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CHARACTERIZATIONS OF DRILLING GLASS FIBER REINFORCED POLYPROPYLENE COMPOSITES

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ABSTRACT
Drilling is an essential operation in the assembly of structural frames of automobile and aircraft. The life of the joint can be critically affected by the quality of drilled holes. Machining of composites in general and fibre-reinforced thermoplastic in particular differ in many respects from metal cutting. The material is inhomogeneous and its machining behavior depends on fibre, matrix properties, fibre orientation, and type of weave and also based on fibre content and orientation properties of the composite. High viscosity of polypropylene (PP) makes it difficult for the impregnation of reinforcements and consolidation of composite laminates. Film stacking and hot compression molding is the technique used for producing glass fiber reinforced PP composites. Drilling experiments were carried with HSS drills on the resultant composite laminates. This study aims at finding optimum process parameters to minimize the drill thrust and consequent defects, Experimental investigations have been carried out with HSS drill on Glass fibre reinforced polypropylene composites. The parametric influence on thrust, specific cutting pressure, tool wear and hole size deviations and SEM (scanning electron micrograph) analysis of chip morphology and tool wear are also reported.

Keywords: Polypropylene, HSS drill, Thrust, Specific cutting pressure, Tool wear, hole size deviations and SEM

I. INTRODUCTION
Till early 1990ís fibre reinforced composites were based mainly on thermosetting polymers. In recent years, a rapid growth occurred in the fibre reinforced thermoplastics (FRTP) composites, yielding a unique combination of high performance, great versatility and processing advantages at favourable cost. The emergence of thermoplastics composites for wider applications was driven by technological advantages such as higher toughness, impact resistance, damage tolerance and recycleability. They offer faster processing cycles and high potential for automation because of the absence of curing reaction. The main difficulty in processing of glass fibre reinforced polypropylene is due to high melt viscosity of PP [4]. Hence, development of a suitable process and characterization of the resultant composites becomes vital for their usage. In the present work, film stacking process is used for producing glass fibre reinforced PP composites where the glass fibre fabric is impregnated by PP film under heat and pressure. Differential Scanning Calorimetry (DSC) was used to determine the melting range of PP. The tensile, flexural, interlaminar and impact properties of glass fibre reinforced PP composites are studied. The glass fibre woven roving (610 gsm) is used as reinforcement. The properties of thermoplastics composites are compared with those of thermoset matrix composites. The results provide useful information on the mechanical behaviour of fibre reinforced thermoplastics composites Drilling behaviour of FRTP composites is compared with that of fibre reinforced thermoset composites. No data is available on drilling behaviour of FRTP composites while a number of publications are available on drilling of thermoset composites.

II. CONVENTIONAL MACHINING:
Fibre reinforced plastic (FRP) composites are used extensively in automobile, aerospace and marine applications because of their high specific strength, high specific stiffness and ease of tailoring for specific requirements. Even though near-net-shape manufacturing of FRP composite structures is possible, joining is an unavoidable process because manufacturing of the whole structures by a single molding process may not be practicable in most cases. Drilling is one of the most important, frequently practiced and unavoidable machining operation used for

components of FRP composite structures. Conventional machining of fibre reinforced composites is difficult due to diverse fibre and matrix properties, fibre orientation, inhomogeneous nature of the material, and the presence of high volume fraction (volume of fibre over total volume) of hard abrasive fibres in the matrix [2]. The material and process related problems encountered in drilling of laminated composites are matrix burning, delamination, debonding, fibre pull out, tool wear, etc [3]. In the present work, the machinability of glass fibre reinforced with polypropylene (thermoplastic) matrix and polyester (thermoset) matrix are studied in terms of thrust, torque, tool wear and surface roughness. A sample of PP was tested using DSC to determine the melting range. The results of DSC are shown in figure.1. Based on this, the mold temperature is kept 50/C higher than the melting temperature of PP.These reinforcements are cut to mold size and weighed. The number of layers of reinforcements and matrix are decided in such a way that their weights are nearly in 50:50 ratios. The glass fibre woven roving (610 gsm) is used as reinforcement.

III. EXPERIMENTAL DETAILS

Materials: The thermoplastic polymer matrix used is polypropylene in the form of 0.5 mm thick film sheet. The process involved here is the film stacking of materials and hot compression molding [5]. Alternate layers of PP film and glass fabric were stacked in a mold of dimensions 310 X 310 mm held in between the platens of the hydraulic press. The platens were closed with stacked composite material and electrically heated to 220/C. Afterwards, the pressure was applied gradually upto 200 bar and maintained for 10 min. Then the material was allowed to cool in the mold to room temperature.

Figure.1 Differential Scanning Calorimetry (DSC) of PP

Table.1 Mechanical properties of thermoplastic

Testing: The laminate was taken out from the mold and the edges were trimmed to size. The laminate was cut to proper dimensions for evaluating various mechanical properties as per ASTM standards.

The tensile strength of the laminate was evaluated as per ASTM D638. In the fabric composites, the elastic moduli were determined from tensile tests considering that composite components (fiber and matrix) behave elastically until matrix cracking and additionally, transverse stiffness (fibers at 90/ to loading direction) contribution to axial stiffness is negligible [1]. Graphs were drawn for the elongation with increasing load. The slope of the curve was used for calculating the tensile modulus.

The flexural tests are conducted as per ASTM D 790. The width of the specimen was 12.7mm and the length was 80 mm (more than 16 times the thickness). The specimens for the Izod impact test are prepared with a V notch in the thickness side. Short beam tests were conducted for evaluating the Inter laminar shear strength. The specimen was mounted on two rollers with a span of around six times the thickness of the laminate. The load was applied centrally through another roller. Burn up tests were conducted for measuring the fibre volume fraction. Samples were weighed and burned in an oven at 600/C for 20 min to remove the polypropylene matrix before the residue was weighed again. The fibre volume fraction of the samples were estimated and averaged. Samples were cut for 50 X 50 mm sizes and weighed. The samples were immersed completely in water for specified duration i.e either 24 hours or one week. The samples were taken out from water and the faces were swiped with cotton. The samples were weighed again and the difference in weight was measured as fraction of the dry weight of them. This was expressed as percent moisture absorption.

Drilling

Drilling experiments were carried with drills of dia 6 mm and 118/ point angle on glass fibre WR / PP composite laminates using a Deckel ñ CNC milling machine. The cutting parameters used: cutting speed 2500 rpm and feed 0.1 mm / rev. The cutting thrust and torque were measured using a drill dynamometer , charge amplifier and CRO arrangement. The tool wear was measured using Tool Makerís Microscope. The surface roughness of machined holes was measured using a Mitutoyo surf test instrument. The variation of thrust and torque with number of holes is shown in figure

2. The variations of surface roughness with number of holes are illustrated in fig.6 and fig.3 and 4.

IV. RESULT AND DISCUSSION

Effect of number of holes drilled on thrust and torque: Apart from drilling conditions, the form stability of the drill (in terms of number of holes drilled) also influences the thrust and torque. The influence of the number of holes drilled on peak thrust and torque is illustrated in Figs. 2, respectively. It is seen that there is a gradual rise in the thrust force with the number of holes drilled up to around 120 holes, which is usually associated with steady state of wear of the cutting wedge. At higher cutting speed, generation of heat will be higher leading to softening of matrix of the work material and thereby the tool experiences reduction in order of thrust and torque as seen in illustrations. Observations on thrust and torque indicate best possible machining condition occurs with drilling speed of 37.68 m/min and feed of 0.15 mm/rev. Also around 45 N thrust, a change in trend of variation can be seen. This can be the critical thrust for drilling of this composite. It occurs around 80 holes of drilling with lower drilling conditions, while it is around 80 holes of drilling with 47.1 m/min of cutting speed.

Figure 2. Feed Vs Peak thrust and torque variation for different speed

Effect of number of holes drilled on drill wear

While drilling multi-layer laminated composites, the difference in cutting directions to glass fibres is expected to affect largely the cutting mechanism and the tool wear. The cutting edge experiences force fluctuation as well as abrasion due to material heterogeneity and relatively gliding of harder glass fibres, respectively. In addition, the drilling point experiences intensive adhesion/sliding contact with the chip and machined surface. This results in different forms of wear. Wear form is found almost uniform on the flank side, whereas on the chisel edge side it is quite insignificant. Thus average flank wear was used as the index in tool wear measurement. Typical variation of flank wear on the cutting lips while drilling thermoplastics composites with varying combination of cutting conditions is illustrated in Fig. 3. The trend is almost similar to thrust forces illustrated earlier. There is a progressive wear up to about 120 holes, which can be attributed to normal performance of the drill point. Beyond 80 holes there is a rapid increase in tool wear is observed. Relatively higher order wear can be seen with drilling condition of 30.14m/min drilling speed and feed of 0.05 mm/rev. Also under such conditions, a rapid increase in wear occurs, after around 0.7 mm of wear.

Figure 3. No. of holes and feed Vs tool wear for different speed

Figure 4. of hole drilled Vs Peak thrust for different speed and feed

(a) (b)

Figure 5. (a) Feed Vs specific cutting pressure for different speed (b) Hole size deviation Vs No. of hole in different speed condition

Effect of cutting variables on hole quality: Hole characteristics can cause stress concentration especially at the fastener assemblies, leading to premature failure. Hence it is essential to establish optimum methods to ensure a consistent quality level in hole generation in drilling of composites. The quality of the hole produced can be described in many ways It can be classified as geometrical error and errors regarding work piece material properties. Regarding the former, the error in hole roundness and hole size have been emphasized as important quality criteria. During drilling, the fibres are bent initially by the action of the cutting edge and then get shear fractured, and after the shear failure, the fibres try to return to reset, causing tightening around the drill and thereby the size of the drilled hole is less than the drill diameter. This phenomenon is observed commonly in drilling of laminated Thermoplastics composites. However, in the case of drilling Thermoplastics composites with woven fabric with higher percentage of fibre content, such shrinkage is not found, since the woven fabric does not allow the fibres to bend much thus minimizing the relaxation of the fibre. This is in contrast to the presence of glass fibres in the form of bundle in the case of composites with BD/low fibre volume fraction, associated with hole shrinkage. An over size of 5ñ15 mm was observed while drilling with fresh drill. As the number of holes drilled increased, some reduction in oversize is observed. This can be attributed to the wear of drill point. It is seen that depending on the drilling conditions, relatively steady state/trend in hole size can be seen after 80ñ120 holes drilled. This can be possibly due to observed reduction in thrust beyond 80 holes. It is seen that with drilling conditions of 37.68m/min m/min of speed and feed of 0.15mm/rev mm/min, as a whole, controlled hole size variation results. From the above illustrations, it can be seen that with thrust constrained drilling, it is possible to control hole size variation.

From the observations of thrust and variation in hole size, it is seen that even after
drilling of around 120 holes, the thrust force and the variation in hole size do not change much, instead they tend to settle towards uniform, which is rather unusual. However, from the tool wear characteristics, it can be seen that tool wear increases rapidly beyond drilling of 80 holes. This shows that the change in the geometry of the cutting wedge due to tool wear ought to have dissipated considerable heat into the work piece and thereby softened the work material which in turn could have resulted in reduced thrust. In addition, the increase in temperature can also has result in thermal shrinkage of the matrix material thereby leading to insignificant change in the hole size.

Quality of entry and Exit: In the both extreme cutting conditions, i e high cutting speed and low feed rate and low cutting speed and high feed rate ,The produced hole is neat. No significant difference or irregularity exits. How ever, quality of hole entry is effected as shown in figure High cutting speed generates a large amount of heat. Being further assisted by the low co-efficient of thermal conduction and low transition temperature of plastics, the accumulated heat stagnates around the tool edge and rising temperature, causes excessive material flow behind tool edge, thus produces fuzzy and rough cuts.

Study on SEM photograph: The Fig shows 6 SEM micrograph of the fracture surface of the GF/PP composites. In the case of the composite with high fibre content (48 vol.%), the composite with high fibre content shows lower impact absorption energy. Also, it is reported that the plastic deformation of the PP matrix makes a large contribution to the impact energy absorption. The impact absorption energy during fibre pull-out process is proportional to the length of pulled-out fibre and layer bending, cohesive tampering, bending more
Figure 6 (a) SEM of chip (b)Fibre breakage during tensile testing

Figure 6©Surface roughness of hole surface (d) SEM of cutting edge of drill

However, larger amount of glass fibres also prevents plastic deformation of PP matrix. In addition, due to contact among the glass fibres, fibre breakage happens more frequently than in the case of lower fibre content. It is observed that sometimes the reinforcements were broken (Fig.6(a)) and also indicate material GF/PP ductile, deform and fail during tensile test. In Fig 6(b) we can observe that erosion high on circle layer of hole and reflection is low, sick erosion on polymer. Fig 6(c) indicate quality of hole surface after drilling, we can serious defect on surface because of fine blanking it effect the material during assembly by means of polymer given reduced friction and no sliding between the materials. Also bending, delamination more on entry than exit In Fig 6(d) indicate tool wear during drilling, edge deformation more it shows clearly figure and polymer stick on to tool when drilling. Polymer act as a lubricant during drilling it melt at high speed drilling and smooth hole surface

There is a significant rise in the trend of thrust variation around 45 holes in GF/PP composites. This may be attributed to the tool wear. The tool has worn out for the entire length of cutting lip on the flank with a maximum wear of 130 microns and the other lip has severe deformations with a larger one measuring 210 microns along the lip and 90 microns normal to the lip. In the GF/PP composites, there is a steady

increase in thrust over a large number of holes. The cutting edges have only deformations over the cutting edges. There is a slight increase in the thrust and surface roughness of machined hole around 230 holes.

V. CONCLUSIONS:

- The thrust is found to be of lower order as compared to thermoset composites and in the range of 30 -70N for all cutting conditions. This could be due to considerable plastic deformation with much energy absorption by the thermoplastics composites prone to thermal softening.
- The variation of thrust with number of holes in general shows progressive trend with a small rise over a long range.
- The chip morphology explain plastic deformation and shearing in machining

- The presence of polymer film on cutting wedge can act as lubricant layer which minimize the tool wear in machining of composites. The tool wear is found to be less for larger number of holes as compared to thermoplastics.
- Unlike the case of hole shrinkage in thermoset composites, the oversized holes result in the thermoplastic composites.
- The surface integrity and hole quality is good for a wide range of cutting conditions. The polymer melt covers the fibre ends producing good surface finish.

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