SOME STUDIES ON DRILLING BEHAVIOR OF METAL MATRIX COMPOSITES

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ABSTRACT

The objective of the present research investigation is to explore the drilling behavior of developed MMCs under the domain of drilling process parameters; cutting speed, feed and drill geometry. The conventional drilling is used worldwide for hole making in MMCs. The machine tool parameters (cutting speed and feed) and cutting tool parameters (tool material, tool hardness, and tool geometry) are some of the important factors which govern the drilling behavior of MMCs.

Keywords: Drilling, Metal Matrix Composites, Tool Geometry

I INTRODUCTION

Machining is one of the costliest processes in the fabrication of components from MMCs [1]. It is because of the high hardness of the abrasive reinforcement that causes rapid tool wear, increase in cutting forces and deterioration in quality of the machined part especially with conventional HSS tools [2-3]. Therefore for extensive applications of MMCs, the development of cost effective and efficient methods of machining has become the major challenge for the research fraternity.

Drilling of MMCs is the most frequently used technique for hole making which facilitates the assembly or joining of MMCs parts. The objective of the present research investigation is to explore the drilling behavior of developed MMCs under the domain of drilling process parameters; cutting speed, feed and drill geometry. Although other machining process like unconventional machining are used to generate holes in the MMCs but they increases the overall cost of the product and therefore not considered as sustainable solution for cost effective production. The conventional drilling is used worldwide for hole making in MMCs. The machine tool parameters (cutting speed and feed) and cutting tool parameters (tool material, tool hardness, and tool geometry) are some of the important factors which govern the drilling behavior of MMCs.

II EXPERIMENTAL SETUP AND MEASURING INSTRUMENTS

The drilling experiments were performed dry (no cutting fluid) on a radial drilling machine (specifications are given in **Table 1**). The experimental setup consists of drilling machine, fixture for holding workpiece, piezoelectric drill dynamometer, charge amplifier, connecting cables and data acquisition system.

Table 1 Specifications of the Radial Drilling Machine

Make	Batliboi& Company Pvt. Ltd., Surat, India
Speed range	90 - 900 rpm (6 No.) 450 - 2800 rpm (6 No.)
Feed range	0.03 - 0.3 mm/rev (6 No.)
Drilling main motor power / speed	1.5 kW / 1420 rpm
Elevating motor power / speed	0.75 kW / 1420 rpm
Coolant pump motor power / speed	0.75 kW / 2800 rpm

2.1 Measurement of Cutting Forces

Four-component piezoelectric (Type 9272, Kistler make) drill dynamometer was used for measuring cutting forces accurately during drilling of MMCs. The dynamometer consists of four component piezoelectric sensors fitted under high preload between a base plate and a top plate. It is compact, robust and capable of measuring moment (M_z) and three orthogonal cutting forces (F_x, F_y and F_z) induced during machining. In drilling, it is used to measure the thrust force (F_z) and the torque (M_z) signals. The dynamometer has high rigidity, high natural frequency and is capable of measuring even small dynamic changes produced by thrust force and torque. The signals for cutting forces generated by the drill dynamometer were amplified with a Kistler charge amplifier (Type: 5070) and transmitted to data acquisition system. Dedicated evaluation software "Dynoware" was used to record and analyze the cutting forces produced during the drilling operation.

The MMC plate of 8 mm thickness was mounted on the dynamometer firmly and necessary clearance between the dynamometer and MMC plate was provided with the help of spacers, in order to ensure that the drill geometry does not contact the dynamometer during the drilling operation. Dynamometer was rigidly mounted on the drilling machine using square headed bolts fitted into the T-slots of the machine table. The simplified schematic diagram of the experimental setup is shown in **Figure 1.** Typical plots showing the output signals of the thrust force and the torque produced during drilling of MMCs with standard twist drill are shown in **Figures 2**and **Figure 3** respectively.

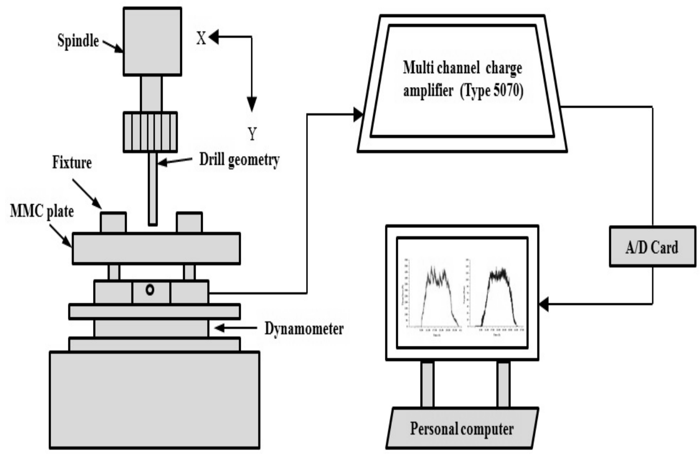

Figure 1 Schematic Diagram of the Experimental Setup

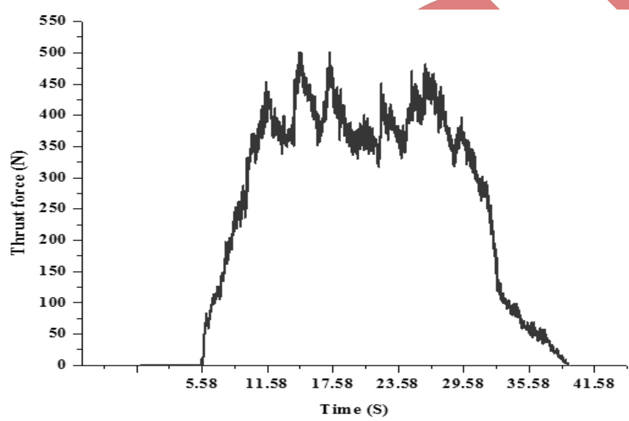

Figure 2 Thrust Force Signal Produced by Twist Drill at Feed of 0.12 mm/rev, Cutting Speed of 450 rpm

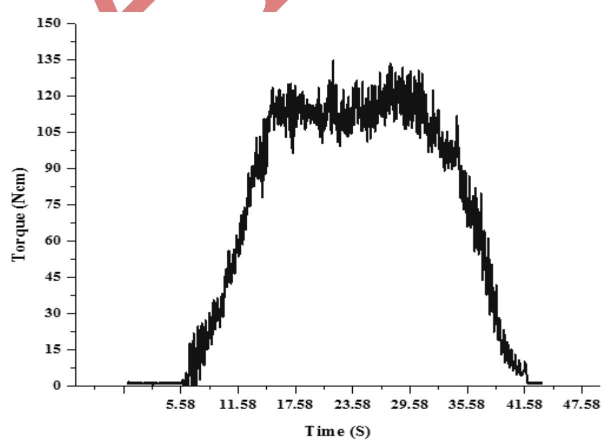

Figure 3 Torque Signal Produced by Twist Drill at Feed of 0.12 mm/rev, Cutting Speed of 450 rpm

2.2 Measurement of Surface Roughness

The surface roughness of the drilled hole wall is very important quality characteristic under consideration during drilling behavior of MMCs. The surface roughness of the drilled hole wall is dependent upon tool material, workpiece material, tool geometry, cutting conditions and rigidity of the machine tool used [2, 7]. Both contact and non-contact methods are used to measure the surface roughness of the drilled hole wall. In contact type, Mitutoyo SJ- 400 surface roughness tester as shown in **Figure 4** was used to measure surface roughness (R_a) at four positions of drilled hole wall spaced at 90° interval. Average of four surface roughness values along circumference of drilled hole was taken as surface roughness of the drilled hole wall. The specifications of the Mitutoyo SJ-400 used in the present study are given in **Table 2.**The photograph of the drilled specimen along with surface roughness tester is shown in **Figure 4.**

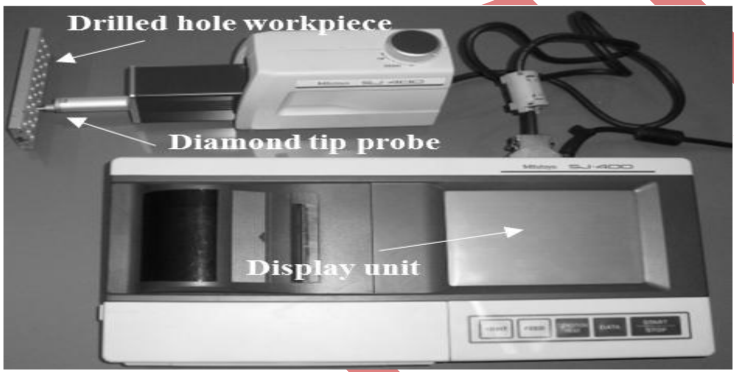

Figure 4 Mitutoyo SJ-400 Surface Roughness Tester

Table 2 Specifications of the Mitutoyo SJ-400

1	Detection method	Differential inductance method
2	Roughness standards	JIS (JIS B0601-1994-1982), DIN, ISO, ANSI
3	Stylus tip geometry	Corn 90°, Radius 5µm, Diamond
4	Measuring range	800µm
5	Cut off length	0.08, 0.25, 0.8, 2.5, 8mm
6	Minimum resolution	0.000125µm

Figure 5Wyko NT 1100 Surface Roughness Tester

In non-contact type of surface roughness measurement, Wyko NT 1100 profiler based on white light interferometry was used. The integrated optics assembly (IOA) is the core of Wyko NT 1100. The IOA contains a CCD camera, a field-of-view lens, a filter assembly, and an illumination source. Objectives are attached to the bottom of the IOA. Light from the illuminator travels through the IOA and is reflected down to the objective by a beam splitter. Once the light reaches the objective, another beam splitter separates the light into two beams. One beam, the reference beam, reflects from a super smooth reference mirror in the objective, while the other (the test beam) reflects from the surface of the sample and back to the objective. If the surface of the sample is in focus, the two light beams recombine and form interference pattern of light and dark bands called fringes. The interference pattern is received by the CCD camera and the signal is transferred to the computer, where it is processed by Wyco Vision 32 software. Wyco Vision 32 will then produce a graphical output display representing a contour map of the sample surface. The photograph of the Wyko NT 1100 profiler is shown in **Figure 5.**

2.3 Measurement of Tool Wear

The drill wear measurement is a complex phenomenon as compared to other cutting tools. The tool wear depends upon the tool material, workpiece material, cutting conditions and temperature generated at the tool workpiece interface. The various tool wear mechanism responsible for tool wear are; two body or three body abrasions, adhesion, diffusion and plastic deformation of the cutting edges. Flank wear, crater wear, rupture of cutting edge or groove formation are commonly observed on drill geometry when working with metal matrix composites. The quality characteristics like surface roughness, burr formation and the dimensional accuracy are governed by the tool wear. The abrasion wear of flank face is predominant cause of tool wear in drilling of MMCs [2, 4].

Tool makers microscope as shown in **Figure 6** was used to measure the flank wear of the drill geometry. A special fixture was designed to hold the drill geometry to make the flank face of the geometry perpendicular to the line of vision for accurate measurement of the drill point wear. Flank wear of the drill geometry was measured on the two cutting edges at about 1/4th of tool radius from the corner of drill [5]. The average value of wear on two cutting edges was considered as flank wear of the tool geometry.

Figure 7 Toolmakers Microscope

2.5 Burr Formation

Burr is defined as 'undesirable projection of material that results from a cutting and shearing operation' [6]. The burr formation causes numerous uninvited features, such as inappropriate contact among current carrying members in electrical components, inappropriate seating of mating surfaces and imprecise assembly of components. The burr formation at the exit side of the drilled hole was analyzed qualitatively in terms of Yes and No. Visual inspection was performed to analyze the burr formation at the exit side of the drilled hole. **Figure 7** shows the burr formation on the exit side of drilled hole wall using twist drill point geometry.

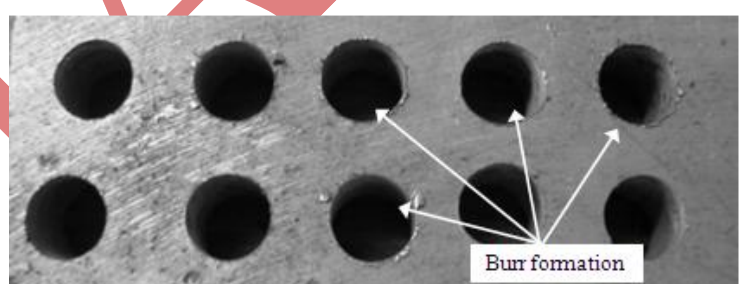

Figure 8 Burr Formation at the Exit Side of the Drilled Hole Wall

III CONCLUSION

The present investigation explore the preliminary study on drilling behavior of metal matrix composites in the domain of cutting forces, surface roughness, tool wear and burr formation. The following conclusions can be drawn from the research investigation:

1. The thrust force and torque signal showsaerratic behavior during drilling of metal matrix composites. Which is a evident of interaction of SiC particles with the cutting edge.

2. The surface roughness of the drilled hole wall surfaces shows the burnishing and honing effect produced by the SiC particles.
3. The predominant wear of cutting tool was observed on flank due to abrasion of SiC particles on the flank Surface.
4. Some burr formation observed on the drilled hole at entrance as well as exit side of the drilled hole.

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