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OVERVIEW STUDY OF THE MACHINING OF COMPOSITE MATERIALS

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ABSTRACT

Composite materials' machining is not that easy to carry out due to the intrinsic physical structure, nature of composites and the high abrasiveness of their reinforcing materials. In this paper, an elaborated review on the problems encountered in the Composite materials' machining has been done and narrated.

KEYWORDS: Machining, Grinding, Drilling, Composite Material

INTRODUCTION

Overview Study of the Machining of Composite Materials

Composite materials' machining is not that easy to carry out due to the intrinsic physical structure, nature of composites and the high abrasiveness of their reinforcing materials. This causes severe damage in the work pieces and development of wear in the cutting tool. Conventional machining processes such as grinding or drilling can be applied to composite materials, provided proper tool design specifications and operating procedures are followed. In this paper, an elaborated review on the problems encountered in the Composite materials' machining has been done and narrated.

The Machining of Composite Materials

The machining of composite material is very essential and it needs standardised to facilititate process design. Manna and B Bhattacharayya [1] investigated on machinability of silicon carbide particulate aluminium metal matrix composite during turning with fixed rhombic tools. They experimented on the. cutting speed, depth of cut on the cutting force and surface finish criteria. They also investigated on the combined effect of cutting speed and feed on flank wear and influence of cutting speed, feed rate and depth of cut on the tool wear. And the chip formation and BUE (Build of edge) also they analysed during their experimentation.

They selected Al/SiC-MMC of 80mm diameter bar as a work piece and they used T-Max-U Positive rhombic insert type tool and it's specification CCGX-90-T3-04-Al-H10. The tool material is uncoated tungsten carbide (WC) (HW-K10) [8]. For this experiment they used Turret Lathe with the cutting speed rang 20—225m/min, feed rate range 0.14-1.00mm/rev and the depth of cut range 0.25-1.5mm. During turning operation the cutting force and the feed rate measured by Kistler Piezoelectric Dynamometer of Kistler type 5501 with load amplifier of Kistler type 5007 [1].

During the experimentation of machining Al/SiC-MMC, they observed [1] that flank wear rate is high at low cutting speed due to the generation of high cutting force and formation of BUE. Cutting speed zone between 60 and 150m/min is recommended for machining Al/SiC-MMC, and the generation of BUE increase the actual rake angel at low cutting speed. They also found that the increment of cutting force which may in turn increase the cutting tool were and they also find Feed is less sensitive to the flank wear as compare to the cutting speed and the high speed, low feed and low depth of cut are recommended for better surface finish.

A. K Sahoo et al [2] discuss on machinability assessment in turing operation on MMC with carbide insert. In their experiment they use Al reinforced in SiCp metal matrix composite as work piece and as a tool they used TiN coated carbide tool for turning operation, this operation done in dry condition. After machining they observed the chips which were metallic partial blue, and built up edge formation, they also observed the variable flank wear. Feed is found to the most significant parameter for surface roughness.

The tool were is very important for any kind of machining it reduced the tool life. During drilling operation the size error of drill hole create various problems in assembling. Taskesen et al. [3] research about this problem, their main aim was to evaluated optimized based cutting parameters, and the multiple characteristics of tool wear, and drill hole size error. In their experiment they used Taguchi's L27. They also observed that in drilling the abrasive wear and built of edge both are found in drill tool, the flank wear of the cutting tool also found. This were mostly depends upon particle mass fraction, followed by feed rate, drill hardness and spindle speed. In their experiment the TiA1N coated carbide drills showed best performance. As result they revealed that optimal combination of the drilling parameters could be used to obtain both minimum tool wear and diametral error.

For mechanical joining composite material create various problems, some times during machining the continuous fibre of composite material damaged and it is reduced the strength load carrying capacity, and this type of damage made fracture in composite material. G. Belingardi et al. [4] experimented on this fact, they observed during drilling on ply wood and glass fibre reinforced polymer specimen the holes are damaged, in their experiment comprehensive notch-edge damage analysis performed with the help of recording test video, digital microscope, polariscope and layer by layer SEM analysis. As experimental observation they observed the effectiveness of finding damaged zone is dependent on the damage observation technique. Predicted damaged zone by numerical solution are in good agreement with experimental observations.

Tool wear also a problem in machining of fibre reinforce polymeric composites. This problem mainly cause of hardness and abrasive nature of synthetic fibres. Umar Nirmal et al. [5] experimented on this issue and they evaluated that, T-BFRP composite caused less damage on testing equipment compared to CSM-GFRP composite, with surface roughness of stainless steel counter face being lower by about 5%.

The Grinding of Composite Materials

Grinding operation is used in large scale for surface finish than general conventional machining in industries. In grinding operation the metal removal rate (MRR) is very low than other conventional machining and surface finish is very good than other. The grinding wheel removed microchips from work piece by sharp abrasive grids with very high cutting velocity. The sharp abrasive grids are strongly held in grinding wheel by suitable bond material [6].

In the case of composite material is also needed grinding operation for good surface finish like other materials. A proper process such as grinding operation makes the surface free from surface damage as like as cracking, splintering and pulling out of reinforced particles. Z Zhong et al. [7] in their experiment they experimented about how to reduce the surface damages as like as cracking, subsurface damaging, pulling of reinforced materials etc. For their experiment they used 2618/Al2O3 10% and 2618/ Al2O3 with 2618 aluminum alloy matrix. And they used grinding wheels with SiC grain two types one is for rough grinding and another for fine grinding. As a result they observed through the rough grinding surface finish value Ra were scattered but in case of fine grinding any cracks and defects are not found on ground surface and the sub –surface damage, rate of rare cracked particle were also be reduced.

The Drilling of Composite Materials

Drilling operation is a commonly use for making cylindrical hole. The drilling operation also used for making tapering hole and also used for enlarge and finish existing holes. And the tool use for making hole called drill bit, the drill bit available in various shapes and size, various material and application. Commonly HSS twist drill with two flutes is used for machining and other types of drill bit are also be used as respect the job piece design requirement. Other drill bits likes as centre drills, step drills, taper drills, spade drills, straight-shank small drills, long or deep-hole drills, slot drills, carbide drills, gun drill etc [8].

In the case of composite reinforced material drilling, delamination is the very serious concern. Navid Zarif Karimi et al. [9] studied the effect of drilling parameters, the delamination factor and compressive residual strength of drilled laminates. The delamination factor is just the ratio of diameter of drilled hole diameter or drill bit diameter and the damage hole diameter. The drill hole diameter denoted 'D0' and the damaged hole diameter denoted as 'Dmax' and the delamination factor denoted as 'Fd' and it is write as ' Fd=Dmax/D0'[9]. For their experiment they used Taguchi method, and the work-piece made by hand-lay-up technique. The job material made of resin reinforced with uni-directional E-Glass fibre. And the composite sample approximately 6mm thickness, 13plies and had 50% fibre volume fraction and the plate area is 100mm X150mm. For their experiments they used the machine tool FP4M vertical machining center with maximum rpm 2500, and the feed rate 200mm/min. The drill bit used standard HSS twist drills of 5mm diameter and 30° helix angle. In this experiment the coolant was not used, so to avoid the tool wear, drill bit was changed after five experiments. The thrust force will measured by Kistler 9255B piezoelectric dynamometer. For the recording of AE events the acoustic emission software AWE in a data acquisition system (PAC) PCI-2 with a sampling rate of 1MH used. The experiment design based on Taguchi method. In this study they selected three base factors for preliminary research, the factors were drill point angle, cutting velocity, and feed rate. After the experiment the conclude that, the feed rate can effected on thrust force when other two factors (cutting velocity and drill point angle) are negligible. The drill point angle and the feed rate felled significant effect on the adjusted delaminaton. Whereas the drill point angle and the cutting speed were negligible almost there feed rate affected on compressive residual strength and it is better obtained when the feed rate was lower. There was a qualitatively linear relation between compressive residual strength and damaged area. Different feed rate showed the delamination factor depend on thrust force during drilling.

The delamination factor really a serious problem to drill composite work-piece, it is actually depends on the thrust force during drilling by the twist drill bit [9]. It is found that the size of the delamination zone has been shown the thrust force developed during drilling [10]. The numerous studies have examined the delamination during drilling [11-14]. And the thrust force depends on cutting condition (cutting speed, feed rate). To minimized delamination factor manufacturer try so many practices as like as, reduce feed rate and increase spindle speed. But H Hocheng et al. [15] tried to find out different way to reduce thrust force and delamination factor also. They used special types of drill bits as like as saw drill, candle drill, core drill and step drill. And they also tried to compare the effect of critical thrust force and delamination factor during drilling by these special types of drill bits. They used composite laminates made of woven WFC200 fabric carbon fibre for their experiment. The laminates were cured in an autoclave at 150°C and 600KPa, this composite plate cut into 60mm×66mm×6mm. This experiment carried out on vertical machining centre. The mean thrust force measured by K9273 four component piezoelectric, and Kistler 5007 charge amplifier. And measured data stored on TEAC DR-F1 DEGITAL RECORDER. HSS made with 10mm diameter twist drill, saw drill, candle stick drill, step drill were used for machining. The drilling operation conducted in totally dry condition. The step drill diameter ratio was 0.2, the core drill diameter plated with diamond. The drill diamond grit size #60 at the front end. For the experiment they selected spindle speed 900 and 1000rpm, the selected feed rate for this experiment were 0.003, 0.005, 0.008, 0.0088, 0.009, 0.01, 0.011, 0.0111, 0.012, 0.0122 and 0.0133 mm/rev. After drilling the holes are scanned by ultrasonic C-Scan and produced images and they observed that the delamination factor increased with thrust force. They also watched that traditional twist drill provide low threshold of the compared to special drill [15]. And also they found the correlation between thrust force and feed rate for various drills, and watched in selected feed rate twist drill showed highest thrust force than saw drill and core drill. And candle stick drill and step drill showed lowest thrust force compare with twist drill in selected feed rate. This proved that the twist drill has more delamination factor than types of other types of drill bit. After their experiment they compare their results with theoretical prediction of critical thrust force at the onset of delamination. In their experiment they used various types of drill bits with different geometry and different level of thrust force. At last of their experiment they conclude that the traditional twist drill shows high dilamination factor in higher feed rate, but compare with twist drill the among five drills the core drill, candle stick drill, saw drill and step drill, makes holes with higher feed rate than twist drill and the delamination factor is almost low than twist drill. That means, the core drill, candle stick drill, saw drill, step drill makes delamination free hole with high feed rate, which is not possible in twist drill. This is shorter cycle time of drilling operation without delamination [16-20].

The delamination factor obviously depends on the thrust force of drilling, to measure or minimised the delamination factor the thrust force must be calculated. The magnitude of thrust force can help to obtain the delamination factor and manufacturer easily done the delamination free holes. The different nature of damage harms the lifespan of the assemblies. In the literature [22] according to three zones of appearance: at the entry of the hole – by the peeling oh the higher plies of laminate, on the wall of the hole- by the fibre wrenching and the resin degradation and at the exit of the hole by the delamination of the last plies (mainly due to thrust force of the cutting tool) [23, 24]. The authors in [25] shows the defects induced by the choice of machining conditions have a large influence on the ultimate strength of bored tubes requested in fatigue. Similary, the absolute cutting modulus is inversely proportional to the defect severity linked to the choice of machining parameters [26]. Zitoune et al. [27] studied on how the thrust force which can control delamonation in their study. Within their study they use two types of UD prepreg in carbon/ epoxy. These raw materials of laminated structure made by Hexcel composites and respectively under Hex ply T2H 268 150 EH25 NS 35% with 59% fibre with 0.25mm thickness. And other sample content 34% Hexply T700 GC 268 M21 with 58% fibre and the thickness was 0.26mm. These two types of plies were named the first one T2H-EH25, and another one named T700-M21. The second type job piece (T700-M21) content 20µm diameter thermoplastic nodules, which represent about13% matrix mass rate. These nodules are improved the damage tolerance of the sample, and also controlled the crack propagation within the laminate. The blind drilling hole was done by NC machine. For their machining they used tungsten carbon micro grain tool with grade K20. And the tool diameter was 4.8mm; the point angle was 118° the tool had also three-slopes sharpen. For their experiment they used machining parameter 0.001mm/rev and 1500mm/rev feed rate. To avoid the delamination in blind hole machining a wooden plate was supported under the lower face of job piece. After blind hole drilling the delamination and the cracks are observed by visual inspection. After the experiment they analysis the drilling condition of long-fibre composite structure. And they made a numerical model based on fracture mechanics. By this model the thrust force criteria can be calculated which caused of fracture. The conformation between critical thrust force and analytical model can be numerically obtained. From this experiment they achieved the thrust force depends on tool feed rate. After their experiment they proposed the critical thrust force analytical model taking into account a crack presence in the vicinity of chisel edge. The integration of shear effects in that analytical model which they proposed also be planed [28, 29, 30 31, 32].

CONCLUSIONS

An overview of the various issues involved in the conventional machining of the composite materials has been presented in this paper. Major researches in the field of machining of composite materials have been reviewed and thus it has been established that machining of composite materials has its own peculiar implications.

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