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Chip Formation in the Machining Of Al-SiC/AlN Matrix Metal Composite (MMC) Using the Uncoated Of Carbide Tool

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ABSTRACT: *This paper presents a study on the chip formation in the milling process of Al-SiC/AlN MMC. The focus this study is the effect of the cutting parameter towards the morphology and the microstructure of the chip. Al-SiC/AlN MMC reinforced with the aluminium nitride (AlN) particle is a new-generation material that is appropriate to be used in the manufacturing of automotive and aerospace components. This material is known to have some advantageous characteristics such as low density, light weight, high strength, high hardness and high stiffness.. The milling process was carried out in the dry cutting condition using the uncoated edge of the carbide tool with 10% AlN particle used in the manufacturing of the composite. The parameters of the machining used are the cutting speed of 250 m/min and 450 m/min, while the feed rate and the depth of the cutting are made constant, at 0.15 mm/teeth and 0.3 mm, respectively. The analysis of the chip formation was done using the video microscope Sometech SV-35, and the scanning electron microscope (SEM). Observations from the SEM reveal that the crescent moon element has been produced. The morphology and microstructure of the chip produced are influenced by the mode of the shear shape alteration in the alteration zone of the main shapes*

KEYWORDS : *Al-SiC/AlN metal matrix composite (MMC), chip formation, milling process*

I. INTRODUCTION

The success of current manufacturing industry depends on the quality of materials used in their production processes, which later upgrades them to be manufacturer of international status [1]. Many initiatives had been employed by companies attempting to utilize quality materials in their production, such as cost savings in production, with the ultimate goal to develop production businesses, such as venturing in aerospace and automotive industries [2]. One of the latest scientific innovations is the study of metal matrix composites (MMCs). The ability of these materials to replace conventional materials in many applications is increasing. One of MMC characteristics is having a combination of metals and ceramics properties [3]. Most MMC was developed in order to meet certain requirements such as suitable for use in the manufacture of automotive and aerospace components. This is due to the nature of MMC which has very good mechanical properties which resulted from a combination of hard reinforcement such as silicon carbide (SiC) and elastic matrix material such as aluminum or magnesium [4]. MMC's development and innovation is not limited to applications in the automotive and aerospace only; recently, it has also been used in the manufacture of electronic and electrical components such as high-voltage power transmission lines [5].

At present, there are only a few reports about the use AlN as reinforcement to the composite Al alloy. Thus the knowledge of machinability of this new material is very limited, as described by Kok [6] on the surface roughness and the performance of carbide coated and uncoated tool as well as wear mechanisms in machining these materials. Venkatesh [7] claimed that MMC is harder than normal materials, therefore causing cutting tool to be easily broken and damaged.To achieve longer tool life of the cutting tool in current production practices, as well as knowledge about the tool that can withstand high cutting temperature, the understanding of the mechanism of chip formation is a fundamental element that influences tool performance. Chip formation depends on the characteristics of the material and machining. Three types of chips are produced in machining [8]: 1) discontinuous chips when the chips are formed with multiple segments and produced when machining brittle materials at low cutting speed, 2) continuous chips are produced when machining ductile materials at high cutting speed and low feed rate [9] and 3) continuous with built-up edge produced when machining ductile materials *i* at low cutting speed.

Chips produced can be divided into two categories, namely acceptable and unacceptable chips [10]. Acceptable chips may not disturb work or machine tool and does not cause problems in chip removal, while unacceptable chips will disrupt manufacturing operations since its tendency to shrink around tools and work piece as well as inflicting security problems to the employee [10].This paper presents chip formation during Al-SiC/AlN MMC machining on different parameters of cutting speed. Factors that influence the formation of chips will be identified, and its role in improving the machinability of new materials will be proposed.

II. RESEARCH METHODOLOGY

2.1 Experimental machining

Al-SiC/AlN MMC was produced using stir casting process in the form of block with a size of 120 mm long x 70 mm wide x 25 mm thick. Its composition is as shown in Table 1, and by an additional 10% of small particles reinforcement of AlN with particle size <10 μm and purity > 98%. To improve the mechanical properties of this Al-SiC/AlN MMC, heat treatment was carried out. Table 2 shows the mechanical properties of 10wt%Al-SiC/AlN MMC materials.

Table 1. Chemical Composition of Materials

Element	Fe	Si	Zn	Mg	Cu	Sn	Co	Ti	Cr	Al
wt %	0.42	11.1	0.02	0.0107	0.02	0.016	0.004	0.0085	0.008	Equilibrium

Table 2. Mechanical Properties 10wt%AlSiC/AlN

Hardness (Hv)	Modulus of Elasticity (Gpa)	Tensile Strength (Mpa)	Elongation (%)
110	7.0 ± 3.5	146± 8	6.2 ± 3.5

CoroMill tool holder R390-020C4-11L and uncoated carbide cutting tool insert with diameter of Ø20 mm with 0.2 mm nose radius were used in this study. Machining was carried out using CNC KONDIA B-640 milling machine under dry condition at cutting speed of 250 m/min and 450 m/min, feed rate of 0.15 mm/tooth and depth of cut of 0.3 mm.

III. RESULTS AND DISCUSSION

Formation and Microstructure of chips

Chips are formed due to the shear between the work piece and cutting [11]. In all of the milling process done, elemental crescent-shaped chips were formed as shown in Fig. 1. Chips of this form has also been observed by Ozcatalbas [12] when machining Al composite materials. Fig. 2 and 3 show SEM images of the cutting conditions at cutting speed of 250 m/min and 450m/min respectively. Observation under SEM showed micro cracks occurred on the outside of the crescent shaped chips. A study conducted by Lin et al. [13] on metal matrix composite also linked chip formation with the initiation of cracks. The main mechanism of chip

Figure 1 Elemental chips on cutting conditions V=250 m/min, F= 0.15 mm/rev, D.O.C 0.3 mm

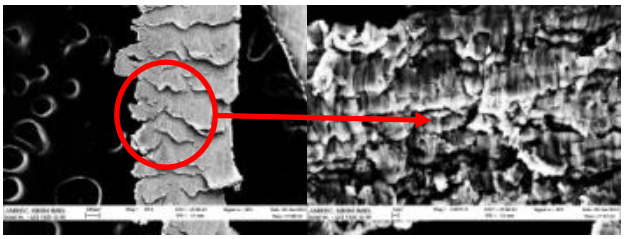

Figure 2 SEM image for chip formation at cutting conditions V=250 m/min, F= 0.15 mm/rev, D.O.C 0.3 mm

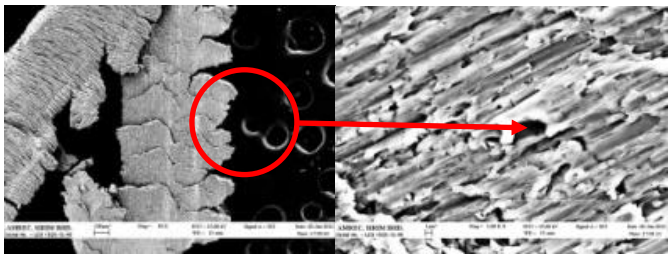

Figure 3 SEM image for chip formation at cutting conditions V=450 m/min, F= 0.15 mm/rev, D.O.C 0.3 mm

formation involves the initiation of cracking of the outer surfaces which are chips-free due to high shear stress. Irregular chip segments are observed as shown in Fig. 2 and 3. Such chips have also been observed by Ozcatalbas [12]. He found that the volume of chips increased with the gross thickness of the segment. He added that these phenomena occur due to the material having sheet-like structure and low hardness. According to Lin et al. [13] it is known that a low hardness and high ductility, causes the adhesion period but reduces the slip period in segment formation. According Jaharah and Sim [10], microstructural changes of the chip are also affected by the addition of cutting speed; constant form of chip thickness or depth of cut, and other factors such as the hardness of the work piece.

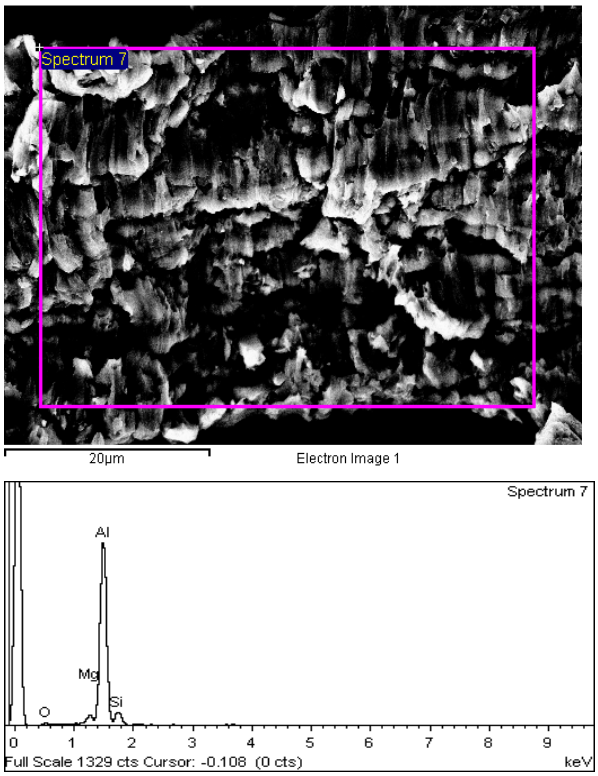

Figure 4 SEM image for chip formation at cutting conditions V=250 m/min, F= 0.15 mm/rev, D.O.C 0.3 mm and EDX analysis

Table 3: Percentage composition of the chip formation at speed of 250m/min

Element	Weight%	Atom%
O K	4.54	7.43
Mg K	3.36	3.62
Al K	79.04	76.77
Si K	13.06	12.19

EDX analysis was performed on chips with cutting conditions V=250 m/min, F= 0.15 mm/rev, D.O.C 0.3 mm for an area as shown in Fig. 4. It was found that 4.54% oxygen content detected on the surface of the chips, as shown in Table 3. The presence of 4.54% oxygen content showed fragments have been oxidized. This moderate oxidation state showed that temperatures generated during cutting are also not very high. Therefore, speed of 250 m/min is appropriate to machine Al-SiC/AlN MMC, since low cutting temperatures were generated, this can reduce the tool wear caused by heat generated during crater wear and diffusion.

IV. CONCLUSION

Chip formation during machining of Al-SiC/AlN MMC produces elemental chip and is crescent shaped. Observations under SEM showed micro cracks occurred on the outside of crescent shaped chip formed with irregular segments. The main mechanism of chip formation involves the initiation of cracking of the outer surfaces which are chip-free due to high shear stress. Chips were observed have suffered a mild oxidation. As a result fragments showed the presence of 4.54% oxygen.

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