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DRILLING OF GFRP COMPOSITES WITH RUBBER AS A INTERMEDIATE LAYER

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Abstract— Polymer Matrix Composites (PMC) applications are increasing day to day, and many applications of composites include functional and non-functional parts in aerospace, marine and some structural engineering areas. In the field of aerospace the joining of composites are done through fastening, to mechanically fasten the composites parts need to be drilled. During drilling, machining process causes stress concentration effect, which leads to reduce the strength of components. In this present work drilling tests were performed to examine the machinability of GFRP composites with rubber as a intermediate material. Conventional drilling process with DOE method has been applied with different drilling parameters. As a result, the introduction of rubber material is not much significant on the drilling but process parameters effects the more.
Index Terms— Design of experiments, GFRP, intermediate material- rubber, process parameters and thrust force.

I. INTRODUCTION

Polymer matrix composite materials (PMC) have proved their work in the modern material field because of their low density and high strength to weight ratio. Generally, parts made of composites are produced to a near final shape, but additional machining operations are often required to facilitate component assembly. One of the important activity required for composite material to aid in its assembly is drilling of holes. Holes are typically drilled using twist drill. Drilling process results in destruction of fiber continuity along with generation of stress concentration in the material and delamination at the hole entry and exit [1]. The damage results in reduction of fatigue strength of the component. Machining of reinforced composite materials differs when compared to metals and alloys as composite is primarily heterogeneous and anisotropic. Hansda and Banerjee studies delamination associated with drilling of glass fiber reinforced polyester composites. High stresses in the rivets and bolts are attributed to poor surface finish of the drilled hole[2]. They optimize the process parameters like feed rate, material thickness and cutting velocity for minimizing delamination and improve surface finish of the drilled hole. Dhavamani investigates the drilling of Aluminium Silicon Carbide process by taking into account the effect of machining time on metal removal rate, surface roughness, volume fraction, surface energy, cutting speed, feed, diameter of cut and flank wear[3]. In their work they attempt to establish a comprehensive mathematical model for correlating the interactive and higher order influences of various machining parameters. Many of researchers [4] worked on the prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick 10% of silicon nitride component tool. They establish between the spindle speed, feed rate, and drill diameter with the generated thrust force and surface roughness in operation of drilling. In the present paper is focused on experimental methods to study the effect of process parameters during drilling of epoxy resin matrix reinforced woven glass fibers (CFRP) and embedded rubber sheet.

2. MATERIALS AND EXPERIMENTATION

2.1 Materials

The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6). This matrix was chosen since it provides good resistance to alkalis and has good adhesive properties. Rubber as a intermediate material. The reinforcement material employed was copped woven E-glass fabric.

2.2 Composite combinations

Hand lay-up technique of laminating the composites was employed for composite fabrication. Three material compositions of Glass/Epoxy (G-E) composites were chosen namely G-E-I, G-E-II and G-E-III with different volume fractions, the details of the percentage volume fractions of epoxy resin and glass fabric are shown in Table 1.

TABLE 1 COMPOSITE COMBINATIONS

Sl. No.	Combination or Volume Fractions excluding intermediate layer	Representation
01	Glass Fabric 40% + Epoxy 60%	G-E-I
02	Glass Fabric 30% + Epoxy 70%	G-E-II
03	Glass Fabric 35% + Epoxy 65%	G-E-III

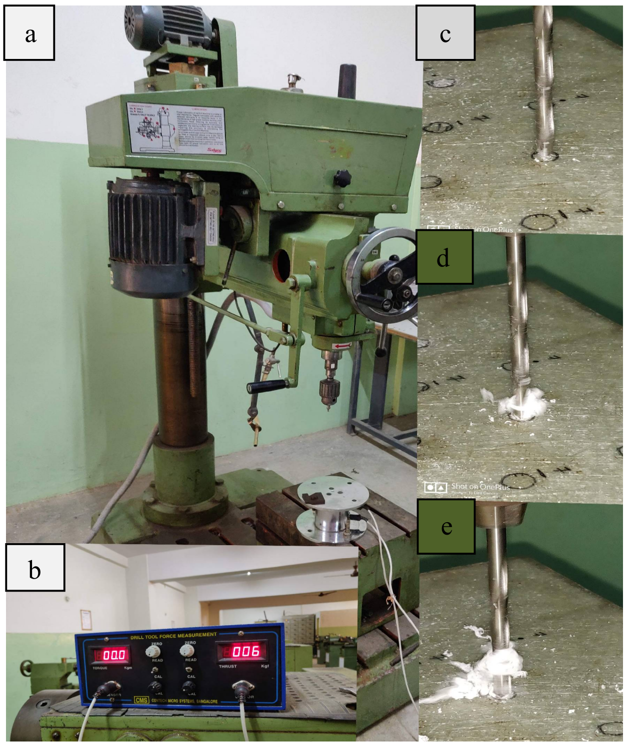


Figure 1. a. Radial drilling machine, b. drill tool dynamometer, c. at start point, d. medium speed and e. at high speed

2.3 Experimentation

Large plates of composites were made in order to carryout drilling operation with 6mm thickness. Drilling has been carried-out in a radial drilling machine. The drilling machine is been connected to a drill tool dynamometer which gives the digital reading. Speed of drilling (S), volume fraction or combination and drill tool diameters (D) are chosen as input parameters and thrust force is considered as the output parameter. During conducting tests the maximum Thrust recorded is considered as the resultant, and has been recorded. The summary of parameters considered for drilling is shown in Table 2 and the drill setup, at start point, at medium speed, full speed and drill tool dynamometer is shown in Figure1.

TABLE 2 SUMMARY OF PARAMETERS CONSIDERED FOR DRILLING

Levels	Combination	S in rpm	D in mm

1	G-E-I	500	6
2	G-E-II	800	7
3	G-E-III	1250	8

III. RESULTS AND DISCUSSION

In order to know the effect of drilling speed, volume fraction in the composite and drill size on the drilling performance, tests have been conducted. Drilling is carried out according to the combination of parameters provided by the L_{27} orthogonal array, results of which are discussed below. In DOE technique the total number of experiments to be conducted are reduced to large extent with the help of an array table, this table consists of permutation and combination of parameters under consideration. Speed of drilling, volume-fraction of composite, and drill tool sizes are the parameters under consideration, and 3 Levels of each parameters is chosen. An L_{27} Orthogonal Array is applied and drilling process is carried out according to combination of parameters given by the orthogonal array table and the thrust force is recorded in each of the case using a Drill-Tool Dynamometer. The parameters and levels chosen are given in Table 2 in the Experimentation part. The values of Thrust Force experienced during each combination of parameters are given in the Table 3. Drilling tests were conducted for varied combination of composites and for L_{27} orthogonal array, composite combinations, drilling speed and drill bit diameter are considered as the parameters. For each parameter 3 levels of values are fixed and thrust force in each combination was taken and tabulated. From the figure 2, it was observed that, in all the levels of drill diameter parameter as the speed increases, the thrust force also increases in the case of combination G-E-II and G-E-III but from G-E-I to G-E-II not much increase in the thrust force values. Larger thrust forces can be observed in the case of G-E-III and less in G-E-II. Similarly the bar charts were plotted for all the combinations of composites by keeping speed as a constant. As the drill diameter increases, the thrust force during the drilling process also increases in all varied compositions of composites, which is shown in the figure 3.

Table 3 DOE for E-Glass epoxy composites

Sl. No.	combination	Speed in rpm	Drill dia. in mm	Thrust in kgf
1	1	500	6	5
2	1	800	6	9
3	1	1250	6	10
4	1	500	7	9
5	1	800	7	10
6	1	1250	7	11
7	1	500	8	10
8	1	800	8	11
9	1	1250	8	14
10	2	500	6	5
11	2	800	6	8
12	2	1250	6	10
13	2	500	7	6
14	2	800	7	9
15	2	1250	7	12
16	2	500	8	8
17	2	800	8	10
18	2	1250	8	13
19	3	500	6	8
20	3	800	6	10
21	3	1250	6	12
22	3	500	7	10
23	3	800	7	12
24	3	1250	7	13
25	3	500	8	12
26	3	800	8	13
27	3	1250	8	14

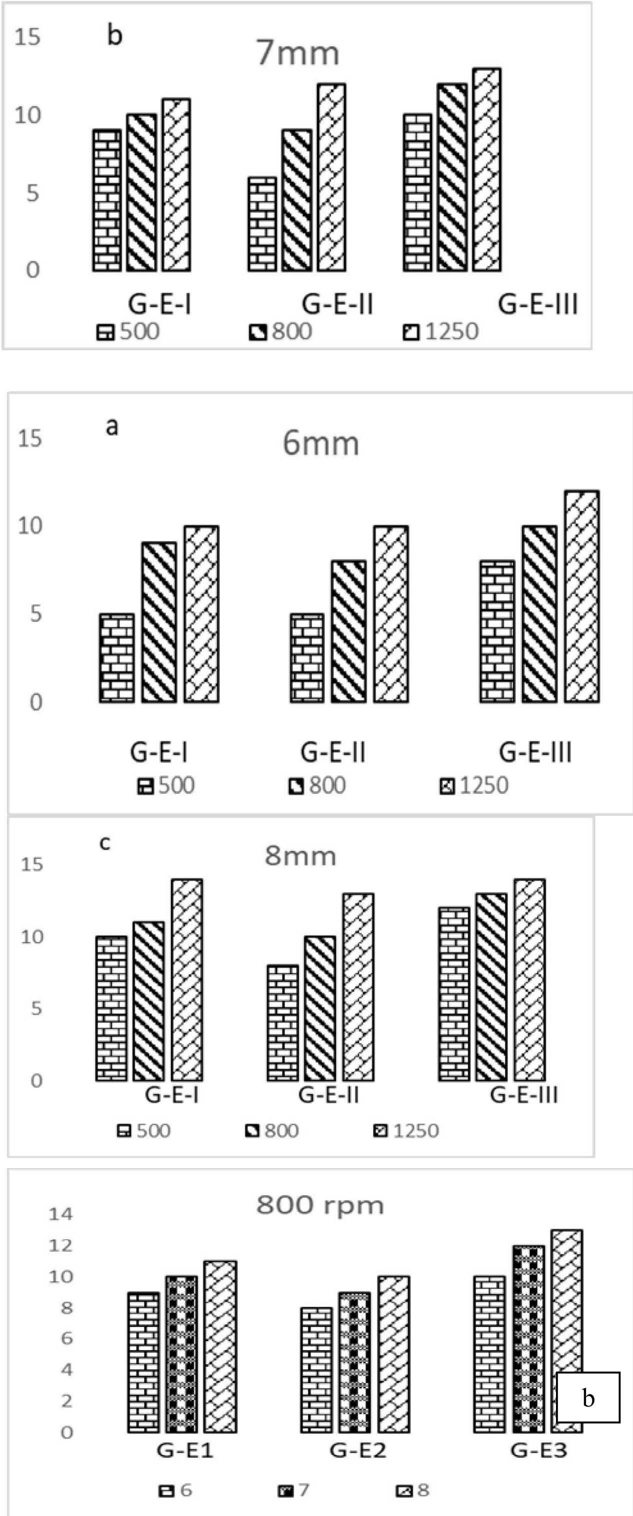
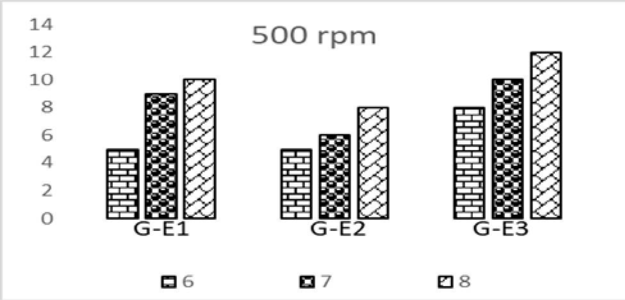


Figure 2. Bar charts showing thrust force versus speed for different drill bit diameter a. for drill dia-6 mm, b. for drill dia-7 mm, c. for drill dia-8 mm.



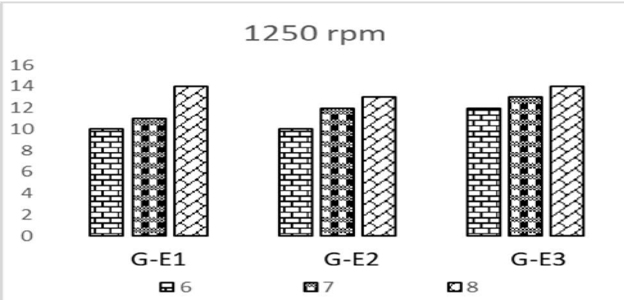


Figure 3. Bar charts showing thrust force versus drill bit diameter for varied speed a. for speed-500 rpm, b. for speed-800 rpm, c. for speed-1250 rpm.

Figure 4 shows the surface plot of thrust against drill diameter and speed of drilling. It can be observed from the graph, that thrust force will be less at lower speeds and smaller drill diameter and also it can be observed from the Figure that, at lower speeds and smaller diameter, the thrust experienced will be less, with the increase in both of these parameters will cause the thrust force to increase.

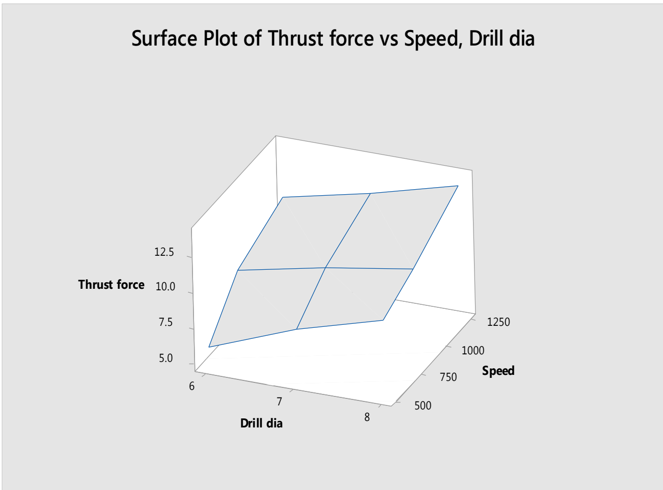


Figure4. Surface plot of thrust force against drill diameter and speed of drilling.

The contribution of each parameter is analyzed using Analysis of Variance (ANOVA) using commercially available ANOVA software. The contribution of each parameter is given in the Table 4 below, and the effect of contribution is found with a confidence level of 92%. The ANOVA table gives the % contribution of each parameter chosen individually, from the table it is clear that, drill speed plays an important role in glass epoxy composites; it contributes almost 46% for generating the thrust force where as drill diameter stands second with the contribution of around 27%. Combination of composites doesn't affect the process and increase in the thrust force and that can comparable with the figure 2 & 3.

Table 4 ANOVA for E-Glass epoxy composites

Factor	SS	d.o.f	Mean sq.	F	Pa
G-E	30.30	2	15.14	26.56	19.2
Speed	72.07	2	36.03	63.18	45.78
Drill dia	43.63	2	21.81	38.25	27.7
error	11.41	20	0.57	--	7.2
Total	157.41	26	--	--	100

IV. CONCLUSION

Drilling tests were conducted for varied composition of E-glass, rubber, Epoxy composites. Results have shown that, thrust force increases as the speed and drill bit diameter increases. With the introduction of rubber as intermediate layer, the thrust force was not exceeding beyond 14kgf. It may be due to experimental, instrumental error or due to perfectly elastic nature of rubber layer. It can be concluded that drill bit diameter and speed of the drilling process were the important parameter which plays dominant rule in the generation of thrust force during the drilling process of composites.

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