Construction and Building Materials 24 (2010) 448–460

[3] Yongli Zhang, Yan Li, Hao Ma, Tao Yu "Tensile and interfacial properties of unidirectional flax/glass fiber reinforced hybrid composites'', Composites Science and Technology 88 (2013) 172–177

[4] Amar Patnaik "Development, Characterization and solid particle erosion response of polyester based hybrid composites", National Institute of Technology, Rourkela, India August, 2008.

[5] C.M. Manjunatha, Ramesh Bojja, N. Jagannathan A.J. Kinloch, and A.C. Taylor, "Enhanced fatigue behavior of a glass fibre reinforced hybrid particles modified epoxy nanocomposite under WISPERX spectrum load sequence", International Journal of Fatigue 54 (2013) 25–31.