International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-1, Issue-10, December 2013

Machining of Glass Fiber Reinforcement Epoxy Composite

Patil Deogonda B, Vijaykumar N Chalwa

***Abstract*— Machining of composite materials is difficult to carry out due to the anisotropic and nonhomogeneous structure of composites and to the high abrasiveness of their reinforcing constituents. This typically results in damage being introduced into the work piece and very rapid wear development in the cutting tool. Conventional machining processes such as turning, drilling or milling can be adapted to composite materials, provided proper tool design and operating conditions are maintained.**

The present work also describes the machining (drilling) of GFRP composites with the help of Step drill of three sets, with three different speeds. 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. The ZnS Filled GFRP composites had better performance than TiO2 filled GFRP Composites.

***Index Terms*— Drilling; Polymer-matrix composites; Thrust force; Delamination.**

I. Introduction

Fiber reinforced plastics have been widely used for manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. Another relevant application for fiber reinforced polymeric composites (especially glass fiber reinforced plastics) is in the electronic industry, in which they are employed for producing printed wiring boards. Drilling of these composite materials irrespective of the application area, can be considered as a critical operation owing to their tendency to delaminate when subjected to mechanical stresses. With regard to the quality of machined component, the principal drawbacks are related to surface delamination, fiber/resin pullout and inadequate surface smoothness of the hole wall. Among the defects caused by drilling, delamination appears to be the most critical [1] Figure 1 shows that the factors such as cutting parameters and tool geometry/material must be carefully selected aiming to obtain best performance on the drilling operation, i.e., to obtain best hole quality, which represents minimal damage to the machined component and satisfactory machined surface.

Composite materials are constituted of two phases: the matrix, which is continuous and surrounds the other phase, often called as reinforcing phase [3]. Epoxy resins are widely used as matrix in many fibre reinforced composites; they are a class of thermoset materials of particular interest to structural engineers owing to the fact that they provide a unique balance of chemical and mechanical properties combined with wide processing versatility [4]. Within reinforcing materials, glass fibres are the most frequently used in structural constructions because of their specific strength properties [3]. The present study focuses on machinability study of GFRP laminated composites with filler material TiO_2 and graphite and evaluation of thrust force, delamination factor for two drill diameters at different speeds

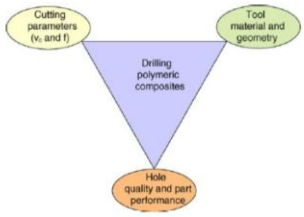


Figure:-1. Principal aspects to be considered when drilling fiber reinforced plastics

II. Machining of Composite Materials

The machining of GFRP is quite different from that of metals and results in many undesirable effects such as rapid tool wear, rough surface finish and defective subsurface layers caused by cracks and delamination. At the beginning of drilling operation, the thickness of the laminated composite material is able to withstand the cutting force and as the tool approaches the exit plane, the stiffness provided by the remaining plies may not be enough to bear the cutting force, causing the laminate to separate resulting in delamination. The delamination that occur during drilling severely influence the mechanical characteristics of the material around the hole. In order to avoid these problems, it is necessary to determine the optimum conditions for a particular machining operation. Drilling is a particularly critical operation for fiber reinforced plastics (FRP) laminates because the great concentrated forces generated can lead to widespread damage. The major damage is certainly the delamination that can occur both on the entrance and exit sides of the work piece [4]. The delamination on the exit surface, generally referred to as push down delamination, is more extensive, and is considered more severe. Hocheng and Tsao have beautifully explained the causes and mechanisms of formation of these push down delamination and they have also reasoned out the dependence of extent of delamination on the feed rate [5]. In earlier studies it has been observed that the extent of delamination is related to the thrust force, feed, material properties and speed, etc. and that there is a critical value of the thrust force (dependent on the type of material drilled) below which the delamination is negligible [6].

Manuscript received December 09, 2013.

Patil Deogonda B, Assistance Professor, Dept. of Mechanical Engineering. SMSMPITR, Akluj

Vijaykumar N Chalwa, Dean R&D, Dept. of Mechanical. Engineering. SMSMPITR, Akluj.

III. SPECIMEN PREPARATION

The method that is used in the present work for manufacturing the laminated composite plates is hand lay-up as shown in Figure.2 which is the oldest method that was used to get the composite materials. The type of Glass Fiber mat selected to make specimens was, Mat–330GSM. The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6), both manufactured by ATUL India Ltd, Gujarat, India. This matrix was chosen since it provides good resistance to alkalis and has good adhesive properties. Based on volume fraction the calculations were made for 60-40 (60% Glass Fiber – 40% Epoxy Resin) combination showed a better result. Two filler materials TiO_2 and ZnS were added to Mat 60-40 combination by keeping Epoxy percentage constant (40%). Based on literature survey the amount of filler added was 1, 2, & 3 % of Tio_2 and 1, 2, & 3% of ZnS, the details are as shown in Table 1 &2. After preparation of the specimen the specimens were tested in tensile test, three point bending test, impact test to obtain the strength of materials.

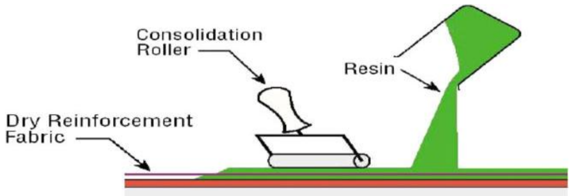


Figure:-2. Hand lay-up Technique

Table 1.Filler Material Specimen Detail

Mat -330GSM				
Sl. No	Glass fibre content %	Epoxy	Filler content in %	
			TiO_2	ZnS
01	60	40	--	--
02	59	40	1	1
03	58	40	2	2
04	57	40	3	3

Table 2.Test specimen detail

Test specimens	ASTM	Size
Tensile test specimens	D-3039	250x25x4 mm.
Impact Test Specimens	D-256	55x10x10 mm.
Bending test specimens	D-790	110x25x6 mm.

IV. EXPERIMENTAL SETUP

The high speed steel twist drill has an 118^0 point angle. Three diameters (step drill) 12/8mm, 10/6mm and 8/4mm were selected to work on radial drilling machine which has a maximum spindle speed of 2650 rpm. There details are shown in Table 3. A piezoelectric dynamometer was used to acquire the thrust force as shown in Figure 3. The damage around the holes was measured using a tool maker's microscope

Table 3.Drill tool diameter and corresponding speed

Tool twist drill diameter mm (step drill)	Cutting speed (rpm)
12/8	625
	1256
	2560
10/6	625
	1256
	2560
8/4	625
	1256
	2560

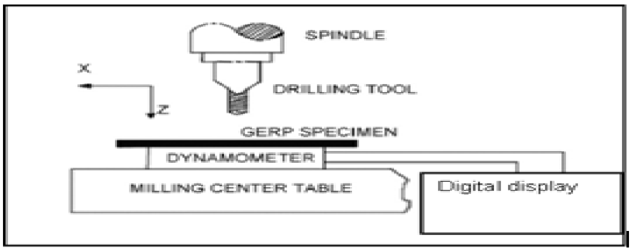


Figure:-3.Schematic diagram of experimental set-up

V. . RESULTS AND DISCUSSIONS

A. *Thrust force*

Cutting forces are very useful for drill-wear monitoring, because these forces generally increase with tool wear. Thus, within the tool wear region, cutting forces provide good assessment of the tool condition. If the tool cannot withstand the increased cutting forces, catastrophic tool failure becomes inevitable. Consequently, tool life, which is a direct function of tool wear, is best determined by monitoring thrust force. Due to the thrust developed during drilling, many common problems exist. Some of the problem causes in drilling are fiber breakage, matrix cracking, fiber/matrix debonding, fiber pull-out, fuzzing, thermal degradation, spalling and delamination. The thrust force and torque developed in drilling operation is an important concern. Monitoring of thrust force in drilling is needed for the industry.

In Figure 4 a qualitative trend of thrust force as a function of the drilling is shown. As can be seen, a pushing action is exerted by the drill on the work piece. In the first phase the thrust force continues to increase as an increasing part of the cutting lips is engaged in the material; in the second phase the thrust force remains at an almost constant value as the drill sinks into the work piece. In the third phase the thrust force rapidly decreases when the twist drill exits.

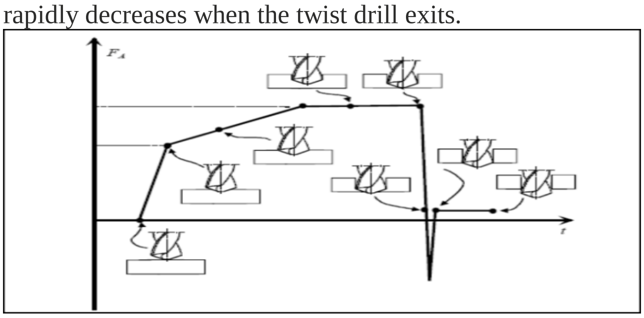


Figure:-4.General trend of the thrust force as a function of drilling time

The value of thrust force was measured using a piezoelectric dynamometer. Figures 5, 6 and 7 show the results of the thrust force for the three sets of drilling tests, as a function of the cutting parameters.

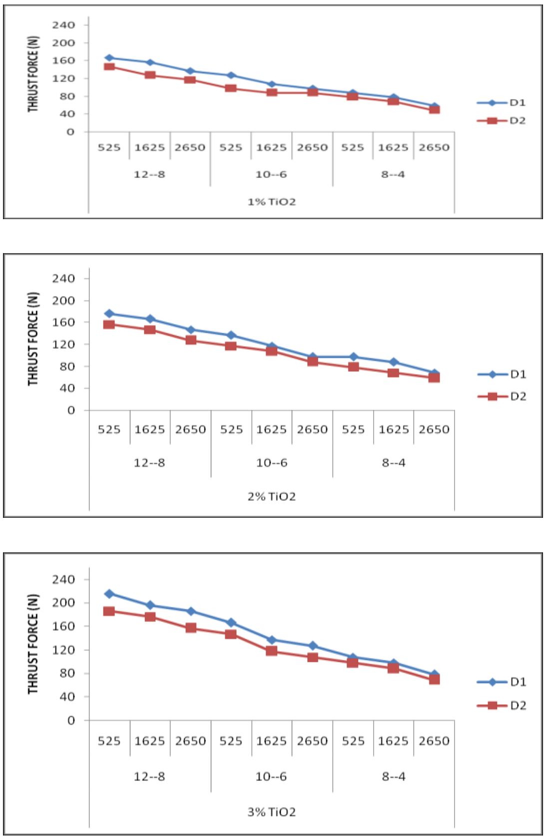


Figure:-5: Comparison of thrust force against drilling speed, feed and drill size for TiO2 filled GFRP composite

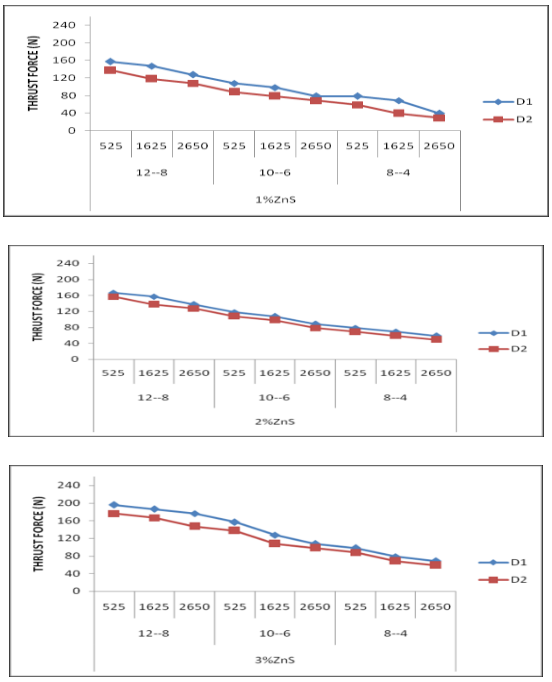


Figure:-6. Comparison of thrust force against drilling speed, feed and drill size for ZnS filled GFRP composite.

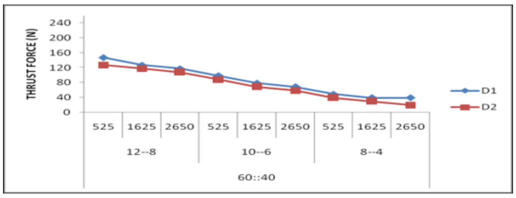


Figure:-7. Comparison of thrust force against drilling speed, feed and drill size for Unfilled (60:40) GFRP composite.

After drilling glass fiber reinforced epoxy composite laminates manufactured by hand lay-up; using three different HSS twist drill and various cutting speeds, the cutting speed is the cutting parameter that has the highest physical as well as statistical influence on the thrust force and surface roughness in

GFRP material, the following conclusions can be drawn:

• From the Figures 5, 6 and 7 it could be seen that as the speed increases the thrust force decreases for all the drill diameters. This is due to abrasiveness inherent property of the filler material.

• As speed increases the thrust force decreases

• Smaller diameter has got greater thrust force than larger diameter in each step drill.

•When compared among all step drills 8-4mm step drill has shown less thrust force than 10-6mm and 12-8mm.

• Unfilled composite has shown less thrust force values than Filled composite.

• ZnS has got significantly better values than TiO2.

B. *Delamination factor (Fd)*

Delamination is caused by different drilling parameters. Several ratios were established for damage evaluation. One of them is delamination Factor (F_d), a ratio between the maximum delaminated diameter (D_{max}) and drill diameter (D_0). $F_d = D_{max}/D_0$. Figure 8 shows Tool Maker's microscope with which delamination was measured.

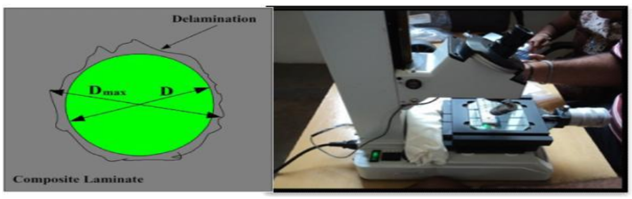


Figure:-8. Schematic view of delamination factor and a view of tool makers' microscope.

Delamination is commonly classified as peel-up delamination at the twist drill entrance and pushdown delamination at the twist drill exit as shown in Figure 9.

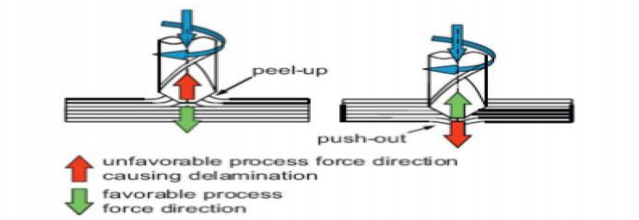
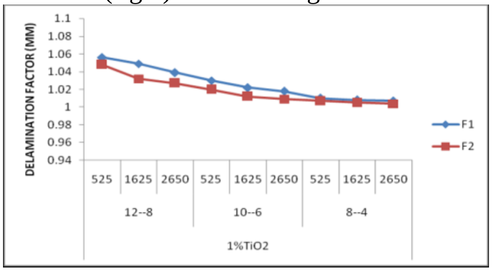
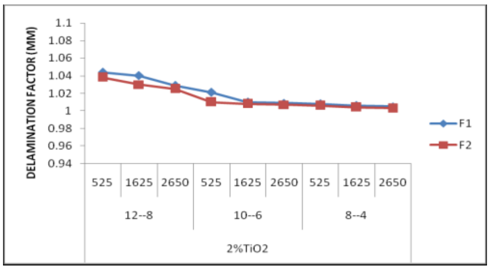
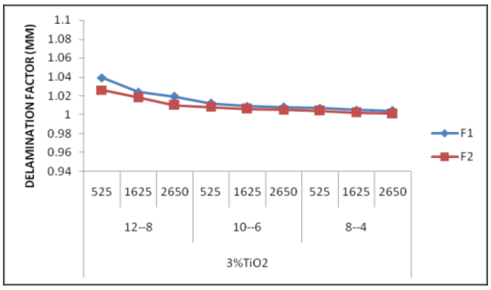
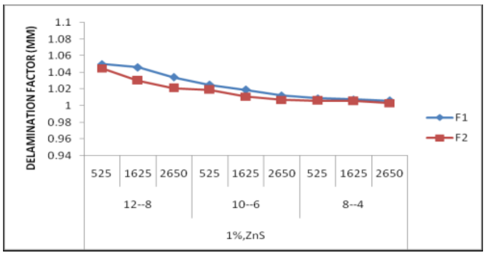


Figure:-9.Delamination at the twist drill entrance (left) and exit (right) when drilling laminates.









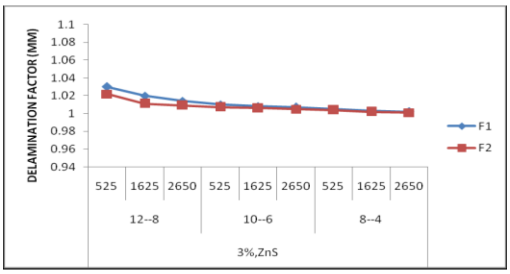


Figure:-10.Comparison of delamination factor against drilling speed, feed and drill geometry for Tio2 and Zns filled GFRP Composite.

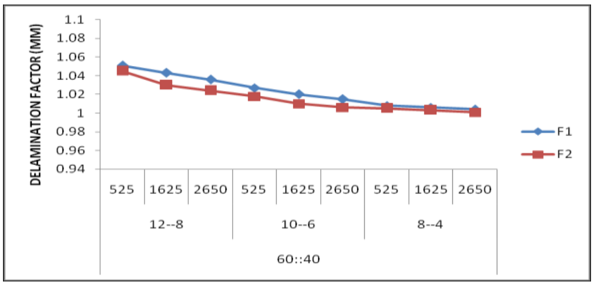


Figure:-11. Comparison of delamination factor against drilling speed, feed and drill geometry for Unfiled filled GFRP.

•Delamination factor decrease as speed increases for all the drill dia.
•12-8mm step drill shows higher damage factor fallowed by 10-6mm and 8-4mm step drill.
•As the filler percentage increased from 1% to 3% for TiO2 and 1% to 3% for ZnS the delamination factor values are less at all the speeds and has shown downward trend.
•Unfilled composite has shown more damage factor when compared to filled composites (TiO_2 and ZnS).
•ZnS Filled composite has shown less damage factor than TiO_2 filled composite.

VI. CONCLUSIONS

Based on the experimental results presented, the following conclusions can be drawn:
Considerable efforts have been focused on the better understanding of the phenomena associated with the cutting mechanism. Conventional high speed steel twist drills are used for drilling operation abrasion, was the principal wear mechanism and led to the elevation of the thrust force. The increasing of thrust force as a result of increasing drill pre-wear leads to destroying the matrix and micro-cracking at the ply interfaces, which deteriorates the surface finish. The principal factors used to evaluate the performance of the process are undoubtedly the damage caused at the drill entry or exit of the hole produced. The damage decreases with cutting parameters, which means that the composite damage is smaller for higher cutting speed within the cutting range tested. Delamination decreases as the spindle speed is elevated, probably owing to the fact that the cutting temperature is elevated with spindle speed, thus promoting the softening of the matrix and inducing less delamination. The effect of addition of filler material like TiO_2 and ZnS have shown that higher the percentage higher the values of thrust and lesser delamination factor, which insists that the better bonding of the filler material with the fiber matrix have increased the capacity of force sustainability.

REFERENCES

[1]. A.M. Abrao et.al,. Drilling of fiber reinforced plastics: A review, Journal of Materials Processing

Technology 186 (2007) 1–7.
[2]. W.D. Callister, Materials Science and Engineering: An Introduction, sixth ed., Wiley, Canada, 2002.
[3]. M.A. Boyle, C.J. Martin, J.D. Neuner, Epoxy resin, in: H. Hansmann (Ed.), Composites Compendium, ASM Handbook FB MVU, Werkstofftechnologien, Kunststofftechnik, 2003.
[4]. S. Jain, D.C.H. Yang, Delamination-free drilling of composite laminates, Trans. ASME J. Eng. Ind. 116 (4) (1994) 475–481.
[5]. H. Hocheng, C.C. Tsao, Analysis of delamination in drilling composite materials using core drill, Aust. J. Mech. Eng. 1 (1) (2003) 49–53.
[6]. H. Saghizadeh, C.K.H. Dharan, Delamination fracture toughness of graphite and aramid epoxy composites, Trans. ASME J. Eng. Mater. Technol. 108 (1986) 290–295.
[7]. Paulo Davim, J; et al: Experimental study of drilling glass fiber reinforced plastics (GFRP) manufactured by hand lay-up, 'Composites Science and Technology', vol. 64, 2004, 289-297.
[8]. Campos Rubio J; et al: Effects of high speed in the drilling of glass fibre reinforced plastic: Evaluation of the delamination factor, 'International Journal of Machine Tools & Manufacture', vol. 48, 2008, 715- 720.
[9]. Abrao, AM; et al: The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite, 'Materials and Design', vol. 29, 2008, 508-513.
[10]. Mohan, NS; et al: Delamination analysis in drilling process of glass fiber reinforced plastic (GFRP) composite materials, 'Journal of Materials Processing Technology', vol. 186, 2007, 265-271.
[11]. Paulo Davim, J; et al: Drilling fiber reinforced plastics (FRPs) manufactured by hand lay-up: influence of matrix (Viapal VUP 9731 and ATLAC 382-05), 'Journal of Materials Processing Technology', 155 –156, 2004, 1828–833.
[12]. Khashaba, UA; et. al: Machinability analysis in drilling woven GFR/epoxy composites: Part II – Effect of drill, 'wear,' Composites: Part A', vol. 41, 2010, 1130–1137.
[13]. Hocheng, H; Tsao, CC: Effects of special drill bits on drilling-induced delamination of composite materials, 'International Journal of Machine Tools & Manufacture', vol. 46, 2006, 1403–1416.
[14]. Khashaba, UA: Delamination in drilling GFR - thermoset composites,' Composite Structures', vol. 63, 2004, 313–327.
[15]. Hocheng, H; Tsao, CC: The path towards delamination-free drilling of composite materials, 'Journal of Materials Processing Technology', vol. 167, 2005, 251–264.
[16]. Hocheng, H; Tsao, CC: Effects of exit back-up on delamination in drilling composite materials using a saw drill and a core drill, 'International Journal of Machine Tools & Manufacture', vol. 45, 2005, 1261–1270.
[17]. Chung - Chen Tsao; Wen - Chou Chen: Prediction of the location of delamination in the drilling of composite laminates, 'Journal of Materials Processing Technology', vol. 70, 1997, 185-189.
[18].S. Basavarajappa;K.V.Arun; J Paulo Davim: Effect of Filler Materials on Dry Sliding Wear Behavior of Polymer Matrix Composites – A Taguchi Approach, Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.5, pp 379-391, 2009.

PATIL DEVGONDA
I am completed BE degree and Master's degree in Mechanical Engineering from VTU, Karnataka in the year 2011 and 2013. Currently I am working as an Assistance professor in Department of Mechanical Engineering at SMSMPITR, Akluj, and Maharashtra State, India.

Vijaykumar N Chalwa
I am completed BE in Mechanical Engineering at REC, Bhalki in the year 2009 from VTU and I got master degree in Machine Design at BEC, Bagalkot in the year 2011. Now I am working as a dean R&D and Asst prof. in Mechanical Engineering Department at SMSMPITR Akluj. I am having three years' teaching experience. And I published eight international journal papers.