A Review on Drilling of Different Types of Composite Laminates

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Abstract:Carbon fiber reinforced plastic materials play a major role in the applications of aeronautic, aerospace, sporting and transportation industries. Mechanical drilling is unavoidable and it is important final machining process for components made of composite material. Delamination is one of the major defects to be dealt with. This review paper showcases the importance of an adequate selection of drilling tools and machining parameters to extend the life cycle of these laminates as a consequence of enhanced reliability. Before we analyze the cause and effects of delamination we need to understand the behavior of different composite materials towards mechanical drilling. Such detailed aspects of drilling on various composite materials will benefit from a comprehensive literature review on drilling of composite materials. This review paper summarizes the characters exhibited by different composite materials over drilling.

I. INTRODUCTION

A Composite material (also called composition material or shortened tocomposite, which is the common name) is a material made from two or more constituent materials with significantly different physicalor chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure.A fiber reinforced composite (FRC) is acomposite building material that consists of three major components- (i) the fibers as the discontinuous or dispersed phase, (ii) the matrix as the continuous phase, and (iii) the fine interphase region, also known as the interface.

Glass fiber reinforced plastics play a vital role in many engineering applications as an alternative to various heavy exotic materials.In GFRP polymeric composites, the matrix of polymer (resin) is reinforced with glass fibers.Composite materials are finding advancedtechnology applications in avionics, automobile, and machine tool industries and so on due to their excellent properties such as high specific strength, high stiffness, high damping, low thermal expansion, and good dimensional stability. Glass fiber reinforced plastic, an advanced composite material, which are widely used in a variety of applications, including aircraft, robots, and machine tools.[1]

Machining operations like drilling are frequently needed in composite structures, as the use of bolts, rivets or screws is required to join the parts. Generally, machined parts have poor surface appearance and tool wear is higher. One of the problems related with composites' machining is the nature of the fiber reinforcement, which is usually very abrasive and causes rapid tool wear and deterioration of the machined surfaces.One of the most common problems relates to the need of drilling without delamination. Several studies on this subject have been reported, and it is therefore now possible to envisage a drilling strategy that keeps delamination risk at a minimum.[2]

II. LITERATURE REVIEW

A. *Electrical Discharge Abrasive Drilling Of Hard Materials Using A Metal Matrix Composite Electrode*

The machined surfaces of mold steel HPM50 and tungsten carbide P20 were examined by scanning electron microscopy (SEM) and their surface roughness measured by a profilemeter.[3]

For electrodes Metal matrix composites can be placed into three categories namely particulate, fiber, and laminar, based on the shapes of the reinforced materials.[3]

SiCp was selected as the reinforcement. Copper was selected as the matrix material for its high electric conductivity.Higher material removal rate and lower surface roughness can be achieved when suitable electrode rotating speed, SiCp size, and working current are chosen.[3]Experimental results showed that when using HPM 50 mold steel as the work piece, the EDAD machining efficiency was 3 to 7 times that of normal EDM operation.[3]

B. Drilling of Hybrid Aluminium Matrix Composites

This paper exhibits the influence of cutting parameters on thrust force, surface finish, and bur formation while drilling in Al2219/15SiCp and Al2219/15SiCp-3Gr composites.Metal matrix composites (MMCs) are currently being used in advanced automotive and aerospace applications. The performance of MMCs is superior to conventional materials in various aspects such as improved physical, mechanical, and thermal properties that include high specific strength and modulus, low density, high abrasion and wear resistance and high thermal conductivity.[4]

The composites were fabricated using the liquid metallurgy method. The tools which were used are commercially available carbide and coated carbide drills.Drilling experiments on Al2O3 aluminiumbased metal matrix composites using different drill materials and found that the abrasive particles cause excessive flank wear.It is found that HSS tools are not suitablefor machining composite materials and it is reported that HSS is not a suitable tool material due to its high abrasive wear, as they observed a flank wear of 1 mm for drilling a single hole at 0.1 mm/rev at 3000 rpm in MMC.[4]

The results indicate that inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the thrust force. Feed rate is found to have significant influence on the thrust force, surface finish, and burr height. The surface roughness(Ra) value increases with the increase in feed rate and decreases with the increase in cutting speed. The chip formed in drilling Al2219/15SiCp-3Gr composite is of discontinuous type making it easier for chip disposal.

C. Drilling of AL/SICP Metal Matrix Composite

This paper presents process parameters for surface roughness in drilling of Al/ SiCp metal matrix composite. The experimental studies were conducted under varying parameters. The optimum drilling parameter combination was obtained by using the analysis of signal-to-noise ratio. Through statistical analysis it is determined that significant factors were the feed rate and tool type.Spindle speed, drill point angle, and heat treatment have been determined being insignificant factors on the surface roughness. drill type was about 15 times more important than the feed rate for controlling the surface roughness.[5]

The effects introduced by tool type and feed rate on surface quality in this study were larger than the effect of spindle speed, heat treatment, and drill point angle.

D. Trepanning Drilling of the Ceramic Composite Armor Using A Sintering Diamond Tool

An experimental study on drilling a typical laminated ceramic composite armor by using a special sintering diamond thin wall trepanning tool has been carried out to analyze the drilling parameters.To improve the machining efficiency, process parameters including the spindle speed and the axial force have been optimized through drilling experiments.[6]

The surface quality of a hole wall machined has been studied, and an advisable measure is given.High speed steel or carbide tipped bits are used for drilling FRP, and by using high-speed machining high-quality holes can be obtained with comparatively high machining efficiency.[6]

The machining efficiency increases evidently with an increase of the spindle speed. The reasons for the tool skidding at hole exit are summarized as two points, namely the non-uniform wear of the tool lip and the bad conditions of discharging chips and cooling at hole exit.[6]

E. Drilling of A Hybrid Al/Sic/Gr Metal Matrix Composites

Drilling tests are conducted with diamond like carboncoated cutting tools on Al/20%SiC/5%Gr and Al/20%SiC/10%Gr. This paper is an attempt to understand the machining characteristics of the new hybrid metal matrix composites.[7]

The results indicated that inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the cutting force. The surface roughness value is proportional with the increase in feed rate while inversely proportional with cutting speed in both composites. The lowest cuttingforce value (324 N) was recorded at drilling of Al/20% SiC/10%Gr. Surface finish is poor at drilling of Al/20%SiC/10%Gr composite compared to Al/20%SiC/5%Gr composite.[7]

F. Machinability Study of Hybrid Nanoclay Glass Fibre Reinforced Polyester Composites

Glass fibre reinforced polyester composites(GRP) and hybrid nanoclay and glass fibre reinforced polyester nano composites (CGRP) refabricated by vacuum assisted resin infusion technique.The optimum mechanical properties are obtained for CGRP with 3wt.% nanoclay. Three types of drills (carbide twist drill D 5407060, HSS twist drill BS-328, and

HSS end mill (4 flutes "N"-type end mill RH-helical flute)) of 6mm diameters are used to drill holes on GRP and CGRP.[8]

Three different speeds (600, 852, and 1260rpm) and two different feeds (0.045, 0.1mm/rev) are selected as process parameters. The effect of process parameter on thrust force and delamination during drilling CGRP is analyzed for optimizing the machining parameters. The delamination factor is low for the optimum process parameter (feed = 0.1mm/rev and speed 852rpm). Microstructural analysis confirms that at higher feeds, delamination is low for CGRP drilled with carbide tools. In order to analyze the effect of nanoclay in CGRP on tool wear, 200 holes were drilled on CGRP samples with 3wt.% nanoclay, and the tool wear is analyzed under optimized parametric condition. Tool wear is high in HSS twist drill compared with carbide drill. The presence of nanoclay also accelerates the tool wear.[8]

G. Effects of Drilling with Varying Spindle Speed Using Different Thickness of GFRP on the Damage Factor

Vacuum assisted resin infusion method is use in fabricating the glass fiber reinforcement polymer samples, where different thicknesses of GFRP were used in the drilling process with different spindle speed. The results show that the temperature influences the damage factor of the drilling. Higher spindle speed will generate higher temperature that softens the matrix thus generating lower damage factor. The suitable drill bit temperature is between 150-200°C. Thickness of the GFRP samples also influences the temperature generated and the damage factor. Thicker GFRP will have lower damage factor compares to thinner GFRP due to its stiffness in withstanding pulling and pushing force generated during the drilling. When drilling thicker GFRP, higher temperature is recorded while generating lower damage factor.[9]

H. Evaluation of Drilling Al/SiC Composites with Cryogenically Treated HSS Drills

This paper evaluates the performance of cryogenically treated M35 high-speed steel(HSS) twist drills in the drilling of Al/SiC metal matrixcomposites (MMCs) produced with the hot pressing methodin terms of dimensional accuracy, surface roughnessand tool life. The cutting tool (Ct), cutting speed (Vc) and feedrate were taken as control factors. The Taguchi method L18(21×37) was used for the determination of optimum controlfactors.The optimum combinations of the control factors for Da and surface roughness were determined as A2B2C1 and A2B1C1, respectively.First order predictive models were developed with linear regressionanalysis, and the coefficients of correlation for Daand Rawere calculated as R2=80.5 and R2=79.0, respectively.[10]

The results of the conducted experiments enlightened the fact thatcryogenically treated drills exhibited better performance thanthe untreated drills in terms of the dimensional accuracy andsurface roughness of the MMCs. In the tool life experiments,when compared to the conventionally heat treatedtools, the cryogenically treated tools gained increasesin tool life of 256 and 161 % at the cutting speeds of 15 and25 m/min, respectively.Moreover, on both cutting tools, builtupedge (BUE) on the chisel edges and flank wear on thecutting could be observed.[10]

I. Drilling Quality of Printed Circuit Board

The drilling machinability of PCB fixture hole is studied;effects of drilling parameters on thrust force, drilling temperature and quality are discussed in detail. The experimental results show that resin will be melted during the drilling process. The increase in spindle speed will lead to drilling temperature rise.[11]

The spallingof glass fibers result in the generation of hole wall roughness. The depth of exit burrs is increased with the elevated feed. Drilling experiments are carried out with 9 drill bits which have different point angles, flue angle, helix angles and length of chisel edges. Analysis of variance(ANOVA) is carried out for hole quality parameters. Desirability function method is used in multiple response optimization to obtainthe optimal tool geometry parameters.[11]

J. Studies on Electro Discharge Drilling of an Al2O3–TiC Composite

An experimental study onEDD of 0.4-mm diameter holes with an aspect ratio of 20 inAl2O3–TiC, using copper electrodes are carried out. Peak current (Ip),pulse-on time (ton), and pulse-off time (toff) are varied asindependent variables.[12]

The results are elaborated and combinedwith the observation of the morphology of drilled surfaces,leading to a process description where the pulse power is theruling factor. The adoption of peak current, voltage, andpulse duration as independent variables, common in literature,fails in the discrimination between process regimes thatoccur in distinct power ranges. The effects regard both theelectrode and the workpiece.[12]

III. CONSTRUCTION

The following conclusions can be drawn with regards to the drilling of composite material:

- Feed rate is found to have significant influence on the thrust force, surface finish, and burr height.
- The effects introduced by tool type and feed rate on surface quality in this study were larger than the effect of spindle speed, heat treatment, and drill point angle.
- Inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the thrust force and cutting force.
- The machining efficiency increases evidently with an increase of the spindle speed. The reasons for the tool skidding at hole exit are summarized as two points, namely the non-uniform wear of the tool lip and the bad conditions of discharging chips and cooling at hole exit.
- Feed rate is the main factor influencing the cutting force in both composites. The surface roughness value is proportional with the increase in feed rate while inversely proportional with cutting speed in composites.
- Delamination is low for CGRP drilled with carbide tools.

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