DRILLING STUDIES OF ALUMINIUM ALLOY–ALUMINIUM OXIDE COMPOSITES

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ABSTRACT

Particle reinforced metal matrix composites (MMCs) are an important class of composite materials. Due to high elastic moduli, strength, fatigue and wear resistance, these lightweight materials have a number of advantages over ordinary aluminum alloys. In the present work, aluminum alloy–aluminum oxide composite was developed using vortex method and pressure die casting technique. The drilling studies were conducted on the aluminum alloy–aluminum oxide composite workpiece using High Speed Steel (HSS) drill tools in a drilling machine. The surface finish is better for higher speeds and lower feeds. The surface finish produced on the plain aluminum alloy is better than that produced on the aluminum alloy–aluminum oxide MMC. The flank wear increases with speed and feed. The drill tool wear is higher on machining the aluminum alloy–aluminum oxide MMC than that on machining the plain aluminum alloy.

Key words: *Metal Matrix Composites, drilling, aluminum, aluminum oxide, surface roughness and high speed steel*

1. Introduction

Metal matrix composites (MMC) are newer materials having many favorable mechanical properties like high strength, hardness, wear resistance and strength to weight ratio. They have a wide range of applications from automotive to aerospace [1–2]. MMCs combine metallic properties of matrix alloys of good ductility and toughness with ceramic properties of reinforcements of high strength and high modulus, leading to greater strength in shear and compression and higher service temperature capabilities [3, 4]. Aluminum oxide (Al_2O_3) and silicon carbide (SiC) fibers and particles are the most commonly used reinforcements in MMCs and the addition of these reinforcements to aluminum alloys have been the subject of a considerable amount of research work [5]. The application of Al_2O_3 or SiC reinforced aluminum alloy matrix composites in the automotive and aircraft industries is gradually increasing for pistons, cylinder heads, etc., where the tribological properties of the material are very important [6–12].

The surface quality of a machined work piece largely depends upon the stability of the cutting nose and the dimensional accuracy is controlled by flank wear of turning tools [13]. Flank wear occurs on the tool flank and it is generally attributed to rubbing of the tool with work piece at the interface, causing abrasive and adhesive wear and high temperatures. The flank wear affects the properties of tool material and work piece materials [14].

2. Experimental Procedure

In the present work, the aluminum alloy - 1 % weight aluminum oxide was die cast, using LM24 aluminum alloy as the matrix material and aluminum oxide particles of average particle size of 16 microns as a reinforcement material. The aluminum alloy was melted in a graphite crucible at a controlled temperature protected with an argon gas atmosphere. The graphite stirrer was introduced into the crucible to perform mixing process when the molten temperature reached 850 ^{0}C. The stirring was carried out for 45 minutes at the rate of 200 rpm. Aluminum oxide particles were preheated to 200 ^{0}C and introduced into the vortex created in the molten alloy. The internal surface of the die is applied with a water based die coat before each casting which acts as a lubricant between the molten metal and die, and also prevents the adhesion between the die cast metal and die. A 420 ton cold chamber hydraulic type die casting machine was used for making the castings. The pouring temperature of molten mixture was 850 ^{0}C and molten metal was injected into the runner of the closed die with the initial velocity of 0.23 m/sec up to runner gate. Then the ram movement is given with 1.8 m/sec for injection and simultaneously shot in the die. The molten mixture is poured into the plunger sleeve and forced into the die cavity with pressure of 100 MPa. The shot accumulation force of 420 tons is applied at the end of injection and the die is simultaneously cooled with demineralized water. Then

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the MMC is ejected from the die with at a temperature of 150 ^{0}C and it is allowed to cool in air.

2.1 Drilling studies

The drilling experiments of the aluminum alloy – aluminum oxide composite were conducted in a drilling machine. Twist drills of M2 grade High Speed Steel (HSS) of 5 mm diameter were used in the present work. The drilling tests were carried at speeds of 10, 15 and 20 m/min and feeds of 0.1, 0.3 and 0.5 mm/rev. The specification of the drills used is ISO 235-1980. The coolant used in the present study was ~~is~~ kerosene. The surface roughness of the machined surface was observed using a stylus type surface roughness tester. The wear of the drills was measured using a toolmakers microscope.

3. Results and Discussion

The microstructure of the plain LM24 aluminum alloy is presented in figure 1. The microstructure shows the interdendritic particles of euctectic silicon and $CuAl_2$ in a matrix of aluminum solid solution. The X-ray diffraction pattern of the plain LM24 aluminum alloy is given in figure 2. The hardness of the aluminum alloy-aluminum oxide composite of 102 BHN is higher than that of the plain LM24 aluminum alloy of 96 BHN, due to particulate hardening.

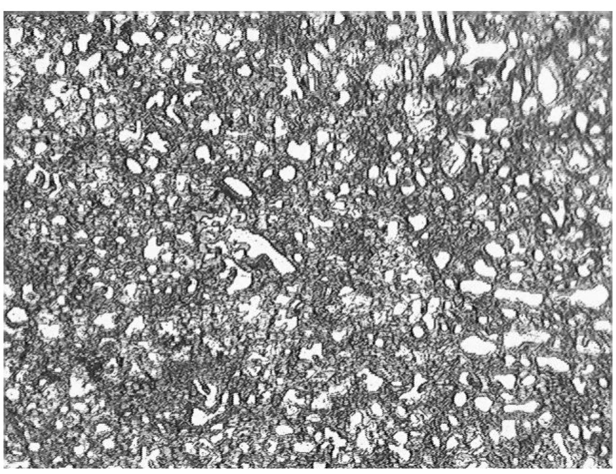

Fig. 1 The microstructure of the plain LM24 aluminum alloy

3.1 Effect of speed and feed on surface finish

Surface roughness and surface integrity are important performance measures which indicate the performance level attained by using the particular work material-tool material combination and the corresponding suitable speeds and feeds. The importance of considering surface roughness and surface integrity when machining aluminum and its alloys arises due to the high thermal conductivity and low melting temperatures. This can result in considerable deformation to the generated surface.

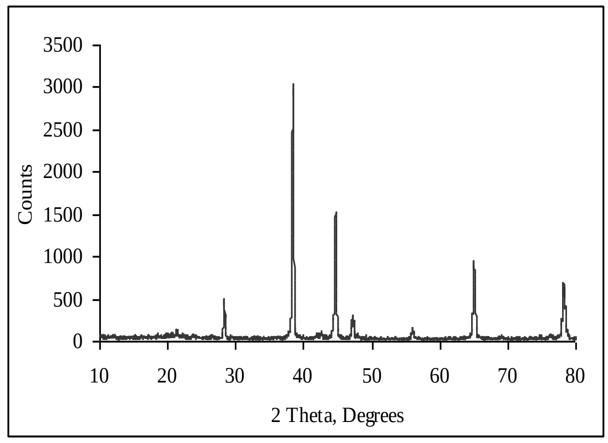

Fig. 2 XRD Pattern of the plain LM 24 aluminum alloy

The effects of speed and feed on surface roughness are presented in figure 3, 4 and 5. The surface roughness decreases with increasing speed. The decrease in surface roughness with the increase in cutting speed is attributed to the increased burnishing effect between the tool and the drilled hole. The surface roughness increases with increasing feed. The increase in surface roughness with the increase on feed is attributed decrease in the contact time between the tool and workpiece and thus reduces the burnishing effect. The surface roughness of the aluminum oxide reinforced LM24 aluminum alloy is poor than the plain LM24 aluminum alloy due to particle reinforcement. This is attributed to defects such as voids and cavities are formed on the surface due to tool – particle interactions and resulting pull-out/fracture and debonding of particles during drilling of the reinforced aluminum alloy.

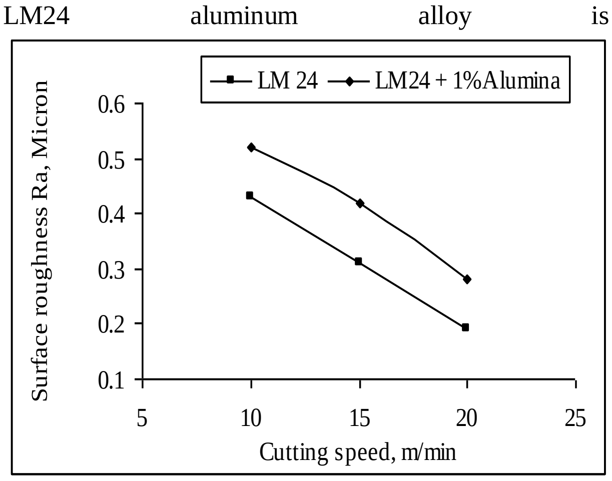

Fig. 3 Surface Roughness vs Cutting Speed at feed of 0.1 mm/rev

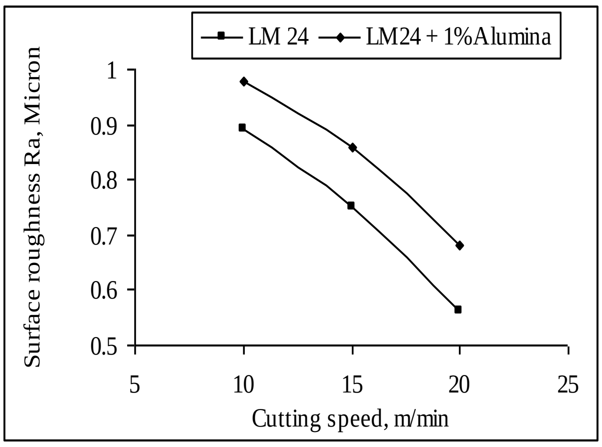

Fig. 4 Surface roughness vs cutting speed at feed of 0.3 mm/rev

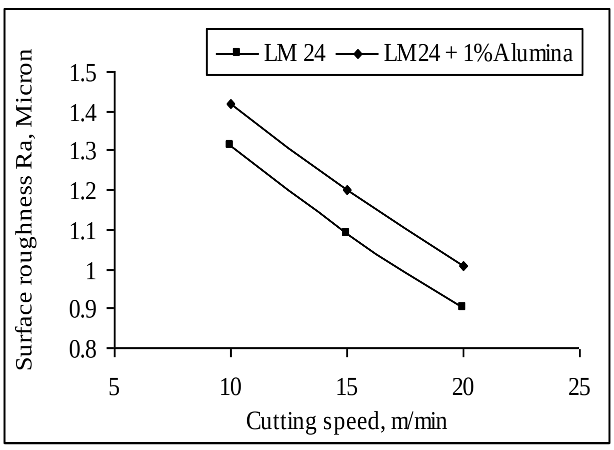

Fig. 5 Surface roughness vs cutting speed at feed of 0.5 mm/rev

3.2 Flank wear studies

The qualitative microscopy studies of the flank wear of HSS drill revealed the adhesive wear; abrasive wear and diffusion wear mechanisms. The maximum wear takes place at the outer edges of the tip and minimum wear occurs at or near the point of the tip. This is because the maximum rotational force and the maximum tip to work piece contact occur further away from the point and thus the point is abraded away more quickly, whereas at the drill point itself little rotational force is experienced by the tip and the force is more like pushing into the work piece rather than cutting. The flanks wear increases with speed and feed. The mean temperature in turning on a lathe is proportional to the cutting speed and feed as follows:

Mean Temperature $\propto$ $V^a f^b$,

Where a and b are constants depends on tool and work piece materials, V is the cutting speed and f is the feed of the tool (Serope Kalpakjian, 1995) [15]. The rise in temperature adversely affects the hardness and wear resistance of the cutting tool. The drill tool wear is higher on machining the aluminum alloy–aluminum oxide MMC than that on machining the plain aluminum alloy, which is attributed to the harder aluminum oxide in the MMC, which is harder than HSS.

4. Conclusions

Aluminum alloy–aluminum oxide composite was developed using vortex method and pressure die-casting technique. The surface finish is better for higher speeds and lower feeds. The surface roughness of the plain aluminum alloy is better than that of the aluminum alloy-aluminum oxide composite. The flank wear increases with speed and feed. The drill tool wear is higher on machining the aluminum alloy–aluminum oxide MMC than that on machining the plain aluminum alloy.

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