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Experimental study on small-hole drilling characteristics of SiC_p/Al composites

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Abstract

In this paper, the small-hole drilling characteristics of high volume fraction SiC_p/Al composites using polycrystalline diamond (PCD) drills are studied experimentally. Wet pecking drilling operation is employed in the tests on account of the frequent fracture of small-diameter drills and serious tool wear. The thrust force and torque, drilled-hole surface quality, entry and exit hole edge defects and tool wear are measured, compared and analysed. The effect of drilling parameters on the thrust force, torque and surface roughness, the defect formation mechanism, tool wear pattern and mechanisms are discovered.

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Keywords: Drilling; Composites; Diamond tool

1. Introduction

Silicon carbide particle reinforced aluminum matrix (SiC_p/Al) composites have been of great potential due to their superior physical and mechanical properties, such as high stiffness-to-weight ratio, high specific strength, high wear resistance, low sensitivity to temperature variations, and excellent corrosion resistance [1-3]. They have promising application prospect in many industrial fields like aerospace, marine, automotive and sport equipment [4,5]. However, SiC_p/Al composites are limited in the actual production applications by their poor machinability since the hard SiC particles embedded in the aluminum matrix lead to serious tool wear and undesired surface quality [6-8].

Carbide drill and PCD drills are mostly used for the drilling of SiC_p/Al composites, while HSS drills are unsuitable due to the rapid tool wear, poor hole quality and higher drilling forces induced. And the solid carbide drills also are characterized by some similar drilling characteristics even though superior to HSS drills. Only PCD drills are most desirable for machining SiC_p/Al composites especially with high volume fraction and large particles because of their highest tool wear resistance [1,9].

Up to now, most research works concentrated on the drilling process of SiC_p/Al composites with volume fraction less than 30% and drill diameter larger than 4 mm. Huang et al. investigated drilling performance of high volume fraction composites 56% SiC_p/Al with PCD drills of 4.6 mm diameter [1]. Very little research work is performed on drilling of high volume fraction SiC_p/Al composites with small-diameter drills, although it has become a much needed technology after the successful breakthrough of narrow slot milling technology in the present industry such as the electronic packaging field.

In this study, experiments of drilling 3mm-diameter holes on 65% SiC_p/Al composite plate with PCD brazed drills are carried out for the investigation of the drilling mechanism, including thrust force and torque, surface quality, entry and exit hole edge defects and tool wear.

2. Experimental procedure

2.1. Workpiece

Materials used for the drilling tests are 65% volume fraction SiC_p/Al (SiC_p/Al6063/65p) composites fabricated by the vacuum infiltration method. The microstructure is shown

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in Fig. 1, in which the dark polyhedral SiC particles with many sharp corners are homogeneously distributed in the light aluminum matrix, and the average size of the SiC particles is 10 μm.

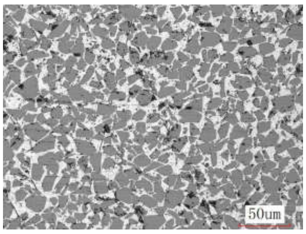
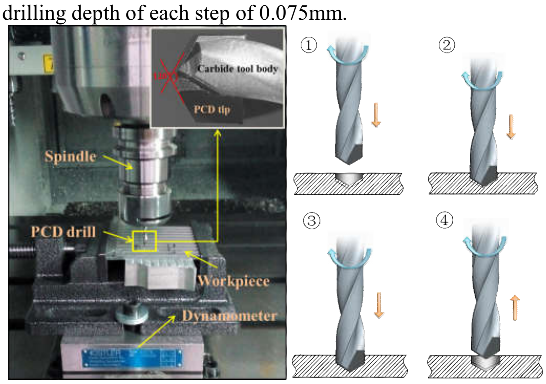


Fig. 1 Microstructure of SiCp/Al6063/65p composites.

2.2. Equipment setup and procedure

The tiny chips always clog at the bottom of the holes and are difficult to get removed without the injection of coolant. And this will result in high temperature, rapid tool wear, high thrust force and frequent fracture of the drills. Therefore, wet pec drilling operation is utilized in the drilling experiments for the in-time cooling of the drill bits and chip removal.

The drilling tests are conducted on an ODG KT-600 CNC machine tool with external cooling system, as shown in Fig. 2. The 3 mm-diameter carbide drills with two brazed PCD tips, a point angle of 120°, relief angle 10°, rake angle 0° and helix angle 30° are used for the experiments. Peck drilling is performed on a 2mm thick SiC_p/Al plate with the combined drilling parameters of a rotation speed of 1500, 2000 or 2500rpm, a feed velocity of 50, 75 or 100mm/min, and a drilling depth of each step of 0.075mm.



(a) (b)

Fig. 2 Peck drilling experiment. (a) experiment setup; (b) 4 parts of one step.

3. Result and discussion

3.1. Thrust force and torque

In the drilling experiments, the drilling forces are recorded using a Kistler 9257B dynamometer. Fig. 3 shows the thrust force variation with the drilling in and out per step at a rotational speed of 2000 rpm and feed velocity of 100 mm/min. As the PCD drill inserts construct a point angle of 120°, it can be calculated that the vertical height of main cutting edge is 0.866mm. It takes 38.2 drilling steps to drill through the 2mm-thick workpiece completely with a drilling depth of 0.075 mm per step, while in Fig. 3 the non-zero force signal covers 40 steps drilling process due to the elastic deformation of the workpiece in drilling. The average peak values of thrust force and torque in the stable feed drilling stage are taken to analyze the variation of thrust force and torque with respect to the rotational speed and feed velocity, as shown in Fig. 4. And it is found that both thrust force and torques are highly dependent on the feed rate and the parameter combination of high rotation speed and low feed velocity is preferred.

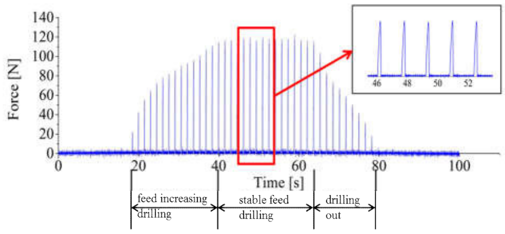
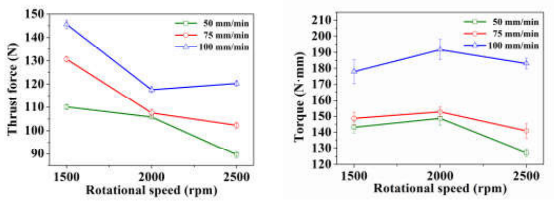


Fig. 3 Recorded thrust force at a rotational speed of 2000 rpm and feed velocity of 100 mm/min.



(a) (b)

Fig. 4 Variation of experiment data in drilling SiC_p/Al6063/65p composites. (a) thrust force; (b) torque.

3.2. Surface quality of drilled hole

In order to measure the surface roughness, the work is cut into two approximately equal pieces along the hole axis. Surface roughness (Ra) is measured along the hole axis at four different positions of hole inner surface with approximately 90° intervals around the circumference by using a VK-X200 3D Laser Scanning Microscope. At last an average value is calculated and used in Fig. 5.

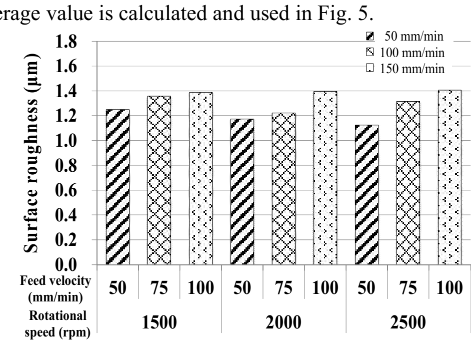


Fig. 5 Surface roughness Ra with variation in rotational speed and feed velocity.