INFLUENCE OF WORKPIECE THICKNESS ON DRILLING OF AL/SIC METAL MATRIX COMPOSITES

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Abstract

This paper investigated the Thrust force and surface roughness in drilling of Al/15%SiC/2%Gr and Al/15%SiC/4%Gr hybrid metal composites fabricated by stir casting method. The experiments were conducted with Tin coated solid carbide twist drill of 4 mm diameter under the dry cutting condition. The result revelled that inclusion of graphite as on additional reinforcement in Al/SiC reinforced composites reduce the thrust force. The cutting speed and its interactions with feed rates are minimum. The feed rate has a major influence on thrust force and surface roughness in both hybrid composites. The less thrust force value and higher surface roughness value for Al/15%SiC/4%Gr hybrid metal composite compared to the Al/15%SiC/2%Gr composite. The thrust forces and surface roughness values are increases with increase in feed rate and decrease with increase in cutting speed in both hybrid metal matrix composites.

Key words: Hybrid metal matrix composites, Drilling, Graphite, Thrust forces, Surface roughness.

I. INTRODUCTION

Metal matrix composites (MMC) have become a leading material among composite materials, and in particular, particle reinforced aluminum MMCs have received considerable attention due to their excellent engineering properties. Metal matrix composites, in general, possess certain superior properties like low density, high specific stiffness and strength, controlled coefficient of thermal expansion, increased fatigue resistance, and superior dimensional stability at elevated temperature. But their poor machinability attributed to the presence of ceramic reinforcements, resulting in very high rates of tool wear, restricts their widespread use. Metal matrix composites (MMC) are rapidly replacing conventional materials in various engineering applications such as the aerospace and automobile industries. Some of the typical applications are bearings, automobile pistons, cylinder liners, piston rings, connecting rods, sliding electrical contacts, turbo charger impellers, space structures, etc. [1]. Drilling of MMCs poses many problems to the manufacturing engineers such as high drilling forces, tool wear, and burr. The drilling process is employed prior to the assembly stage for fastening and riveting purposes. During drilling of MMCs, the cutting tool undergoes severe abrasive wear due to the presence of hard reinforcements and is considered highly unproductive. These hard particles cause excessive tool wears even when machining with diamond tools [2]. Tosun et al. [3, 4] investigated the effect of the various cutting parameters on the surface quality and microstructure on drilling of Al/17% SiC particulate MMC by using various drills. They have suggested that TiN coated HSS drills can be used for drilling Al/SiC-MMC rather than solid carbide tools. The quality of the drilled part is greatly influenced by the cutting conditions, tool geometry, tool material, machining process, chip formation, work piece material, tool wear, vibration during cutting, etc. Thus in material removal process improper selection of cutting condition will result in rough surfaces [5]. Moreover, it is necessary to optimize the cutting parameters to obtain an extended tool life and better productivity, which are influenced by cutting force [6]. Ramulu et al. [7] conducted drilling experiments on Al_2O_3 aluminium based hybrid metal matrix composites using different drill materials and found that the abrasive particles cause excessive flank wear. They also found that HSS tools are not suitable for machining hybrid composite materials. The machinability during turning of Al/Si/Gr composites was studied by Brown and Surappa [8]. They found that the machining forces were considerably reduced for the graphitic composites. Songmene and Balazinski [9] also found that incorporation of graphite particle in two aluminum MMCs Improve the machinability of the compared to the ceramic reinforced composites. S. Basavarajappa et al. [10]. Prepared two different metal matrix composites-Al2219/15SiCp and at 2219/15SiCp-3Gr by stirring casting technique and performed drilling studies on them Sharma et al. [11]. They reported that ceramic–graphite reinforced composite has better machinability than those reinforced with silicon carbide particles only. Bell et al. [12] reported that the SiC/Gr MMC has better machinability and can be machined at higher metal-removal rates than other existing SiC reinforced composites. The main aim of the paper is to study the influence of cutting parameter on Thrust force and surface roughness in the drilling of Al/15%SiC/2%Gr and Al/15%SiC/4%Gr. hybrid metal matrix composites.

II. MATERIALS AND METHODS

A. Materials

Aluminum (6061) is used as the matrix material. The Al-SiC-Gr matrix alloy has a composition (% by weight) of Si = 0.4-0.8, Iron = 0.7 Max, Cu = 0.15-0.40, Mn = 0.15 Max, Mg = 0.8-1.2 max, Zn = 0.25 max, V = 0.005, Ti = 0. 0182, Cr = 0. 04-0.35, Al = balance. The materials Al 6061/15%SiC/2%Gr and Al6061/15% SiC-4%Gr are fabricated stir casting method. The average sizes of SiC and Graphite particles are 50 microns are used as reinforcing material to fabricate the composite. The meeting was carried out in the electrical resistance furnace. The aluminium scraps of 6061 were first preheated at 600°C before melting. The SiC and graphite were also preheated at the required temperature. The preheated aluminium scraps were first heated above the liquidus temperature to melt them completely, They were then slightly cooled below the liquidus temperature to maintain the slurry in semi-solid state.The pre-heated reinforcement were mixed manually then composite slurry were heated to a liquid state, The final temperature was controlled to be within 800°C and pouring temperature was controlled to be around 820°C. The melt was poured in to steel moulds and allowed to cool to obtain 110 mm $\times$ 110 mm $\times$ 5 mm size of plate. The microstructures of the composite are shown in Fig 1.

B. Experimental procedure

The experiments were carried out in a ARIX-CNC machining center manufactured by ARIX CNC machine Co. Ltd., Taiwan. The details of the cutting parameters and tools used for the experiments are given in Table 1. The drilling fixture was mounted on the dynamometer and the thrust forces were measured using a computer-aided data acquisition system. Drilling dynamometer (SI-67) was used for measuring the thrust force. The voltage from the

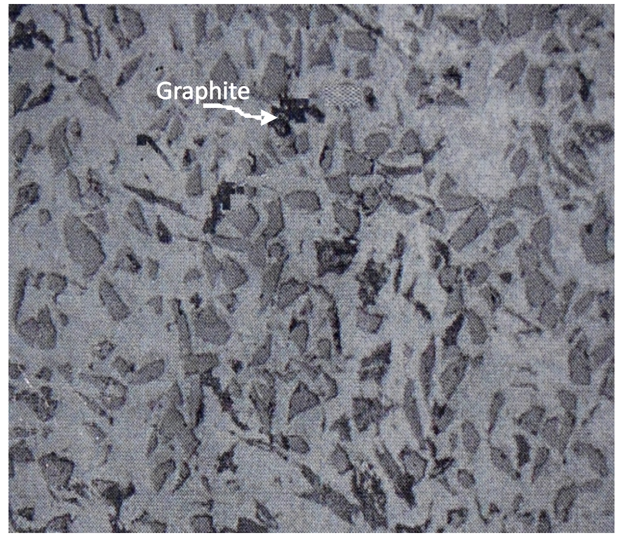

Fig. 1.(a) Microstructure the hybrid composite Al/15% SiC/2%Gr

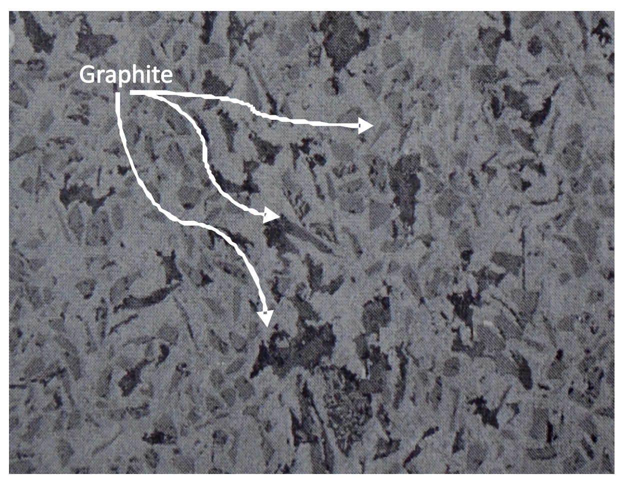

Fig. 1.(b) Microstructure the hybrid composite Al/15% SiC/4%Gr

Dynamometer was fed into the amplification circuits. The amplified voltage was fed into the system interfaced with data acquisition system. These voltage signals were taken as input to the LABVIEW program and the maximum thrust force value was calculated. The surface roughness [*Ra*] was measured with a

Mitutoyo Surftest SJ-201 surface instrument. The *Ra*-value was used to characterize the surface quality The surface roughness was an average taken from three measurements along the drilled hole wall and average results are considered in the analysis. The Experimental device for surface finish is shown in Fig. 2.

Table 1. Summary of Experimental condition

Machine	ARIX vertical CNC machining center
Drills	Solid carbide TiN coated twist drill of diameter 4 mm
Workpiece Materials	Al6061/15% SiC/4% Gr & Al6061/15% SiC/4% Gr
Cutting condition	Speed 1000, 2000, 3000 rpm; feed rate 0.05, 0.10, 0.15 mm/rev;
Surface Roughness	Mitutoyo Surftest SJ-201, portable Surface Roughness Tester

Fig. 2. Experimental device for surface finish

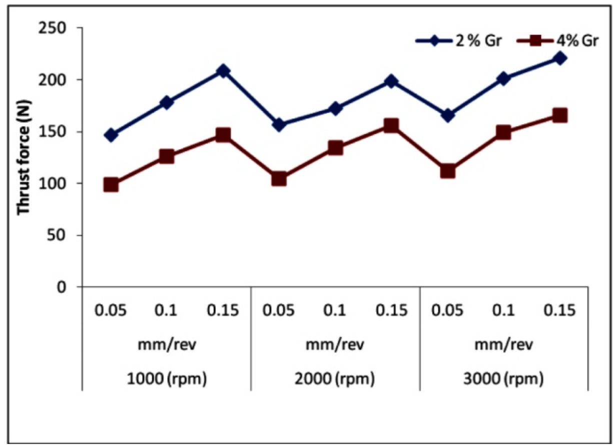

Fig. 3. variation of thrust force for various cutting speeds and feed rates when machining Al/ 15%SiC /2%Gr and Al/15%SiC/4%Gr using coated carbide drills

III. RESULTS AND DISCUSSION

A. Thrust forces

Cutting speed and feed rate are two major drilling parameters are considered in the experiments. Fig. 3. Shows shows the variation of thrust force with increasing feed rate for various cutting speeds of 1000, 2000 and 3000 rpm for both workpiece materials. The results reveal that as feed rate increase from 0.05 to 0.15 mm/rev. The cutting force increases for all spindle speeds for all spindle speeds for the both the workpiece materials. The difference between the thrust forces becomes larger at higher feed rates compared to lower feed rates. The feed rate is the predominant factor. When feed rate is increased from 0.05 to 0.15 mm/rev, the value of thrust force (from 99 N to 147 N) increase by almost 49% (by the addition of 4% graphite and cutting speed is 1000 rpm). Whereas when cutting speed is increased from 1000 to 3000 RPM, the value of thrust force (from 99 N to 112 N) increase by almost 13% (by adding 4% graphite and the feed rate is 0.05 mm/Rev). It can also be observed that there is no predominant variation In thrust force on increasing cutting speed for all feed rates considered. Similar variation is found to be Ramulu et al. [7], who reported that drilling forces are significantly influenced by the feed rate when drilling both10% and 20% Al_2O_3 reinforced 6061composites Thrust forces are high for machining of Al/15%SiC/ 2%Gr composite compared to Al/15%SiC/4%Gr composite. The cutting force decreases with the increase in graphite content for all cutting conditions. The addition of 4% graphite reduces the cutting forces significantly, which is evident from Fig. 3 the test results, it can be concluded that when the feed rate is 0.05 mm/Rev, the addition of 4% graphite reduces the thrust force (from 147 N to 99 N) by almost 49%. This is attributed to the solid-lubricating property of the graphite particles. The graphite particles reduce the interface friction between the tool and the work piece materials. This helps in sharing the material along the shear plane and influences the shear flow stress Basaravajappa et al. [10], reported that the SiC/Gr MMC has better machinabiliy and can be machined at higher metal removal rates than other existing SiC reinforced composites. Sharma et al. [11], reported that when drilling ZA-7/graphite reinforced composites, the thrust force decreases with the increase in graphite content.

B. Surface roughness

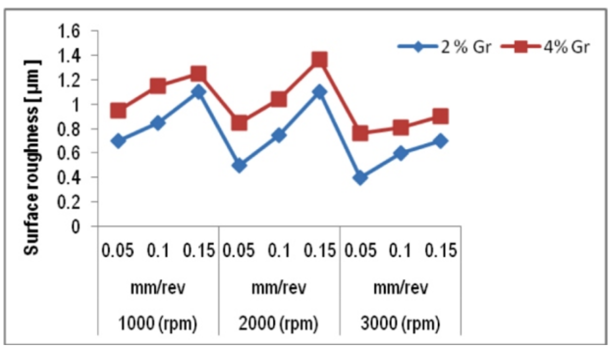

Fig. 4. Variation of Surface roughness value for various cutting speeds and feed rates when machining Al/15%SiC/2%Gr and Al/15%SiC/4%Gr are using coated carbide drills

Figure 4 shows the variation of surface roughness values for various spindle speeds and feed rates for both workplace materials. It is evident that the surface roughness value for both composite materials. Increase with increase in feed rate, while decrease with increasing in cutting speed. The increase in feed rate has a more predominant effect on surface roughness than cutting speed The surface roughness values always increase with increase in feed rate and decrease with the increase in cutting speed,when drilling both work piece materials.The lowest surface roughness values (0.41% m for Al/15% SiC/2% Gr and 0.78% m Al/15% SiC/4% Gr) occurred at the lowest feed rate at the highest cutting speed. This may be attributed to the honing or burnishing effect produced by the rubbing of small particles trapped between the flank face of cutting tool and workpiece surface.

The surface roughness values of Al/ 15%SiC/ 4%Gr composite are relatively more when compared to the Al/15%SiC/2%Gr composite for all cutting conditions. The higher surface roughness values for Al/15%SiC/4%Gr composite can be attributed to the release of graphite particles between the workpiece materials and the flank face of the cutting tool.when the cutting tool passes over these regions, the crushed graphite particles from a deep valley; and hence increase the surface roughness of the material. This graphite particles will reduce the friction and honing effect that causes the increased surface roughness. The removed graphite particles get smeared on the machined surface.

C. Scanning electronic microscope investigations

Figs 5 and 6. Shows the scanning electron microscope image of the surface of drilling holes on Al/15%SiC/4%Gr hybrid metal matrix composite.

Fig. 5. Scanning electronic microscope image of the surface of drilling holes Al/15%SiC/4% Gr (speed 3000 rpm feed rate 0.05 mm/rev)

The investigations have revealed that fine grooves, scratches and many deep valleys have been observed over the machined surface composites. Cracks and pits (Figs 5 & 6) are also observed on the composites. Comparing Fig. 5 with Fig. 6, it can be seen that the amount of cracks and pits are less on the machined composite surface.

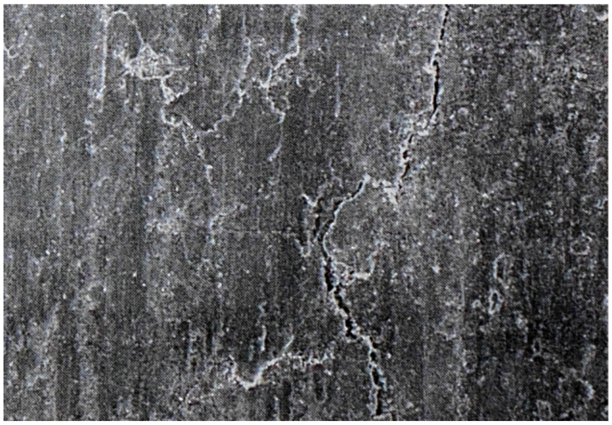

Fig. 6. Scanning electronic microscope image of the surface of drilling holes Al/15%SiC/4% Gr (speed

IV. CONCLUSION

The study of the cutting variables on thrust force and surface roughness during drilling of Al/15%SiC/2%Gr and Al/15%SiC/4%Gr enabled following conclusions.

1. The inclusion of graphite particles as on additional reinforcement Al/SiC composite reduces the thrust force. The lowest thrust force Value (99N) recorded at the drilling of Al/15%SiC/4%Gr composite material.
2. The feed rate is found to have a significant influence on the thrust force and surface finish on both composites.
3. The surface roughness values are always increase with increase in feed rate and decrease with increase in cutting speed in both composites.
4. Surface finish is poor when drilling Al/15%SiC/4%Gr composite when compared to Al/15%SiC/2%Gr composite.
5. The lowest surface roughness values, (Ra 0.41% m for Al/15%SiC/2%Gr and 0.78% Al/15%SiC/4%Gr) occurred at the lowest feed rate, (0.05 mm/rev) with the highest cutting speed (3000 rpm).

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