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An Experimental Study on Drilling of Jute/Epoxy Composites with Ceramic Fillers

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ABSTRACT
An experimental investigation was carried out to evaluate the effect of drilling parameters (feed and speed) as well as the effect of ceramic fillers (SiC and Al_2O_3) on the thrust force, torque, delamination factor and hole quality in drilling of Jute/epoxy composites. Drilling experiments were conducted on Radial drilling machine (Batlibai Make) using HSS twist drill bit (118^o) of 10 mm diameter. The thrust force and drill torque during drilling were recorded using two channel drill tool dynamometer. Three different feeds viz., 0.13 mm/rev, 0.36 mm/rev and 0.71 mm/rev were selected for drilling. For each feed, experiments were conducted at three different speeds viz., 200 rpm, 500 rpm and 1000 rpm. It was observed that the thrust force increases with the increase in the feed rate for all the values of speed. It was also observed that, as the filler content increases, the thrust force increases at all the values of feed rate. The result showed that the torque increases with the increase in the feed rate. However, with respect to speed, the values of torque are found to be much scattered and no particular trend was observed as was seen in the case of thrust force. The delamination factor was found to increase with the increase in the feed rate. Al_2O_3 filled jute/epoxy laminates exhibit higher thrust force and torque compared to SiC filled jute/epoxy laminates. This indicated that Al_2O_3 filled jute/epoxy laminate is stiffer and harder and offers greater resistance to cutting than SiC filled jute/epoxy composite.
Keywords - Drilling, Jute/epoxy composite, Ceramic Filler, Delamination factor

I. INTRODUCTION

Machining involves the removal of any extra or unwanted material. Some of the most common machining processes are drilling, cutting, turning and milling. Earlier composites were machined like metals. But poor surface finish and faster tool wear led to further study on machining of composites. Although tools used for machining of metals can still be used for composite, care must be taken to optimise the levels of feed rate, thrust force and other factors. Metal tool tend to wear out faster when used for machining of fibre composites. Among the various machining processes, drilling is the most important one, as large number of holes may be required during manufacturing of structural components, for joining and other purposes. Drilling in fibre composites may lead to defects like, fibre pull out, delamination, poor surface finish etc. Drilling is most often a final operation during assembly and such defects resulting from drilling may lead to rejection of the part. The part being rejected at this stage will be an expensive loss. Hence there is a need to understand the issues associated with the drilling of fibre composites. Faria et al., [1] investigated the influence of the drilling parameters and tool material/coating (high speed steel and plain and coated carbide) on the thrust force and tool wear when drilling glass fiber reinforced epoxy composite. The results indicated that the high speed steel tool presented remarkable wear rates, resulted in a thrust force of 492N after 1000 holes. The cemented carbide drill presented superior wear resistance, with a thrust force of 147N after drilling 24 000 holes. Finally, the use of the titanium nitride coated drill did offer a significant contribution neither to the tool wear resistance nor to the machining thrust force.

Kilickap et al., [2] discussed on Optimization of cutting parameters on delamination based on Taguchi method during drilling of GFRP composite.The conclusion revealed that feed rate and cutting speed were the most influential factor on the delamination, respectively. The best results of the delamination were obtained at lower cutting speeds and feed rates. Jayabal et al., [3] conducted experiments to study the effect of point angle, spindle speed and feed rate on thrust force and torque using HSS twist drills. The optimum values of cutting parameters were determined to get minimum value of thrust force and torque.

Mihai-BogdanLazar and Paul Xirouchakis [4], conducted experimental study to determine the cutting loads distribution (axial and tangential) along the work-piece thickness and tool radius by analyzing the thrust and torque curves when drilling with 3 different drills carbon-fiber (CFRP) and glass-fiber (GFRP) reinforced composite plates. A wide range of cutting parameters is tested. The highest loads are found at the tool tip in the vicinity of the chisel edge for all cases. It is also found that the maximum load per ply varies mainly with the axial feed rate and tool geometry, while the spindle speed has little or no influence. Murugesh et al., [5] conducted an experimental study to evaluate the influence of TiO_2 and graphite as filler materials in glass/epoxy composite during drilling. Thrust force and delamination factor were evaluated using two different types of drill bits at different speeds. They found that higher the percentage of filler, lesser will be the values of thrust and delamination factor. Basavarajappa et al., [6] investigated the effects of spindle speed and feed thrust force, hole surface roughness, and specific cutting coefficient during drilling of glass epoxy composites. The drilling experiments were performed as per full factorial design for both glass epoxy composites and silicon carbide-filled glass epoxy composite materials. They concluded that the thrust force increases with the increase in feed for a specified value of spindle speed for both the composite materials tested. For a given feed, the thrust force is more or less the same with the increase in spindle speed and less sensitive to feed variations for the drilling of glass epoxy composite material without filler. On the other hand, the thrust force decreases with the increase in spindle speed for a given value of feed during drilling of silicon carbide-filled glass epoxy composite material. Dilli Babu et al., [7] and Aravindh et al [8] studied the factors and combination of factors that influence the delamination of drilled unidirectional hemp fibre reinforced composites and jute fibre reinforced composites, respectively, using Taguchi, ANOVA analysis to achieve the conditions for minimum delamination.

Though, extensive work on drilling of synthetic fibre composites was published in the literature, not enough work has been done till date on drilling of natural fibre based composites. In the present work, the effect of drilling parameters (feed and speed) on thrust force, torque and hole quality of jute /epoxy composite was investigated. The effect of SiC and Al_2O_3 fillers on hole quality of jute /epoxy composite has also been investigated.

II. FABRICATION OF COMPOSITE LAMINATES

Woven jute fabric (22 × 12) having surface density of 400 gsm was used as reinforcement material. The fabric was supplied by jute vendor, M/s Indarsen Shamlal Pvt Ltd, Kolkota. SiC of 32 μm and Al_2O_3 of 48 μm mesh size were used as filler materials. Resin system consists of Epoxy resin (LY 556) and hardener (HY 951) in the ratio 10:1. Both resin and hardener were supplied by Petro Araldite Pvt Ltd, Chennai, India. All the laminates were fabricated using hand lay up technique using a mold. The laminates were cured at 30 bar pressure under a hydraulic press for about 24 hrs. For the preparation of filled jute-fiber reinforced epoxy resin composites, the filler in the required proportion is added to the epoxy resin and thoroughly stirred to ensure uniform distribution of filler particles in the resin. The hardener is then added to filled epoxy resin and further stirred. The process of stirring was continued till the resin system is applied to last layer. All the composite laminates were fabricated with 8 layers and with 5%, 10% and 15% filler by weight of resin. One unfilled composite laminate was also fabricated for comparison purpose. Fig. 1 shows the unfilled and some of the filled jute laminates fabricated.

(a) Unfilled

(b) 5% Al_2O_3 filled

(c) **5% SiC filled**

Fig. 1 Jute Epoxy Laminates

III. EXPERIMENTATION ON DRILLING OF COMPOSITES

Drilling experiments were conducted on Radial drilling machine (Batlibai Make) using HSS twist drill bit (118^o) of 10 mm diameter. The thrust force and drill torque during drilling were recorded using two channel drill tool dynamometer (Contech Instruments Pvt Ltd). For each composition of laminate, three identical holes were drilled and average values are reported. Three different feeds viz., 0.13 mm/rev, 0.36 mm/rev and 0.71 mm/rev were selected for drilling. For each feed, experiments were conducted at three different speeds viz., 200 rpm, 500 rpm and 1000 rpm. Fig. 2 shows the experimental set up for drilling experiment. The specimen is mounted on the vice clamped over the dynamometer. Pad supports were used during drilling.

Radial Drilling Machine (Batlibai)

Drill force and Torque indicator

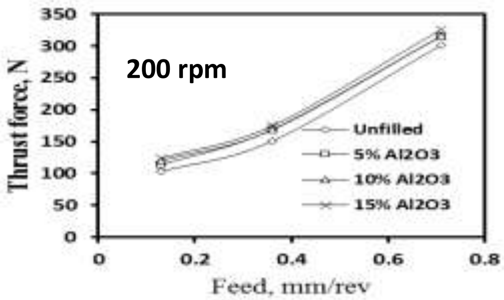
Fig. 2 Experimental set up for drilling

IV. RESULTS AND DISCUSSION

In general, the thrust and torque parameters mainly depend on the machining conditions employed, such as feed, cutting speed, tool geometry, machine tool, and cutting tool rigidity. A larger thrust force occurs for larger diameter drills and higher feed rates. In other words, feed rate and drill diameter are recognized as the most significant factors affecting the thrust force [9]. The thrust developed during drilling, leads to many problems in fiber composites such as fiber breakage, matrix cracking, fiber/matrix debonding, fiber pull-out, fuzzing, thermal degradation, spalling and delamination. Hence, the thrust force and torque developed in drilling operation is an important concern.

4.1 Effect of feed and speed on thrust force

The thrust force continues to increase as the drill tool penetrates into the material. It then remains almost at a constant value as the drill sinks into the work piece. The thrust force then rapidly decreases as the twist drill exists. The maximum value of thrust force indicated by the instrument is recorded. Figs. 3(a) -3(c) illustrate the effect of feed rate on thrust force for unfilled, SiC filled and Al_2O_3 filled jute/epoxy composites at different speeds. It can be seen from figures that the thrust force increases with the increase in the feed rate for all the values of speeds. The reason is that while increasing the feed rate the load on the drill bit increases, which in turn, increases the thrust force. It can be further seen that, as the filler content increases, the thrust force also increases at all the values of feed rate. This may be because of the reason that the presence of filler material increases the hardness of material which in turn increases the cutting resistance of the material. It can be noticed from the figures that the thrust force decreases with the increase in the speed for all types of laminates. Similar trend is obtained in drilling of sisal-glass epoxy composites [9]. At higher spindle speeds, material removal rate is high, but thrust force is low. Further, the variation in the thrust force is not significant beyond 500 rpm. At lower feed rate (0.13 mm/rev), a marginal increase in the thrust force is noticed for filled composites, beyond 500 rpm. A comparison of thrust force between two types of fillers indicates that Al_2O_3 filled composite exhibit higher thrust force than SiC filled composites. This indicates that Al_2O_3 filled jute/epoxy composite is much harder than SiC filled jute/epoxy composites. The maximum value of thrust force obtained for SiC filled composite (15%) was 311.45 N at 0.71 mm/rev feed rate and 200 rpm whereas it was 325.62 N for Al_2O_3 at 0.71 mm/rev feed rate and 200 rpm speed. For unfilled composite the maximum value of thrust force was obtained as 300 N at 0.71 mm/rev feed rate and 200 rpm speed. The minimum value of thrust force obtained for SiC filled composite (5%) was about 100 N at 0.13 mm/rev feed rate and 1000 rpm whereas it was about 110 N for Al_2O_3(5%) at 0.13 mm/rev feed rate and 1000 rpm speed. For unfilled composite the minimum value of thrust force was obtained as 96 N at 0.13 mm/rev feed rate and 1000 rpm speed.



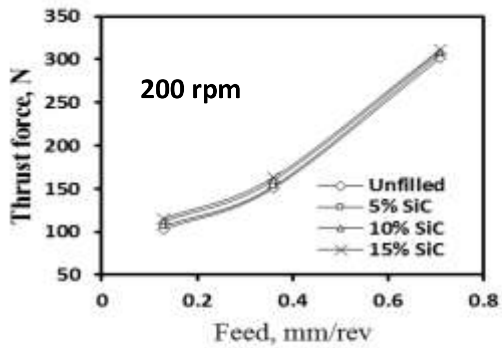
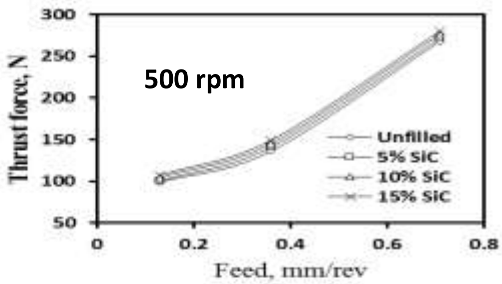


Fig 3(a) Variation of thrust force with feed at 200 rpm



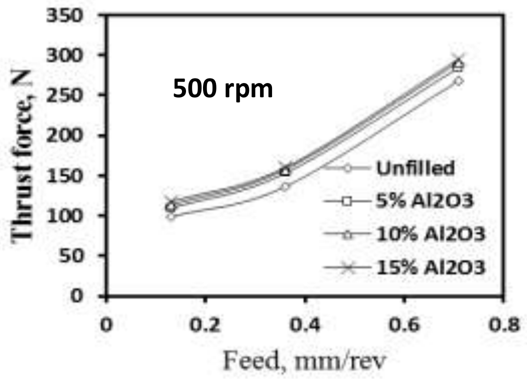


Fig 3(b) Variation of thrust force with feed at 500 rpm

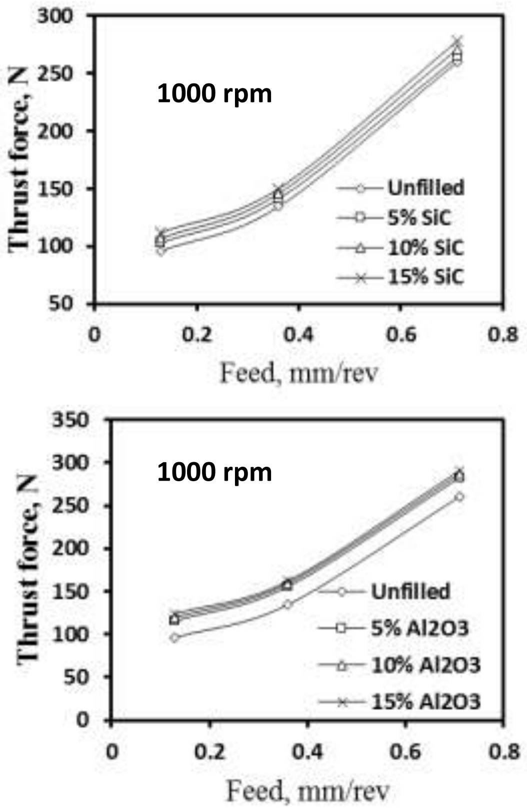


Fig 3(c) Variation of thrust force with feed at 1000 rpm

4.2 Effect of feed and speed on torque

The average of the maximum value of torque indicated by the instrument is plotted as a function of feed at different speeds for unfilled, SiC filled and Al_2O_3 filled composites in figures 4(a) – 4(c).

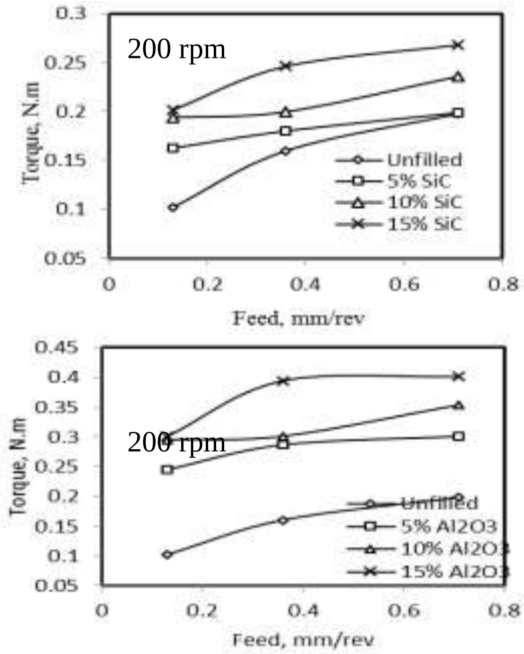


Fig 4(a) Variation of torque with feed at 200 rpm

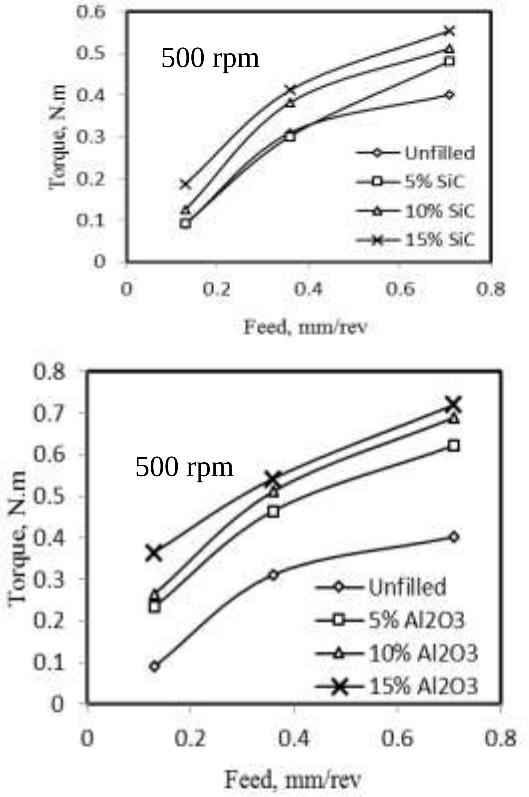
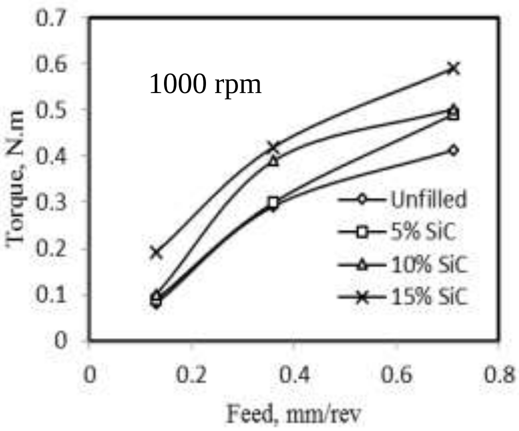


Fig 4(b) Variation of torque with feed at 500 rpm



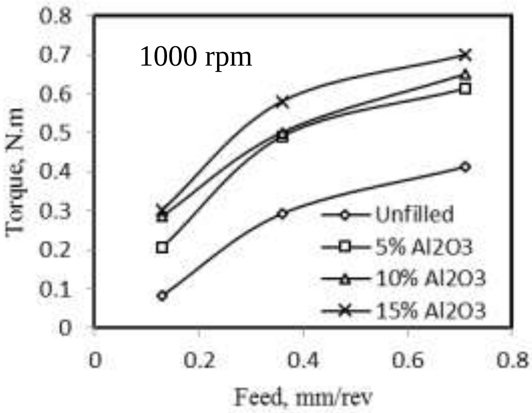


Fig 4(c) Variation of torque with feed at 1000 rpm

The values of torque during the drilling process are found to be much scattered and no particular trend was observed as was seen in the case of thrust force. It can be observed that the torque increases with the increase in the feed rate for all types of composites at all speeds. This is due to higher friction between the drill and the hole surface. However, at lower speed (200 rpm), filled laminates indicated marginal increase in the torque, beyond 0.36 mm/rev feed.
At lower feed rate (0.13 mm/rev), a continuous decrease in the torque with the increase in the speed was noticed for all types of laminates except for 15% Al_2O_3. At feed rates of 0.36 mm/rev and 0.71 mm/rev, the torque was found to increase with the increase in the feed rate up to 500 rpm, beyond which, marginal variation in the torque was noticed. In all the cases, the torque was found to increase with the increase in the filler content. This indicates that filled composites offer greater resistance to cutting. A comparison of torque between two types of fillers indicates that Al_2O_3 filled composite exhibit higher torque than SiC filled composites at all the speeds. This reveals that Al_2O_3 filled jute/epoxy composite is much stiffer and harder and offers greater resistance to cutting than SiC filled jute/epoxy composite.

4.3 Delamination factor and hole quality

After drilling, it is necessary to define criteria for the comparison of the delamination caused by different drilling parameters. Several ratios were established for damage evaluation. One of them is delamination Factor (Fd), which is defined as the ratio between the maximum delaminated diameter (Dmax) and hole nominal diameter (D) as given in equation (1).

$$F_d = \frac{D_{\max}}{D} \qquad (1)$$

Where, Dmax is the maximum diameter of the delamination/damage zone and D is the hole diameter (Figure 5).

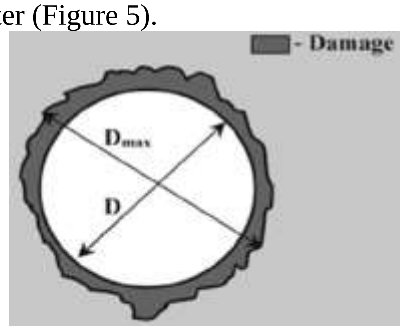


Fig. 5 Schematic of delamination

The delaminated diameter is usually measured using Tool Maker's microscope. However, in the present work, the delaminated diameter (at the entry) was measured using a magnifying lens to a reasonable accuracy. Typical plots of delamination factor at the entry versus feed rate are shown in figures 6(a)-6(c).

The delamination factor is sensitive to drilling parameters like feed rate and speed. The delamination factor increases with the increase in the feed rate at all speeds for all types of laminates. The delamination factor was also found to increase with the increase in speed. The delamination factor decreases with the increase in filler content. This indicates that the damage due to delamination is less in filled composite compared to unfilled composites. A comparison between the delamination factor plots for SiC filled and Al_2O_3 filled composite reveal that the delamination factor is marginally affected by the type of filler.

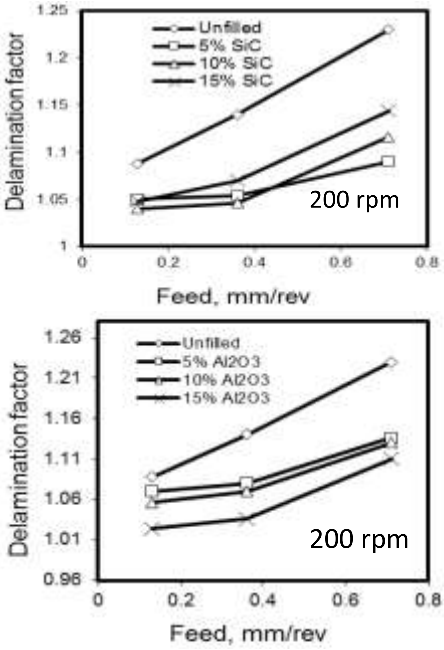


Fig. 6(a) Delamination factor versus feed rate at 200 rpm

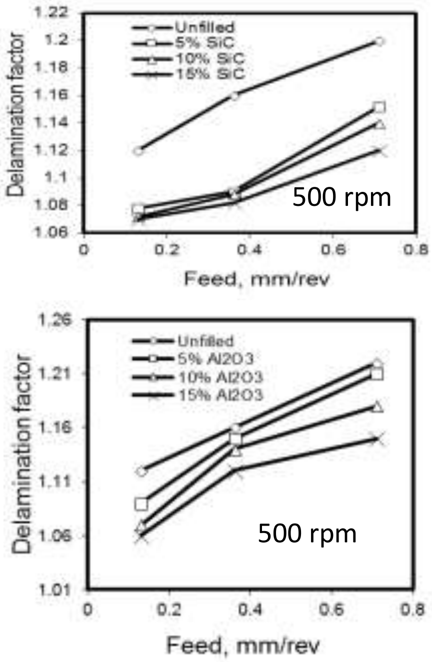


Fig. 6(b) Delamination factor versus feed rate at 500 rpm

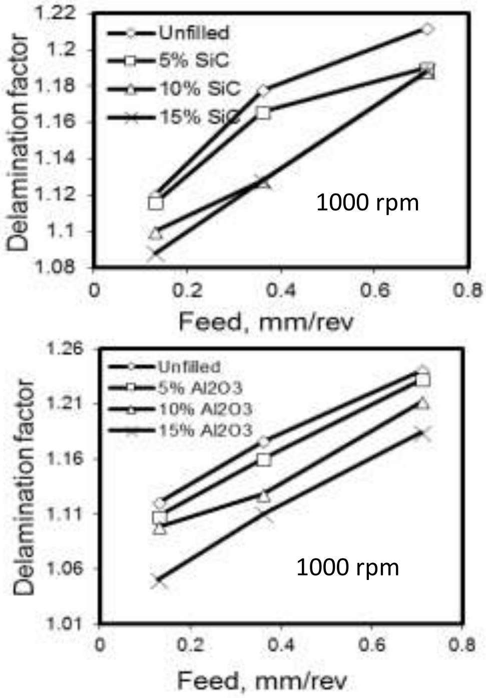
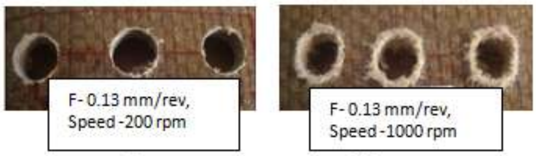


Fig. 6(c) Delamination factor versus feed rate at 1000 rpm

Figure 8(a) - 8(f) shows the samples with best and worst quality holes for SiC filled and Al_2O_3 filled composites respectively. The best quality holes were obtained at low speed (200 rpm) for all the laminates except 10% Al_2O_3 filled laminate, where the best quality hole was obtained at 500 rpm. For unfilled and 5% SiC filled jute/epoxy laminates, the best quality hole was obtained at 0.13 mm/rev feed rate. For 10% SiC, 15% SiC and 5% Al_2O_3 laminates, the best quality hole was obtained at 0.36 mm/rev whereas for 10% and 15% Al_2O_3 laminates, the best quality hole was obtained at 0.71 mm/rev feed rate.



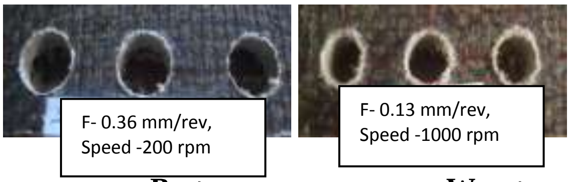
Best **Worst**

(a) Unfilled jute/epoxy composites

Best **Worst**

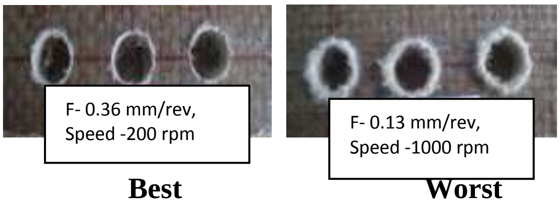
(b) 5% SiC filled jute/epoxy composites

(c) 10% SiC filled jute/epoxy composites



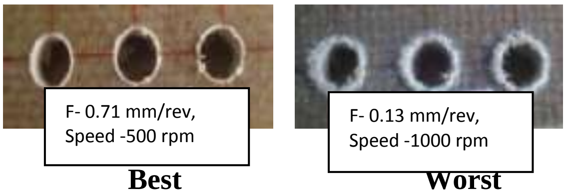
Best **Worst**

(d) 15% SiC filled jute/epoxy composites



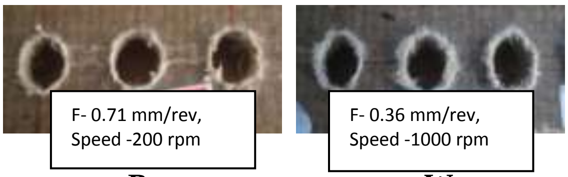
Best **Worst**

(e) 5% Al_2O_3 filled jute/epoxy composites



Best **Worst**

(f) 10% Al_2O_3 filled jute/epoxy composites



Best **Worst**

(g) 15% Al_2O_3 filled jute/epoxy composites

Fig. 8 Best and Worst quality holes in composites

V. CONCLUSION

The effect of drilling parameters (feed, speed) and filler (SiC and Al_2O_3) composition on thrust force, torque, delamination factor and hole quality of ceramic particles filled jute/epoxy composites was experimentally investigated. Based on the results, the following important conclusions are drawn.

1. Both thrust force and the torque increases with the increase in feed at all speeds. The thrust force decreases with the increase in speed from 200 rpm to 500 rpm at all feed rates. Beyond 500 rpm, the variation in thrust force is marginal.
2. At feed rate of 0.36 mm/rev and 0.76 mm/rev, the torque increases with the increase in speed from 200 rpm to 500 rpm beyond which the variation in torque is marginal.
3. Alumina filled jute/epoxy laminate exhibit higher thrust force and torque compared to SiC filled jute/epoxy laminates under identical conditions of drilling. This indicates that alumina filled jute/epoxy laminates are much harder than SiC filled jute/epoxy laminates offering greater resistance to cutting.
4. The delamination factor increases with the increase in feed rate. Best quality holes were in general obtained at lower feed rate and speed. Drilling in unsupported laminates resulted in significant damage at the exit. Pad support may be used to improve the quality of holes at the exit.
5. The surface of the drilled holes was found to be much rough leading to difficulty in measuring in the surface roughness.

REFERENCES

[1]. P.E. Faria, R.F. Campos, A.M. Abrão, G.C.D. Godoy and J.P. Davim, Thrust Force and Wear Assessment When Drilling Glass Fiber-Reinforced Polymeric Composite, Journal of Composite Materials, Vol. 42, No. 14/2008, pp.1401-1414.

[2]. E. Kilickap, Optimization of cutting parameters on delamination based on Taguchi method during drilling of GFRP composite, Expert Systems with Applications, 37 (2010) pp.6116–6122

[3]. S Jayabal and U Natarajan, Influence of cutting parameters on thrust force and torque in drilling of E glass/polyester composite, Indian Journal of Engineering and Materials Sciences, Volume 17, December 2010, pp.463-470.

[4]. Mihai-BogdanLazar and PaulXirouchakis, Experimental analysis of drilling fiber reinforced composites, International Journal of Machine Tools and Manufacture, Volume 51, Issue 12, , pp. 937-946, December 2011

[5]. M.C.Murugesh1 and K.Sadashivappa, Influence of filler material on glass fiber/ epoxyComposite laminates during drilling, International Journal of Advances in Engineering & Technology, Vol. 3, Issue 1, pp. 233-239, 2012

[6]. S. Basavarajappa and Abay Venkatesh, V.N. Gaitonde, Experimental Investigations on Some

Aspects of Machinability in Drilling of Glass Epoxy Polymer Composites, Journal of thermoplastic Composite Materials, Vol. 25—May 2012, pp. 363-387
[7]. G.Dilli Babu, K.Sivaji Babu and B Uma Maheswar Gowd, Optimization of machining parameters in drilling hemp fibre reinforced composites to maximize the tensile strength using design experiments, Indian Journal of Engineering and Materials Sciences, Vol.20, Oct 2013, pp 385-390
[8]. S. Aravindh and K. Umanath, "Delamination in Drilling of Natural Fibre Reinforced Polymer Composites Produced by Compression Moulding", Applied Mechanics and Materials, Vols. 766-767, 2015, pp. 796-800,
[9]. M. Ramesh, and A. Gopinath, "Measurement and analysis of thrust force in drilling sisal-glass fiber reinforced polymer composites", IOP Conf. Series: Materials Science and Engineering 197 (2017) 012056 doi:10.1088/1757-899X/197/1/012056