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PROCEEDING

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Surface Roughness Analysis in Machining of TiC Reinforced Aluminum LM6

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Abstract

With increasing quantities of applications of Metal Matrix Composites (MMCs), the machinability of these materials has become important for investigation. This paper presents an investigation of surface roughness dry machining of aluminum LM6–TiC composite using uncoated carbide tool. The experiments carried out consisted of different cutting models based on combination of cutting speed, feed rate and depth of cut as the parameters of cutting process. The cutting models designed based on the Design of Experiment Response Surface Methodology. The objective of this research is finding the optimum cutting parameters based on workpiece surface roughness, the minimum values of *Ra* are the good machinability of MMCs. The results indicated that the minimum value of surface roughness was found at the cutting parameters (v = 250 m min^{-1}, f = 0.05 mm rev^{-1}, ap = 1 mm).

Keywords : Aluminum composites, cutting parameter, surface roughness.

Introduction

Now a day's metal matrix composites (MMCs) are the new class of materials and rapidly replacing conventional materials in various engineering applications, especially in the automobile and aerospace industries. Aluminum alloy is light metal commonly used in the MMCs as matrix phase reinforced with particles reinforcement such as SiC, TiC, SiO_2 and Al_2O_3. Aluminum MMCs have low density, excellent wear resistance, high specific strength and high specific modulus over conventional materials. The machining process of these materials is more difficult than the conventional materials, due to the addition of reinforcing materials which are harder and stiffer than the matrix (Bhushan, *et al.,* 2010; Seeman, *et al.,* 2010; Muthukrishnan, *et al.*, 2011; Yusuf, *et al.*, 2014).

In machining operations, the surface finish requirement restricts the range of cutting parameters and tool geometries which can be used, especially finishing operations. Surface finish is a factor of great importance in the evaluation of machining accuracy. A lot of factors affect the surface condition of machined part. However, machining parameters such as cutting speed, feed and depth of cut have a significant influence on surface quality.

The machinabilty of aluminum matrix composites reinforced particulate has investigated by several researchers. Bahera was investigated manchinability of LM6 reinforced with 5 and 10 wt.% SiC particles (Bahera, *et al.*, 2011). The effect of SiCp reinforcement on the machinability and the effects of machining parameters such as cutting speed and depth of cut at constant feed rate on surface roughness and the cutting forces has been investigated. The experiment was conducted on a conventional lathe machine using HSS cutting tool without use of coolant. The results show that higher weight percentage of SiC reinforcement produced a higher surface roughness. At constant feed rate and different cutting speed, the cutting forces are increases on increasing the depth of cut, it is indicated that the power consumption increases on increasing the depth of cut. The surface roughness increases on increasing the depth of cut and decreases on increasing the cutting speed at constant feed rate.

Surface roughness and wear of the cutting tool during the turning of LM6 aluminum with 2 wt.% TiC composite using uncoated carbide tool in dry cutting condition was investigated (Yusuf *et al.,* 2014). The results indicated that the minimum values of surface roughness was found at high cutting speed of 250 m min^{-1} with various feed rate within range of 0.05 to 0.2 mm rev^{-1}, and depth of cut within range of 0.5 to 1.5 mm. Turning operation at high cutting speed of 250 m min^{-1} produced faster tool wear as compared to low cutting speed of 175 m min–1 and 100 m min^{-1}.

This study is concerned with the effect of cutting parameters (cutting speed, feed and depth of cut) on the surface roughness in turning process aluminum LM6 reinforced with 10 wt% of TiC (Titanium Carbide) particles composite. The objective of this research is to obtaining the optimum cutting parameters to get a better surface quality

Experimental Setup

Material

Metal matrix composite of LM6 aluminum alloy (BS 1490–1988 LM6) type was used as the matrix material with 10 % wt TiC (Titanium Carbide) particles as reinforcement was prepared by liquid metal stir casting technique. The chemical compositions of LM6 aluminum in percentage of mass have been included in Table 1. The small ingot of LM6 is melted in crucible using an electrical resistance furnace. The TiC particles were preheated at the temperature of 600°C before mixed with the LM6 liquid to make their surface oxidized. The melt was mechanically stirred by using a hard steel impeller and then the preheated titanium carbide particles added with the stirred LM6 liquid. The processing of the composite was carried out at the temperature of 720°C with the stirring speed of 200–250 rpm for 20 minutes (Figure 1). The melt composite was poured into the round bar sand mould with the dimension of diameter of 50 mm and length of 300 mm. The vibration technique was used during solidification process by putting sand mould on the vibration table as shown in Figure 2. This technique has a remarkable effect on the castings properties. Figure 3 shows the round bar casting products of LM6 aluminum reinforced with 10 wt.% TiC particles.

Machine and cutting insert

The machining were carried out under dry cutting condition on CNC lathe machine (Mazak SQT 200MY). The round bar casting product of aluminum LM6 with 10 % wt TiC composite used as the workpiece material in machining trials. The cutting tool insert uncoated carbide VCGT 160402 FL K10 with tool holder SVJCR was used in the experiment. The cutting parameters which are cutting speed (v), feed (f) and depth of cut (a_p) were selected as the control parameters of the machining. The cutting parameters and levels each parameter were set as shown in Table 2. The combination of cutting parameters as the cutting condition models designed based on the Design of Experiments (DOE) Response Surface Methodology represent Box–Behnken design (Myers and Montgomery, 2002). The surface roughness was measured using portable MarSurf PS1 to measure of average surface roughness (Ra).

Table 1. Chemical composition (wt. %) of LM6 aluminum

Si	Fe	Cu	Mn	Mg	Ni	Zn	Sn	Ti	Other	Al
10–13	0.6	0.1	0.5	0.1	0.1	0.1	0.05	0.2	0.15	Rest

Table 2. The cutting parameters process and their levels

Factor	Unit	Levels		
		Low	Medium	High
Cutting speed (v)	m min^{-1}	100	175	250
Feed (f)	mm rev^{-1}	0.05	0.125	0.2
Depth of cut (a_p)	mm	0.5	1.0	1.5

Figure 1. Stirring process of liquid LM6 with TiC particles

Figure 2. Vibration technique for solidification process

Figure 3. The round bar casting products of LM6 aluminum reinforced with 10 wt.% TiC particles.

Results and Discussion

Surface roughness is a factor of great importance in the evaluation of the machinability of metal matrix composites. Surface roughness is the final surface quality formed after the machining on a workpiece. Many factors affect the surface roughness of a machined part such as properties and constituents of workpiece material, tool geometry, and machine condition. However, cutting parameters such as cutting speed, feed rate and depth of cut have a significant influence on surface roughness.

In the present study, the value of surface roughness of cast TiC reinforced aluminium LM6 has been investigated at selected cutting speed, feed and depth of cut as the cutting parameters. Based on DOE response surface methodology, with use of Minitab software was found fifteen the cutting condition models represent Box–Behnken design to run the experiment. The cutting condition models and the experimental results as given in Table 3.

The effect of different cutting parameters on machining of LM6 composites can be studied by using response graph and response table. The effect of cutting parameters on surfaces roughness is shown in Figure 3. It is clearly observed that in figures, cutting parameters has significant effect on surface roughness.
Figure 3 shows that surface roughness is low at high cutting speed. This was due to the velocity of chips flow that is faster at high cutting speed than low cutting speed. This causes a shorter time for the contact of chips with the newly formed surface of the workpiece (Boothroyd, 2006). The surface roughness increase with increased feed parameter. Actually this case is commonly expected, due to agreeable with a popular model to estimate the surface roughness with a tool having nonzero nose radius (Boothroyd, 2006), is:

$$\mathrm{Ra} = \frac{f^2}{32\,.\,r} \quad (1)$$

where *Ra* is the average surface roughness, *f* is the feed parameter, and *r* is the cutting tool nose radius. The surface roughness increased with increased dept of cut.

The minimum values of surface roughness are the good quality of workpiece surface. From Tabel 3, machining of LM6 aluminum reinforced with 10 wt.% TiC composite was found at the cutting parameters (v = 250 m min^{-1}, f = 0.05 mm rev^{-1}, ap = 1 mm).

Table 3. The cutting condition models and the experimental results

Cutting models	Cutting parameters			Ra (μm)
	v (m min^{-1})	f (mm rev^{-1})	a_p (mm)	
1	100	0.05	1	7.014
2	250	0.05	1	3.022
3	100	0.2	1	7.379
4	250	0.2	1	6.208
5	100	0.125	0.5	6.344
6	250	0.125	0.5	3.381
7	100	0.125	1.5	9.405
8	250	0.125	1.5	4.156
9	175	0.05	0.5	3.390
10	175	0.2	0.5	7.614
11	175	0.05	1.5	4.137
12	175	0.2	1.5	7.851
13	175	0.125	1	5.099
14	175	0.125	1	4.937
15	175	0.125	1	5.018

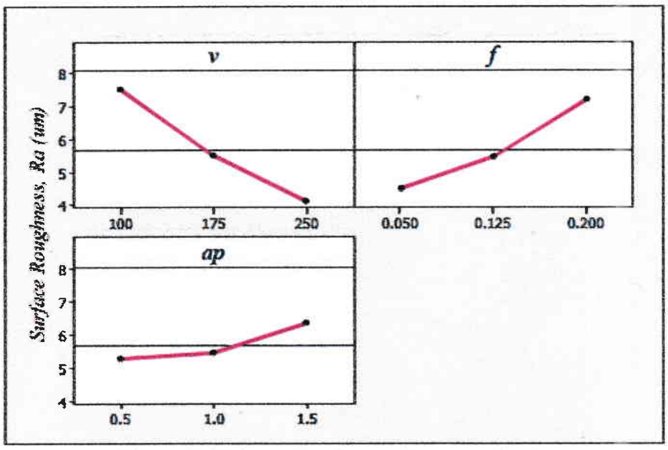

Figure 3. Effect plot for surface roughness

Conclusions

In this study, effect of parameters cutting speed, feed, and depth of cut on surface roughness during machining of LM6 aluminum with 10 wt.% TiC composite using uncoated carbide tool have been analyzed. Based on the results, it was found that cutting parameters has significant effect on surface roughness. The minimum value of *Ra* in the workpiece was found at the cutting parameters (v = 250 m min^{-1}, f = 0.05 mm rev^{-1}, ap = 1 mm).

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