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A Review on Micro Drilling of Glass Fiber Reinforced Polymer Composites

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Abstract— Drilling can be defined as a metal removal process in which holes of required size & depth from minimum to maximum can be obtained with the help of a rotary cutting tool called the drill bit. The requirement of micro holes in various applications such as filters in the medical field and circuit boards have resulted in the development of Micro Drilling operation as they reduce the production time and cost. In this paper, the literature survey on various challenges in the micro drilling of GFRP such as tool wear, drilling parameters (speed, depth of cut and feed), de-lamination, use of coated and uncoated tools, tool materials and their micro structural characterization has been performed. From the past few years, it can be concluded that there is a very small work that has been done in the area of micro drilling of GFRP. Today there is a need for the development of various advanced techniques to fulfill the need at a better cost and reduced time.
Keywords— Micro drilling, GFRP, delamination, tool materials.

I. INTRODUCTION

Over the past few decades, composite materials have been dominating the world in almost all the sectors. From cradle to coffin all are being manufactured with these composites. Due to the peculiar mechanical properties such as high strength to weight ratio, low weight, fire, chemical and weather resistance, design flexibility and manufacturing economy, these composite materials have been used in various applications in medical, aerospace, automobile, military, and so on. Composites are the assembly of reinforcement and a matrix which are physically separable. The individual properties of the reinforcement and the matrix and totally summed up in the laminate.

Drilling is a machining operation in which holes of required dimension (size and depth) can be obtained with the help of a rotary tool called drill bit. Due to the advancements in science and technology this operation has gained a special importance in the field of manufacturing. Though holes can be made with the help of various other operations, conventional drilling has its own place. Micro drilling is one of the upcoming machining operations in which holes of micro sizes can be drilled. Generally, drilling of 0.03mm to 3mm diameter is categorized into micro drilling operation. Typical applications of micro drilling are in manufacturing of circuit boards, manufacturing of filters in medical applications and several other applications in automobile, aerospace and marine industries.

TABLE 1.COMPARISON BETWEEN MICRO AND MACRO MACHINING OPERATION

S. No	Parameter	Micro Machining	Macro Machining
1.	Minimum chip thickness is obtained when	Depth of cut should be greater than critical chip thickness.	Chip thickness before cut should be greater than chip thickness after cut.
2.	Microstructural level	Grain size	Grain boundary
3.	Tool dimensions	Tools less than 5mm	Tools greater than 5mm
4.	Vibrations caused produces	Distortion in micro level	Distortion in macro level
5.	Speed	Very high speeds of about 50,000rpm	Low to medium speeds of about 10,000rpm.
6.	Feed	Very low feed of about 0.01-0.05mm/min	Average feed of above 0.1mm/min

Glass fiber reinforced composites come under an organic type of polymers. In the present study micro drilling of GFRP has been studied. Drilling the composite materials is a very serious issue to be considered because of their high abrasiveness, heterogeneity and anisotropy which results in delamination, fibre pull out, spalling and hole shrinkage. The various process parameters which play a vital role in minimizing the effect of resulting effects have been evaluated. The process parameters that are studied are tool wear, speed, depth of cut, feed, use of coated and uncoated tool, tool material, tool geometry and the delamination effect. Delamination occurs at the hole entry and exit as shown in the figure. Results of delamination are fiber pullout and fiber protrusion, which majorly affect the Geometric tolerances such as cylindricity, circularity and surface roughness. This effect can be minimized with the help of specially designed tools with a better geometries, appropriate feed, speed and tool materials.

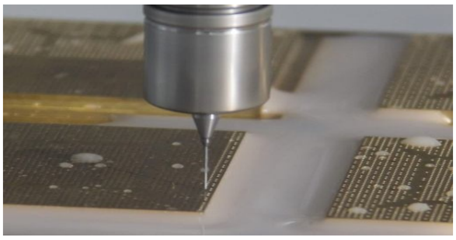

Fig. 1.Micro drilling operation

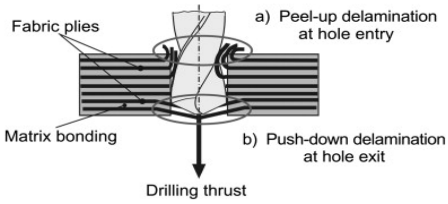

Fig. 2.Delamination during drilling of FRP

II. LITERATURE SURVEY

MeltenAltinKaratas and HasanGokkaya [1] reviewed the machinability of CFRP and GFRP composite materials. The failure mechanisms in machining GFRP and CFRP were studied. From the literature survey it was concluded that in conventional machining, feed is proportional to compressive forces induced and hole quality and surface roughness are proportional to speed and inversely proportional to feed. In unconventional machining process the cutting forces are directly proportional to maximum crack length.

Suresh R et.al., [2] has evaluated the effect of process parameters on drilling of Borosilicate glass and GFRP composites with abrasive jet machining. Input parameters are Standoff distance, pressure, abrasive grain size and time taken, and the output parameters are MRR and taper angle. SiC are the abrasive particles used and air is the medium. The results obtained are pressure is directly proportional to MRR and inversely proportional to taper angle. MRR was high when pressure was 6 bar and size of abrasive is 200µm and standoff distance is 0.5mm

Kishore Kumar Panchagnulaet.al., [3] has reviewed the current state drilling of FRP and Nano polymer composite laminates. The parameters considered were tool geometry, drilling forces, tool material, surface roughness, delamination aspects and tool wear. Cutting forces were analyzed in detail where spindle speed varied from 500-1500 rpm, drill diameter varied from 5-10mm and the feed was 0.01-0.1 mm/rev. Paper concluded that while drilling of Nanocomposite laminates, coated carbide tools and angle drills can minimize the delamination defect.

GautamSankar Tate etal. [4] has studied the process parameters and the tool parameters that are responsible for minimizing the delamination effect. The drilled holes were examined with the help of tool makers microscope and the delamination factor has been evaluated. The parameters that are selected were speed, depth of cut and feed and the performance measures were surface roughness, delamination factor and material removal rate. The paper concluded that by optimal selection of the process parameters the performance measures can be improved.

N. ZarifKarimietal., [5] evaluated the cutting parameters responsible for delamination of woven GFRP with functionalized multi-walled carbon nanotubes. Various process parameters such as cutting speed, feed rate, weight % carbon nanotubes and drill size are evaluated with the help of Taguchi's L16 orthogonal array and ANOVA study was conducted for optimization of parameters. The results showed that feed rate has a significant effect (about 68%) on delamination factor. While Nano content and spindle speed have an effect. Optimum parameters determined are 0.1% Nano content, 530rpm spindle speed, 0.04mm/rev feed rate and 5mm drill diameter.

Dhiraj Kumar et.al [6] has studied the delamination effect in GFRP with the use of three dissimilar tools with different geometries and materials. Laminates were prepared with vacuum bagging method. Spindle speed was 2000rpm and drill diameter was 6mm. Three drills used were helical flute drill made of HSS, solid carbide eight facet drill and carbon tipped straight shank drill. Image processing software was used to examine the holes. The conclusions made were helical flute drill was not suitable for asymmetric laminates. Though carbon tipped straight shank drill was suitable asymmetric laminates, the delamination factor was compared with solid carbide eight facet drill is higher. Hence solid carbide facet drill has shown good surface roughness and delamination factor.

E. Uhlmann et.al., [7] studied the comparison between axial drilling and helical milling of carbon and glass fiber (hybrid) composite laminates in terms of quality of the workpiece and processingtime of workpiece. Generally, fiber pull out and protrusion are some of the major complications while drilling of FRP's. Some extent of these defects can be controlled by high speed drilling (here 60000rpm). The tool used for drilling was made of uncoated cemented carbide of diameter 5mm. Similarly, helical milling has been carried out to produce the holes. The observations made were, the time required for milling was less than drilling for producing 10 holes of 5mm diameter, 5 holes of 12mm diameter and 5 holes of 8mm diameter. In terms of quality the fiber pull out and protrusion was low in case of helical milling.

SathishRaoUdupiet.al., [8] evaluated the criteria behind the minimization of tool wear during drilling of GFRP. The tool material used was uncoated HSS drill of 10mm diameter. Tool wear was observed with a metallurgical microscope of magnification 500x. A wear mechanism map was plotted and safety wear zone (zone of minimum wear) was identified where spindle speed should be between 1200-1590 rpm and feed should be 0.01-0.1 mm/rev.

Widodoet.al., [9] has examined the hole roundness obtained while drilling Austenitic Stainless Steel (AISI 304) with solid carbide micro drill of 0.8mm. DOE was conducted with 23 factorial design. Roundness was measured with CMM. From the results obtained it was concluded that hole roundness majorly depends on feed and spindle speed. When spindle speed was high, the effect of depth of cut was low and hence hole was accurate.

R. Domingo et.al., [10] investigated the delamination polymeric materials such as Poly Amide, Poly Ether Ether Ketone and Poly Tetra Fluoro Ethane (Teflon). The feed rate was 300-500mm/min and speed was 6000-8000rpm. A tool was specially designed which was made of Tungsten Carbide with a diamond point with a point angle of 900, helix angle of 350 and drill diameter of 6.3mm. ANOVA study was conducted, and significance of each factor was evaluated. Student-Newman-Keuls test was applied to confirm the ANOVA result. The results found were, the drill design can be applied for Poly Amide, Poly Ether Ether Ketone and Poly Tetra Fluoro Ethane.

U Ashok kumar et al. [11] investigated on a micro hole in workpiece material they took SS316 as workpiece material and study on micro hole through Die sinker EDM by un conventional machining process by optimized the input process parameter is current, pulse off time, pulse on time using Design of Experiment by Taguchi L9 orthogonal array method with copper of 300μm diameter electrode were studied. Optimization were made a conclusion that Electrode Tool wears rate of experiment and predicated values difference were up to 0.00021 mg could be achieved by this process and a combination of A3B1C3 i.e. current of 0.8 Amps, T-on 6μs, T-off 8μs. From Signal to noise ratio the optimum parameters combination value is 32.207

From the literature survey it can be said that there is a little research that has been conducted till date in micro drilling operation. The machining conditions, tool specifications, geometrical tolerances, micro structure analysis and optimization techniques that were used are listed above. Based on the literature survey the parameters that are to be optimized for micro drilling process are listed below.

TABLE 2.PARAMETRIC OPTIMIZATION FOR MICRO DRILLING PROCESS

Parameter	Description
Spindle Speed	Very high range of speeds are required to avoid damage to the tool
Feed	Very low feed is required to produce a smooth finish
Tool materials	Generally, HSS is not preferred. Tungsten Carbide is expected to serve the purpose better.
Coating on the tool	A coated tool produced a better finish.
Use of a backup support	Using a backup support reduces the effect of delamination to a maximum extent.
Tool geometry	Using a specially designed tool shows a better performance
Work environment	A lubricated type of drilling produces a good finish by absorbing all the heat produced from the cutting zone.
Laminate thickness	Laminate should be hick enough to withstand the thrust force produced.

III. FUTURE SCOPE FOR RESEARCH AREAS

Compared to conventional drilling a limited work has been done on micro drilling of composites, especially Glass Fiber Reinforced Polymer Composites. Apart from delamination, fiber pullout and fiber protrusion, the effect fiber debonding, presence of voids, use of filler materials, use of various fiber orientations and barely visible impact damages on micro drilling of the laminate should be studied. The effect of various process parameters on these defects should be evaluated while machining these laminates.

IV. CONCLUSIONS

Due to the various advantages of composite materials, the application of these materials in almost all the fields is growing day by day in the development of Micro Drilling operation as they reduce the production time and cost. A literature survey on Micro drilling of GFRP composites has been studied. The various process parameters such as feed, speed, tool geometry, tool material are studied and their effect on geometric tolerance and micro structure has been evaluated. Use of various optimization techniques such as Taguchi's Orthogonal Arrays, ANOVA, Artificial Neural Networks have been used for determination of the influence of each process parameter on the machining process was studied.

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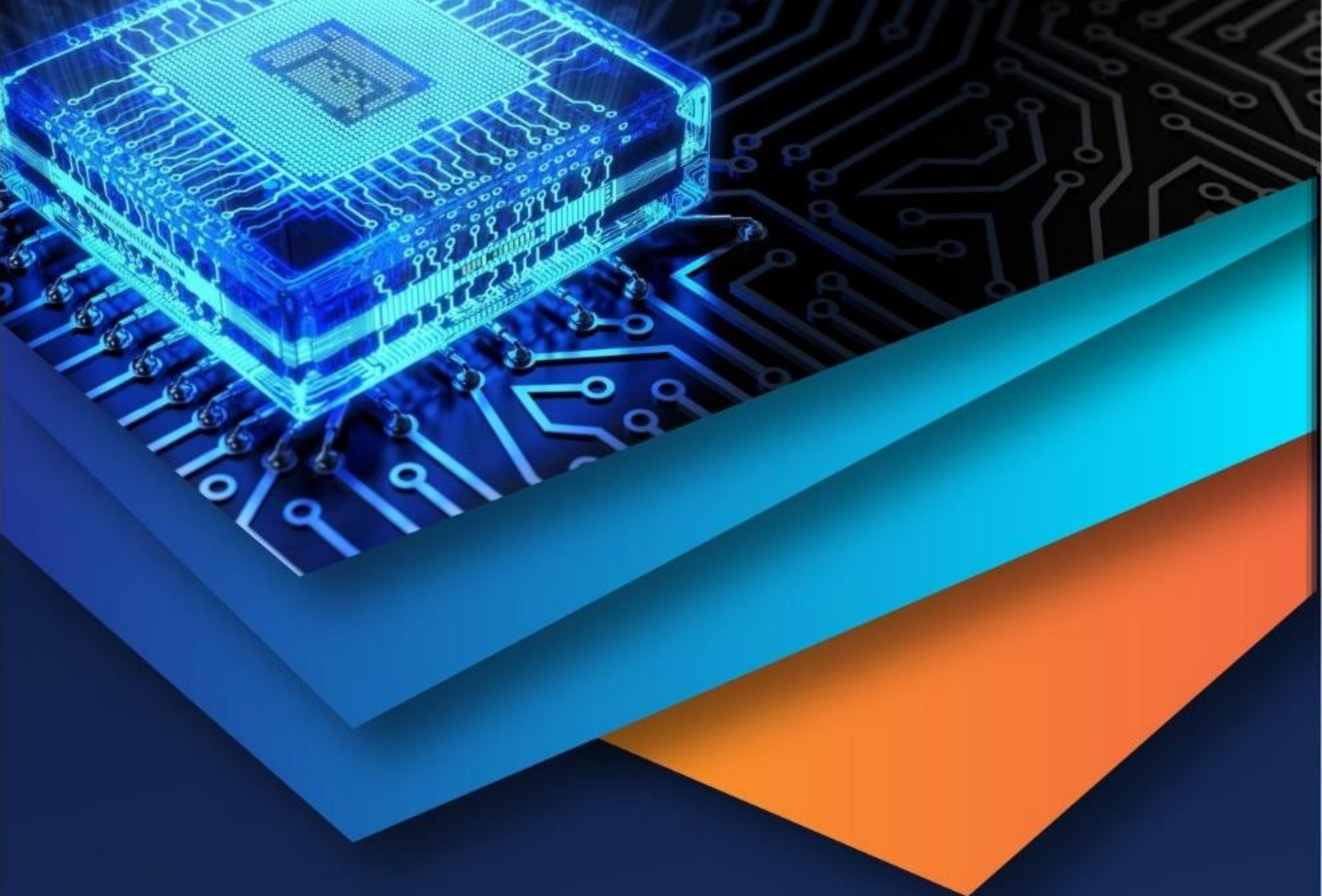

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