An Experimental Study on "Drilling of Glass Fibre Reinforced (GFRP) Filled Epoxy Composite Material"

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Abstract— The present work describes the drilling (machining) of GFRP composites with the help of Step drill of three sets, with three different speeds. Further work has been carried out by immersion of GFRP composites in sea water for 8 hrs, 16 hrs and 24 hrs duration and performed drilling operation. Results revealed that 8-4 mm step drill showed better machining characteristic than the other two 12-8 mm and 10-6 mm step drills. GFRP composites, with ZnS filler material soaked in sea water for 16 hrs duration had better machining capability. The ZnS Filled GFRP composites had better performance than TiO2 filled GFRP Composites. The mechanical performance of a composite material is decisively controlled by the state of fiber-matrix interface. Its properties influence the integrity of composite behavior because of its role in transferring stress between the fiber and the matrix. The factors affecting the interface are too complex to be precisely concluded. Also, tests have been performed to study the delamination occurred during drilling on different material compositions of Glass Fibre , Epoxy & Fillers such as TiO2 & ZnS in different proportions. Samples of several Glass-Epoxy composites were manufactured using the traditional hand layup method where the stacking of the plies were alternate and the weight fraction of fiber and matrix was kept at 40-60%.Specimens were cut according to the ASTM (1989) standards. Specimens were prepared of Glass Fibre, Epoxy & fillers (TiO2 & ZnS) in different compositions like 60%-40%, 59%-40%-1%, 58%-40%-2%, 57%-40%-3%.The specimens were tested for their strength & properties. The test like Tensile test, three point Bending test & Charpy test are performed on each of the composition. Also Experimental studies have been carried out to study the effects of thermal ageing, sea water. Finally step drilling with different size is carried out on each specimens. The present work also describes the development and mechanical characterization of new polymer composites consisting of glass fiber reinforcement, epoxy resin and filler materials such as TiO2 and ZnS. The newly developed composites are characterized for their mechanical properties. Experiments like tensile test, three point bending and impact test were conducted to find the significant influence of filler material on mechanical characteristics of GFRP composites.

Key words: Drilling, Thrust Force, Torque, HSS, GFRP, Composites, Fibre Volume Fraction, Delamination Step Drill, Drill Speed-Feed, Resin Matrix

I. INTRODUCTION

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibres of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. Composite properties (e.g. stiffness, thermal expansion etc.) can be varied continuously over a broad range of values under the control of the designer. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement.

They find applications in

- Automobiles
- Aerospace
- Bicycles
- Marine

Fiber Reinforced Polymeric (FRP) composites are becoming most popular materials in aerospace and other industries where high strength to weight ratio is the requirement. Their application have shown a promising future in such areas where fatigue and stress corrosive cracking are considered the dominant mode of failure. Extensive investigations have taken place in the past decade in research and development area to manufacture composite components economically. Among FRP's, Glass fibre reinforced plastic surfaced the industrial market because of their low cost and excellent properties they enhance. GFRP components are usually manufactured by near-net shape fabrication. However for fastening and assembling purposes, secondary machining processes such as drilling, turning, trimming, sawing and slitting and so on are essential.

Among the defects caused by drilling, delamination appears to be of most critical. Delamination can result in lowering of bearing strength and can be detrimental to the material durability by reducing the in-service life under fatigue loads. Delamination during drilling is due to compressive thrust force acting on the uncut portion and peeling force acting on the cut portion. Though the thrust force that cause delamination is higher near the exit and entry where the uncut portion is minimum, the mechanical property of a composite which is based on fiber resin proportion, play a vital role in drilling.

Much of the literature reporting on the drilling of FRP material by conventional tools has shown that the quality of cut surface is strongly dependent on drilling parameters. An improper selection of these parameters can lead to unacceptable material degradation, such as fibre pullout, matrix cratering, thermal damage and wide spread delamination.

II. Experimental Details

Drilling experiments on 10 mm thick flat specimen made of cross woven E-Glass fibre roving reinforced with epoxy resin were performed using radial type drilling machine. Three HSS twist step drills of 12/8 mm, 10/6 mm & 8/4 mm diameter were used. Eight specimens with fibre content & Fillers were prepared by hand lay-up technique. Specimens were cured at ambient temperature and macroscopic tests were performed for the occurrence of voids. By controlling the number of layers of cross woven fibres in the composite laminate fibre percentage was controlled. Two holes of same size were drilled on each specimen. Thrust force while drilling was measured by connecting dynamometer to the drill machine. Below photo shows the specimens (100*100mm) cutted down from 250sq.mm wide plate.

Photo1: Specimens Preparation

A. *Composite Combinations*

In the present work specimens were prepared for two different fillers, one at a time. Also the specimen were prepared for three different filler volumes glass fabric staking sequence of ±90^0 is considered during lamination in all cases. Tables below gives the details information of the compositions of composite prepared a used,

Sl.No	Filler	Combination or volume fraction
01	---	Glass fabric 60% + Epoxy 40%
02		Glass fabric 59%+TiO_2 1%+ Epoxy 40%
03	TiO_2	Glass fabric 59%+TiO_2 2%+ Epoxy 40%
04		Glass fabric 58%+TiO_2 3%+ Epoxy 40%
Sl.No	Filler	Combination or volume fraction
01	---	Glass fabric 60% + Epoxy 40%
02		Glass fabric 59%+ Zns 1%+ Epoxy 40%
03	Zns	Glass fabric 59%+ Zns 2%+ Epoxy 40%
04		Glass fabric 58%+ Zns 3%+ Epoxy 40%

Table 1: That is sum of volume of glass fabric+ filler +Epoxy=1

The volume of filler required is calculated from the above relation, and equivalent weight % of filler is calculated using the relation:

$$\text{Mass (gms)/volumes(mm}^3\text{)=density(gms/mm}^3\text{)}$$

III. Experimental Results

Three point bending test is the one which enables us to test the specimens with mixed mode of loading a typical bending test includes the combined shear and tensile/compressive stresses. To know the effect of filler on the bending strength of Glass-epoxy composites the bending tests were conducted for two different filler and with varied filler proportions. TiO_2 and ZnS were used as the filler materials and the filler content is varied as 1%, 2%, 3% vol. The effect of filler content on the bending strength is discussed in the following pages.

A. *Effect of Filler on Bending Characteristics*

The load displacement graph for the tested specimen is given in Fig 11.

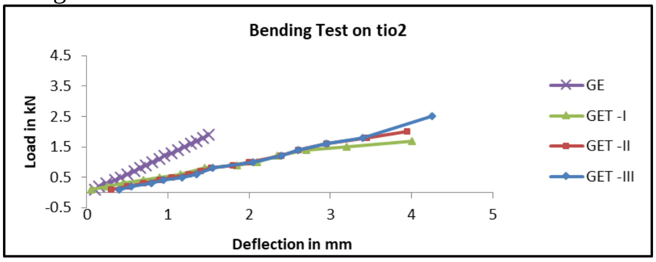


Fig. 1: Load-Displacement Relation for TiO_2 Filled Composite with Different Volume % of Filler.

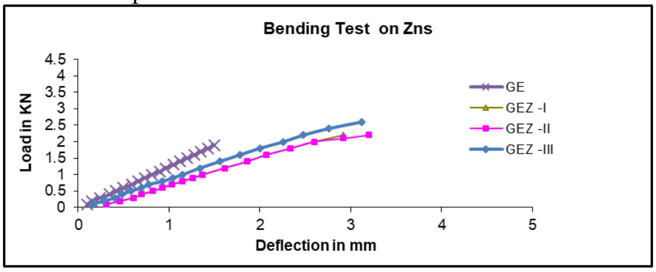


Fig. 2: Load- Displacement Relation for ZnS Filled Composite with different Volume % of Filler.

Comparison of the load-deformation relation for unfilled composite and TiO_2 filled composite. From the graph it can be observed that there is linear relation of load-displacement, while comparison it can be seen that the filled composites bear more bending load than the unfilled composites. When the bending load is applied on the member under testing, the fibers at the upper portion of the member faces the compression load and the fibers at the other end faces the tensile load. Due to tensile load at the opposite end of loading surface, the fiber gets elongated in this region for some time i.e., upto yield point, thereafter the deformation increases at a faster rate. When the crack initiates at this end, this crack propagates to the other end and hence failure and the bending load takes place.

Fig. 1 shows load-deformation relation for bending test specimens. It can be observed that the bending load bearing strength of composite increases with the addition of filler. The addition of TiO_2 as the filler material to glass/epoxy composite makes the material harder than normal glass/epoxy composite, this leads to bear more bending load than the normal composite material. Basically the glass epoxy composite itself is a brittle material and further addition of TiO_2 as filler made the material still harder and hence the bending strength increased with addition of filler content. Also it can be observed that there is a sharp yield in case of TiO_2 filled composite.

The addition of ZnS leads to increase in the bending strength compared to normal GFRP composites. As observed from the graph, there is no sharp yield in the case of ZnS filled composites. Since ZnS is a ductile material, the addition of filler had enhanced the bending strength of composites and there is proportional deformation with respect to load.

– Both TiO_2 and ZnS bending strength order is as follows 3%, 2% and 1%.

– Compared to TiO_2 and ZnS filled composites, the ZnS filled composite takes more load before fracture

B. Effect of Filler on Tensile Characteristics

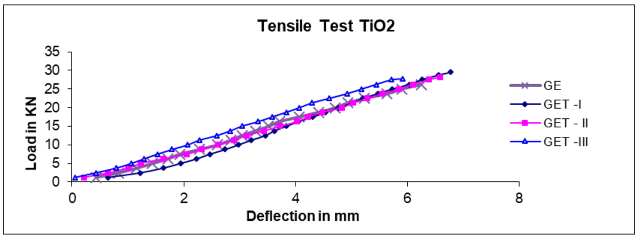


Fig. 3: Load-Displacement Relation for TiO_2 Filled Composite with Different Volume % of Filler

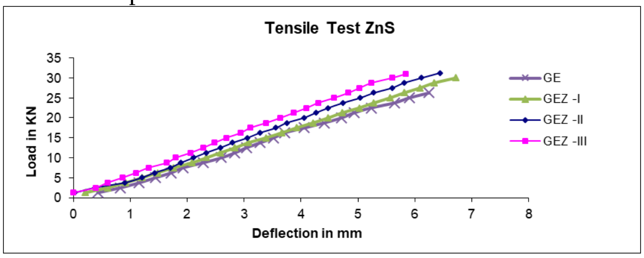


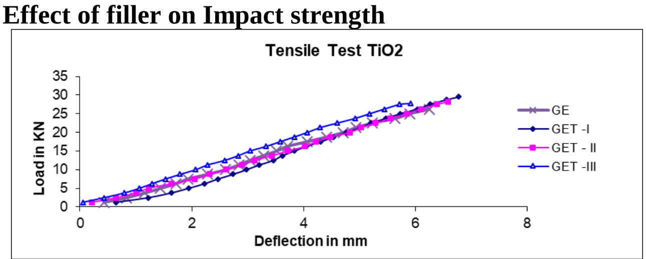
Fig. 4: Load- Displacement Relation for ZnS Filled Composite with Different Volume % Filler

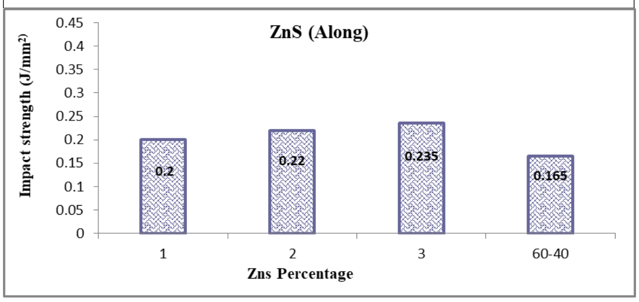
Comparison of the load-deformation relation as shown in the Fig.3 and 4. From the graph it can be observed that filled composites bear more load than unfilled glass epoxy composites, damage mechanism in composite materials during tension involves various combinations of damage modes are matrix cracking, de-bonding, ply failure and fiber breakage occurs during testing. As seen in the graph, unfilled glass epoxy composite bear less load than 1% volume fraction filler, maximum load is for 3% volume fraction whereas 2% volume fraction is moderate for both the filler materials (TiO_2& ZnS).

1) Conclusion

1) For both TiO_2& ZnS load bearing capacity order is of WF, 1%, 2% and 3%.
2) ZnS filled glass epoxy composite can sustain more load than that of TiO_2 filler.

Effect of filler on Impact strength





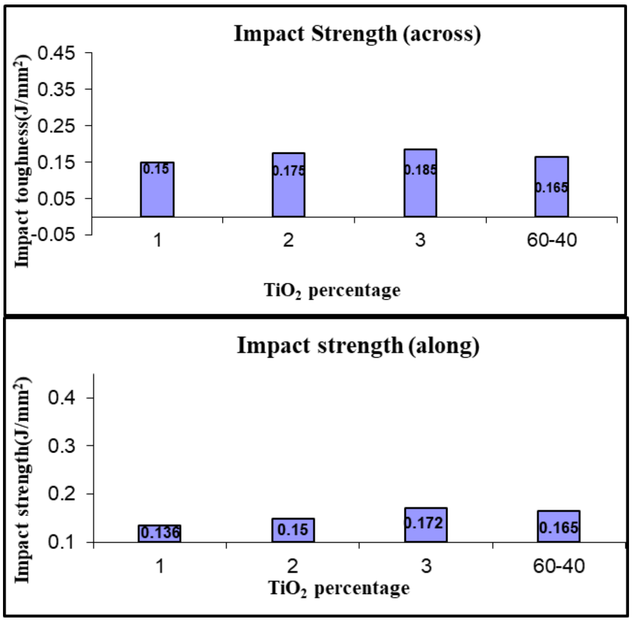


Fig. 5: Comparision of Impact Strength against Volume Fraction of Specimens Along and Across the Notch

From Fig.5, it is observed that decrease in the impact toughness with increased percentage content of filler.

It is also very clear that the impact toughness of the test specimen with the notch grooved across the laminates is higher than that of specimens with the notch along the laminates irrespective of percentage of content.

The three main mechanisms identified to be responsible for the increase or decrease in the impact toughness in these composites are

1) Fracture and failure of fibers.
2) Frictional sliding that takes place in the fiber matrix interphase as fiber pull-out during failure.
3) Matrix cracking or deformation of matrix in shear and transverse tension/compression.

From the Fig.5.3, we can make the observation that impact toughness value for unfilled glass epoxy composite is more than filled glass epoxy composite both for TiO_2 and ZnS. The addition of TiO_2 and ZnS as the filler material to the glass/epoxy composite makes the material harder and brittle which is the main reason for reduction in impact toughness value for filled glass epoxy composite material.

IV. Conclusions

1) Bending strength increases with addition of filler material.
2) ZnS filled composite shows significantly good results than TiO_2 filled composites.
3) Tensile strength increases with addition of filler.
4) ZnS filled composite shows more tensile load in comparison with unfilled and TiO_2 filled composites.
5) Impact toughness notch across the laminates is higher than that of along the notch.
6) Impact toughness value for unfilled glass composite is more than filled composite.
   TiO_2 and ZnS filler material makes material harder and brittle which is the reason for reduction in impact toughness value

REFERENCES

[1] B. Ravi Sankar1, P. Umamaheswarrao2, A.V. Avinash Reddy3, P. Koushik Kumar,2014, ''Drilling of Composite Laminates- A Review''Journal of Basic and Applied Engineering Research, pp. 19-24
[2] B.V.Kavada*, A.B.Pandeya, M.V.Tadavia, H.C.Jakharia, 2014 "A Review Paper on Effects of Drilling on Glass Fiber Reinforced Plastic", ICIAME.
[3] Shivakumar S1, 2011, "LITERATURE REVIEW OF FIBER REINFORCED POLYMER COMPOSITES, IJAET.
[4] Syed Altaf Hussain 1*, V. Pandurangadu 2, K. Palani Kumar,2011, "Machinability of glass fiber reinforced plastic (GFRP) composite materials",International Journal of Engineering, Science and Technology,Vol. 3, No. 4, pp. 103-118.
[5] M.Sakthivel1*, S.Vijayakumar2, Channankaiah1, D.Athikesavan, 2015, "A Review on thrust force and torque in drilling of glass fiber reinforced polymer composite,IJCRGG.
[6] Pegoretti, L. Fambri, G. Zappini, M. Bianchetti, 2001, "Finite element analysis of a glass fiber reinforced composite endodontic"; post Department of Materials Engineering, University of Trento.
[7] Ravikumar, M.S.Sham Prasad, 2014, "Fracture Toughness and Mechanical Properties of Aluminum Oxide Filled Chopped Strand Mat E-Glass Fiber Reinforced–Epoxy Composite"; IJSR.
[8] "Composite Materials Science and Engineering"; Krishna K. Chawla; Second Edition; 1998.
[9] "Material Science"; G.K. Narula, V.K. Gupta; FirstEdition; 44th reprint 2012.
[10] S. R. Patel1, 2013,"A Review on Machining of Fiber Reinforced Plastic using Abrasive Water jet",jetsam.
[11] T.D. Jagannatha, 2015 "Effect of Process Parameters on Thrust Force in Drilling of Carbon-Glass Fibers Reinforced Epoxy hybrid Composites,"ijrame.
[12] Bannister, M. (2001). Challenges for composites into the next millennium - a reinforcement perspective. Composites Part A: Applied Science and Manufacturing, 32(7), 901-910.
[13] Kishore, R.A.; Tiwari, R.; and Singh, I. (2009). Investigation of drilling in [(0/90)/0]s glass fibre reinforced plastics using taguchi method. Advances in Production Engineering and Manangement, 4(1-2), 37-46.
[14] Rawat S, Attia H., "Wear mechanisms and tool life management of WC-Co drill during dry high speed drilling of woven carbon fibre composites" Wear, 2009;261, pp.1022–30.
[15] I.singh, N.Bhatnagar, "Drilling of uni-directional glass fiber reinforced plastic (UD-GFRP) composite laminates", The International Journal of Advanced Manufacturing Technology, February 2006, Volume 27, Issue 9-10, pp.870-876.
[16] E M.A. Azmir, Praveena Nair Sivasankaran, Z. Hamedon., "Experimental Study on Drilling Process of CFRP Composite Laminate", Materials Science Forum, Volumes 638 – 642, pp.927-932.
[17] T. N. Valarmathi, K. Palanikumar and S. Sekar., "Parametric Analysis on Delamination in Drilling of Wood Composite.
[18] Khashaba, U.A. (2004). Delamination in drilling GFR-thermoset composites. Composite Structures, 63(3-4), 313-327.
[19] Vimal Sam Singh, R.; Latha, B.; and Senthilkumar, V.S. (2009). Modeling and analysis of thrust force and torque in drilling GFRP composites by multifacet drill using fuzzy logic. International Journal of Recent Trends in Engineering, 1(5), 66-70.
[20] Hocheng, H.; and Dharan, C.K.H. (1990) Delamination during drilling in composite laminates. Journal of Engineering for Industry, 112(3), 236-239.

