Influences of cutting parameters on surface roughness of SiCp/Al composites

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Abstract. Poor surface roughness may reduce the safety and the stability of the parts, to analyse the relationship between cutting parameters and surface roughness is significative to increase the machining quality of SiCp/Al composites. In this paper, the influences of tool rake angle, cutting speed and cutting depth on the surface roughness of SiCp/Al composites were studied by the two dimension cutting experiments. The Ra values were measured by using type TR200 roughness machine. The results indicate that tool rake angle and cutting depth are the main parameters which affect the surface roughness while cutting speed has no significant effects on the surface roughness.

1. Introduction

SiCp/Al composite is a type of new composite which contains good integrated properties, such as high specific strength, high specific stiffness, high specific modulus, excellent dimensional stability, good wear resistance, good fatigue resistance and temperature resistance, low coefficient of thermal expansion[1,2]. Because of that, SiCp/Al composites are used more and more widely in aerospace, military, automotive, electronic packaging and sports products[3,4].

Existing research studies suggest that the hard SiC ceramic particles are embedded in the soft ductile aluminum alloy matrix, difficulties arise during machining SiCp/Al composites. The main difficulties are rapid tool wear, high processing cost and low processing efficiency. In the past, some researchers have studied the effects of cutting parameters on the cutting force[5] and the exit edge defects[6] of SiCp/Al composites in cutting machining. The experiment results indicated that the cutting depth was one main cutting parameter that affected the cutting force while the cutting speed and tool rake angel had no significant effects on the cutting force. The exit edge defect sizes were influenced greatly by the cutting depth and the tool rake angel, but were influenced slightly by the cutting speed. Regrettably the influences of cutting parameters on the surface roughness of SiCp/Al composites have not been studied enough.

Due to the fact that SiCp/Al composites are hard to be processed, the roughness of the processed surfaces is always poor, which may reduce the machining quality and the stability of the products. To study the influences of cutting parameters on the surface roughness is meaningful for the application of SiCp/Al composites in the future. In this paper, the influences of tool rake angle, cutting speed and
cutting depth on the surface roughness of SiCp/Al composites were studied by the two dimension cutting experiments. The study results may be worthy of reference.

2. Experimental details
The volume fraction is 56% and the average edge size is 60 μm for SiC particles in CY1110 SiCp/Al composites. The size of the workpiece is 59mm×47mm×4mm. Figure 1 shows the microstructure of CY1110 SiCp/Al composites, figure 2 shows the SiCp/Al composites workpieces, table 1 shows the material parameters of CY1110 SiCp/Al composites. The cutting experiments were carried out on the vertical machining center EUMA ME650. The cutting edge width of the PCD tool is 5 mm and the clearance angle (α) of the PCD tool is 5°. The Ra values of the processed surfaces were measured by using the type TR200 roughness machine. The sampling length (l) is 0.8 mm and the assessment length (ln) is 3l. Two measuring directions of the Ra values were chosen, one was in the cutting direction, the other one was perpendicular to the cutting direction. Figure 3 shows the experimental setup, table 2 shows the experimental parameters.

![Al matrix and SiC particles](image1)

**Figure 1.** The microstructure of CY1110 SiCp/Al composites.

![Workpieces of CY1110 SiCp/Al composites](image2)

**Figure 2.** The workpieces of CY1110 SiCp/Al composites.

**Table 1.** Material parameters of CY1110 SiCp/Al composites.

| Parameter name                     | Parameter value |
|-----------------------------------|-----------------|
| SiC particles volume fraction (%) | 56              |
| SiC particles average edge size (μm) | 60              |
| Elastic modulus (Gpa)             | 220             |
| Flexural strength (Mpa)           | 400             |
| Poisson's ratio (1)               | 0.23            |
| Density (kg/m3)                   | 2940            |
Figure 3. The experimental setup.
Table 2. Experimental parameters.

| Variables          | Parameter value |
|--------------------|-----------------|
| Tool rake angle $\gamma_0$ ($^\circ$) | -10, -5, 0, 5, 10 |
| Cutting speed $V_c$ (m/min) | 1, 3, 5, 7, 9 |
| Cutting depth $ap$ (mm) | 0.05, 0.1, 0.15, 0.2, 0.3 |

3. Results and discussion

3.1. The influence of tool rake angle on the surface roughness

In the experiments, cutting speed was kept at 5m/min, five kinds of cutting depth (ap=0.05 mm, 0.1 mm, 0.15 mm, 0.2 mm, 0.3 mm) were chosen for comparative analysis while tool rake angle varied. The results are shown in figure 4, (a) is that the measured direction of the Ra values is in the cutting direction, (b) is that the measured direction is perpendicular to the cutting direction.

As shown in (a), when $\gamma_0$ is less than $-5^\circ$, Ra values increase obviously with the reducing of $\gamma_0$. When $\gamma_0$ is at the range of $-5^\circ$~$5^\circ$, Ra values wave and increase slightly. When $\gamma_0$ is more than $5^\circ$, Ra values decrease obviously. It can be explained when $\gamma_0$ is less than $-5^\circ$, the pressure action of tool to SiC particles is very significant. SiC particle is more harder than Al matrix and is pressed into Al matrix, then some pockets form on the Al matrix surface, which cause Ra values increasing. When $\gamma_0$ is at the range of $-5^\circ$~$5^\circ$, the pressure and shear action of tool to SiC particles is almost equivalent, SiC particles mainly fracture, which make the processed surface smooth. When $\gamma_0$ is more than $5^\circ$, the shear action of tool to SiC particles is very significant. SiC particles are mainly extracted from Al matrix because the connection between SiC particle and Al matrix is not firm enough, then some pockets form and are filled immediately by Al matrix that happens plastic flowing, which cause the Ra values decreasing.

As shown in (b), the wave amplitude of Ra values is more larger, which prove that the processed surface is more rougher in this measured direction. It can be explained that the direction of SiC particle’s breaking is perpendicular to the cutting direction when SiC particles break.
3.2. The influence of cutting speed on the surface roughness

In the experiments, cutting depth was kept at 0.1 mm, five kinds of tool rake angle ($\gamma_0=-10^\circ$ , $-5^\circ$, $0^\circ$, $5^\circ$, $10^\circ$) were chosen for comparative analysis while cutting speed varied. The results are shown in figure 5, (a) is that the measured direction of the $Ra$ values is in the cutting direction, (b) is that the measured direction is perpendicular to the cutting direction.

As shown in (a), $Ra$ values increase and wave slightly with the increasing of cutting speed $V_c$, which prove the influence of cutting speed on the surface roughness is not significant. It can be explained when cutting speed increase, the removal rate of SiCp/Al composites decrease slightly, the residuary area rate increase, which cause $Ra$ values increase slightly.

As shown in (b), the wave amplitude of $Ra$ values is also small, which prove the influence of cutting speed on the surface roughness is not significant.

Maybe the cutting speeds in those experiments were all not high enough, so high cutting speed may fit to machining SiCp/Al composites.
3.3. The influence of cutting depth on the surface roughness

In the experiments, cutting speed was kept at 5m/min, five kinds of tool rake angle (γ0=−10°, -5°, 0°, 5°, 10°) were chosen for comparative analysis while cutting depth varied. The results are shown in figure 6, (a) is that the measured direction of the Ra values is in the cutting direction, (b) is that the measured direction is perpendicular to the cutting direction.

As shown in (a), Ra values increase with the increasing of cutting depth, when ap is at the range of 0.05 mm ~ 0.2 mm, the wave amplitude of Ra values is small. When ap is larger than 0.2 mm, Ra values increase obviously. It can be explained that the deeper the cutting depth is, the larger the cutting force is, the bigger the chip is, the more serious the vibration is, the more serious the wear of the tool is. All of those factors cause that the SiCp/Al composites are not cut enough when cutting depth is deeper than 0.2 mm, then some pockets and bulges form on the processed surface, which cause Ra values increasing obviously.

As shown in (b), the wave amplitude of Ra values is smaller than (a), which prove that the influence of cutting depth increasing is not significant in this direction.
4. Conclusions
The influence of tool rake angle on the surface roughness is significant. When $\gamma_0$ is larger than $5^\circ$, $Ra$ values decrease obviously. The influence of cutting speed on the surface roughness is not significant. Maybe high cutting speed is needed to machine SiCp/Al composites. The influence of cutting depth on the surface roughness is significant. When $a_p$ is larger than 0.2 mm, $Ra$ values increase obviously. The wave amplitude of $Ra$ values which is perpendicular to the cutting direction is larger than the ones in the cutting direction.

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