Surface roughness a measurement of in-situ metal matrix composite Al7075/B_4C

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ABSTRACT

The machinability of metal matrix composites (MMCs) faces many challenges such as rapid tool wear, larger machining time and hence, increases the overall machining cost. This paper deals with the fabrication of Al7075/B_4CMMC and its machining during conventional turning on CNC lathe. It includes the measurement of surface roughness as well as elements of surface integrity. The response surface methodology (RSM) is used to predict the mathematical relations and to identify the significant process parameter. The morphology of compositesurface before and after machining is also discussed using SEM images. At last, the atomic force microscopy (AFM) has been applied to evaluate the irregularities on machined surface.

Keywords: Surface roughness, Response surface methodology, Scanning electron microscopy, Atomic force microscopy

I. INTRODUCTION

In today's industry, the demand for new class of advanced materials are increasing continuously. Its leads to the development of metal matrix composites (MMCs). MMCs are popular in the manufacturing industries due to their excellent properties like high strength to weight ratio, light weight, better wear and corrosion resistance **[1, 2]**. MMCs possesses two or more distinct materials which have their own distinctive properties **[3].**VanSuchetclan**[4]**stated that composites are the mixture of heterogeneous materials consisting of two or more solid phases. MMCs have most of the desired properties but still not used at large scale due to its reduced performance during machining. The presence of hard reinforcement particles leads to the rapid tool wear which increases the overall machining cost **[5]**. Conventional machining involves the operation via single-point or multipoint cutting tools with definite geometry. The machining outcomes and elements of surface integrity such as morphology, topography are highly influenced by cutting tool as well as workpiece material. Most of the work has been reported to explain the surface roughness as well as its topography like surface cracks, hardness variation, irregularities. etc.**[6, 7]**.

Y.F. Ge et al. **[8]** investigated the effect of reinforcement particles and its volume fraction, cooling condition on surface integrity during turning operation via various cutting tools.Kilickap et al**[9]**concluded that cutting speed is the most influencing factor to evaluate the surface roughness while turning Al/5%SiC MMC. Kannan et al**[10]** investigated micro hardness variation and also describes the surface defects like pits, micro-cracks etc., It was examined that the de-bonding of reinforcements from machined surface increases the surface defects. Tomac and Tonnesson **[11]**describes the relation for tool life during turning of Al/SiC MMC at lower speed (100m/min). Ranganath MS et al **[12]**stated that feed rate and cutting speed was the most influencing factor during machining of Al-6061 Alloy under dry condition.**Devaraju A.et.al.[13]** describes the development of hybrid composite ofAl–SiC/Gr by friction stir processing. Optical microscopy has been used to explain the microstructural details. further they examined the effect of tool rotational speed on wear resistance. **Looney et al. [14]**used the various cutting tools to machined Al/SiC MMCs. The effect of process parameters on machining outcomes and tool wear has been explain. **Ozben et al. [15]**examined the effect of reinforcement percentage in Al/SiC MMC. They also explain the machinability of developed composite.**Vishal et al.[15]** stated that cutting speed, feed rate and depth of cut is most influence factor during machining of EN 31 by CBN tool. It can be observed that most of the work has been reported on the development and machinability of MMCs. However, the optimum machining condition and improved surface finish is still a keen area of research for today's researchers. In this work, an experimental investigation is conducted to measure the effect of process parameters of CNC lathe on surface roughness and surface integrity.

II. EXPERIMENTAL PROCEDURE

In the present work Al7075 is used as matrix material and B_4C particles of size 20 um as a reinforcement. The chemical composition of Al7075 is given in table 1 and its Mechanical and physical properties are given in table 2 and 3, respectively. Boron carbide (B_4C) has different kind of characteristics such high hardness and better nuclear properties with low density. The physical properties of B_4C is given in table 3.

Table 1 Chemical Composition

Elements	AA7075 Content (%)
Aluminum, Al	89.58
Zinc, Zn	5.95
Magnesium, Mg	0.055
Copper, Cu	0.098

Chromium, Cr	2.33
Silicon ,Si	0.4
Manganese, Mn	1.41
Titanium	--
Other	--

Table 2 Mechanical Properties of Al7075

Properties	AA7075
Tensile strength	220 MPa
Yield strength	95 MPa
Shear strength	150 MPa
Fatigue strength	160 MPa
Elastic modulus	70-80 GPa
Poisson's ratio	0.33
Elongation at break	17%
Hardness	60

Table 3Physical Properties of Al7075 and B_4C.

Properties	AA7075	B_4C
Density	2.8 g/cm^3	2.52
Melting point	483°C	2445°C
Thermal expansion	23.2 (10^{-6}/ºC)	5 (10^{-6}/ºC)
Thermal conductivity	130 W/mK	30 – 42 W/mK

Stir casting method has been applied to develop the MMC of Al7075/10% B_4C. The setup of stir casting process is shown in figure 1. The capacity of melting pot was 2kg of Al7075, maximum continuous operating temperature was around 1000^{0}C and the process temperature was indicated by digital display. The temperature of the process can be controlled by electronic ON/OFF type temperature controller. The operating voltage was 440V AC and App. Power consumption was 7.5 KW of furnace and 5KW of motors and the stirrer speed was varied from 0-2000 revolution per minute.

In the experiment, the aluminum alloys are placed into the crucible and further placed in to the muffle furnace. The heating temperature is gradually increasing up to 750°C which is above the melting temperature of matrix material. The reinforcement was also preheated at temperature nearly 350°C to increase the wettability during mixing. The stirrer speed was kept between 300 to 400 rpm for better mixing results and to provide sufficient turbulence. The stirring process was done for 4 to 5 minutes to mix the reinforcement particles. The poring can be done in the previously made moulds and leave to solidify in natural air. **[16, 17, 18].**

Fig. 1 Stir Casting equipment

In the present work, the prepared composites are machined on the CNC lathe. CBN insert is used for machining of developed composites under different machining conditions. Cutting speed, depth of cut and feed rate are considered as input machining parameters The Batliboi sprint 16TC CNC lathe is used for machining (figure 2). The NC programme is prepared for the turning operation for composites. The specifications of 16TC CNC lathe machine is given in table 4.

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Fig.2 CNC lathe machine

Table 4 Specifications ofCNC SPRINT 16 TC

Main Specifications	Sprint 16 TC
Swing over Bed	400 mm
Turning Diameter	225 mm
Turning Length	300 mm
Power Chuck	165mm
Spindle Speed	30 - 5000 rpm
Spindle Motor	5.5 / 7.5 kw
Z – axis Stroke	325 mm
X – axis Stroke	125 mm

Max. No. of Tools in Turret	8
Rapid Traverse	20 m / min
Tail stock	Hydraulic

In the present work, the study of influence of machining parameters on the surface integrity of metal matrix composites have been investigated in terms of selected input parameters such as cutting speed, feed rate, depth of cut. In order to design the experimental plan, Minitab 17 software was used to develop the mathematical model of surface roughness. The RSM technique was employed to quantify the relationship between input machining parameters and response factors.

III. RESULT AND DISCUSSION

Metal matrix composite of Al7075/B_4C has been successfully developed. The SEM micrograph of developed sample is shown in figure 3. It raveled the uniform mixing of B_4C particles throughout the matrix material. The range of variable process parameters and their level of design is given in table 5.

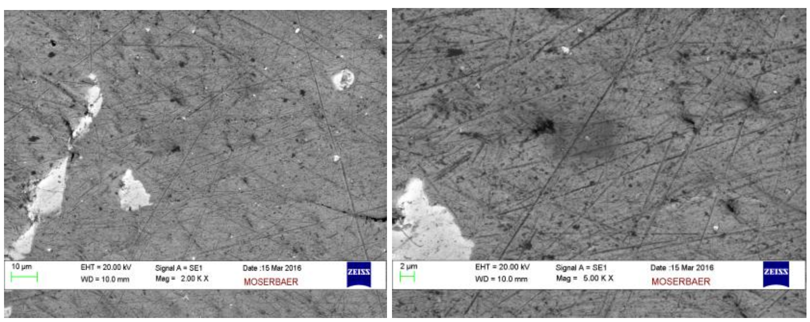

Fig. 3 SEM micrograph of developed MMC Al7075/B_4C

Table 5 Variable process parameters in CNC lathe and their level of design

S. No.	Process parameters	Symbol	Level of design		
			-1	0	+1
1	Rotational speed (rpm)	A	800	1000	1200
2	Feed rate (mm/rev)	B	0.025	0.05	0.075
3	Depth of cut (mm)	C	0.2	0.3	0.4

Surface roughness has been measured at each set of process parameters in order to evaluate the machinability. Surface roughness has been measured by Mitutoyo make (SJ-210) roughness tester. Total 15 experimental run has been conducted to predict the more accurate results in terms of output response. The design table and their corresponding output response (surface roughness) is given in table 6. The residual plots are shown in figure 4. It shows that most of the experimental values are nearly close to the predicted line. hence, the model is significant. The individual effect of process parameters on surface roughness has been measured to check its level of significance. Figure 5 shows the main effect plot of process parameters on surface roughness. It is clear from the graph that while increasing the rotational speed, the value of surface roughness goes down whereas increasing of feed rate and depth of cut, roughness value increases. The SEM micrograph of developed MMC after machining is shown in figure 6. The tool marks can be seen on the machined surface. Few porosities on the machined surface can also be seen. This is due to the dislodgement of reinforcement from surface during machining operation.

Table 6 Design table and output response

S. No.	Rotational speed(rpm)	Feed (mm/rev)	DOC (mm)	Roughness (μm)
1	1200	0.05	0.2	1.2
2	1000	0.05	0.1	2.8
3	1000	0.05	0.3	2.75
4	1000	0.075	0.2	2.8
5	1000	0.025	0.2	2.42
6	800	0.05	0.2	2.45
7	1000	0.05	0.3	2.15
8	1000	0.05	0.1	2.15
9	1200	0.05	0.2	1.65
10	1000	0.075	0.2	2.74
11	1000	0.025	0.2	2.45
12	800	0.05	0.2	2.55
13	1000	0.05	0.2	2.50
14	1200	0.05	0.1	1.25
15	800	0.025	0.2	2.35

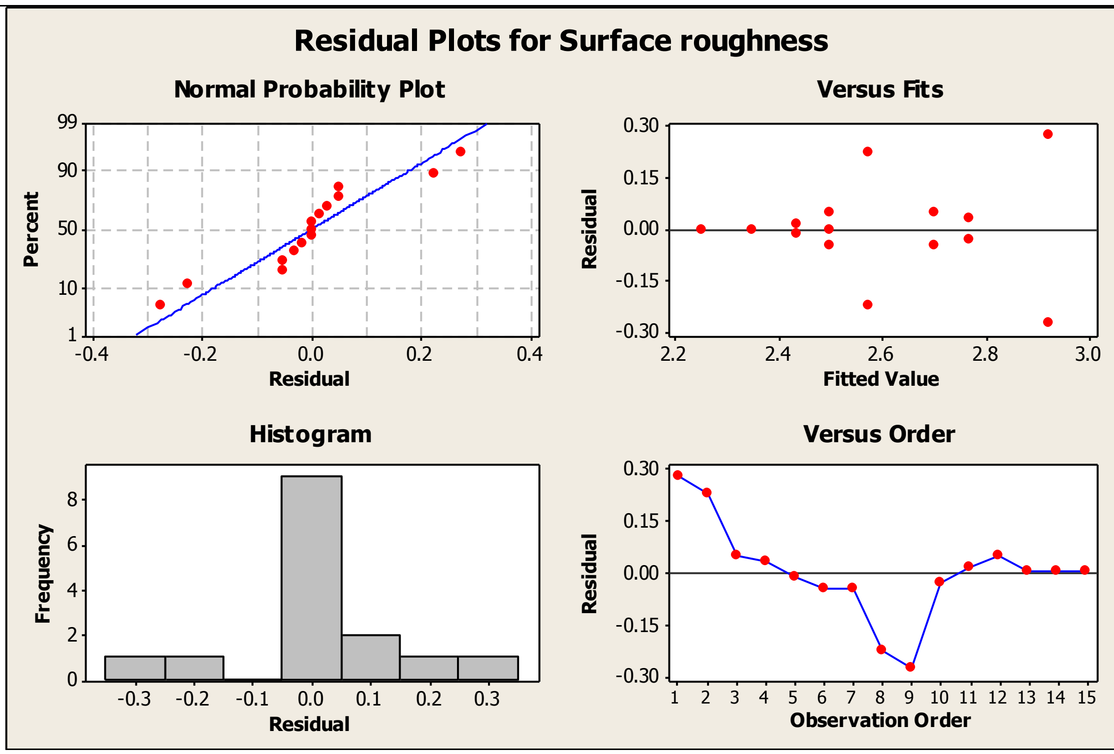

Fig. 4 Residual plots for surface roughness

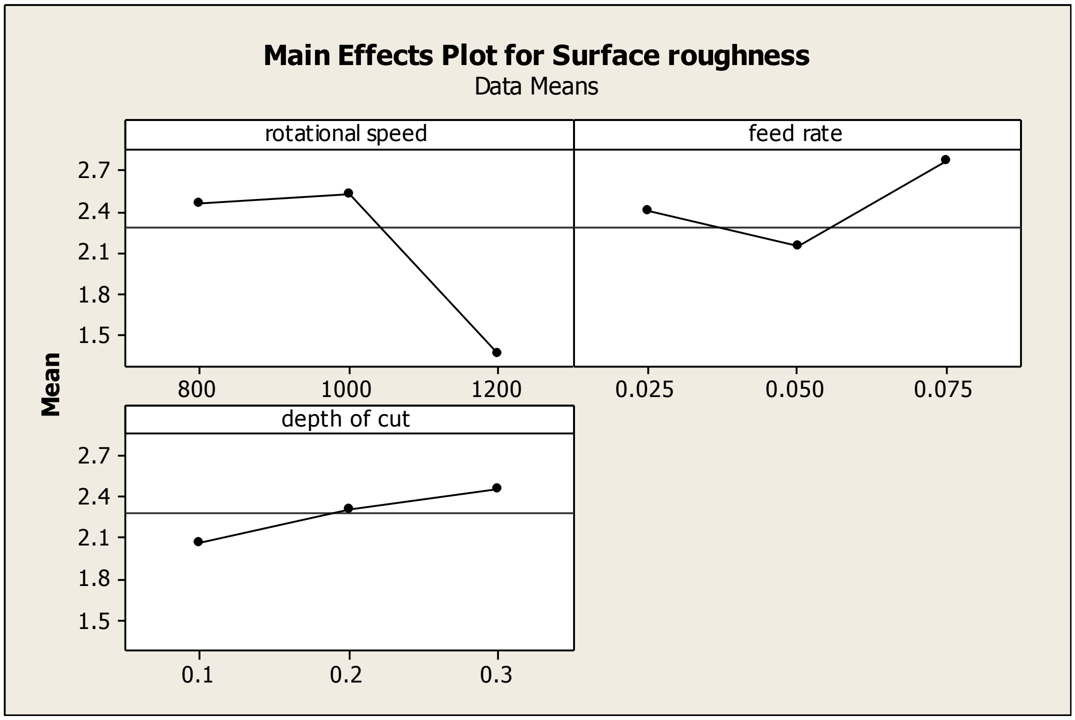

Fig.5 Main effect plot of process parameters on surface roughness

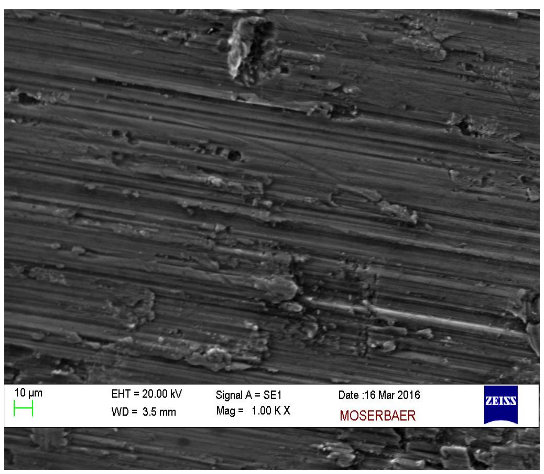

Fig.6 SEM micrograph of MMC after machining

Atomic-force microscopy (AFM) was also applied to measure the minimum and maximum fluctuation and irregularities on the machined surface for a randomly picked sample. The peaks and valleys can also be measured by these graphs. The graph of AFM study is shown in figure 7. It is clear from the figure 6 that minimum surface roughness of 1.544 µm can be obtained on the machined surface.

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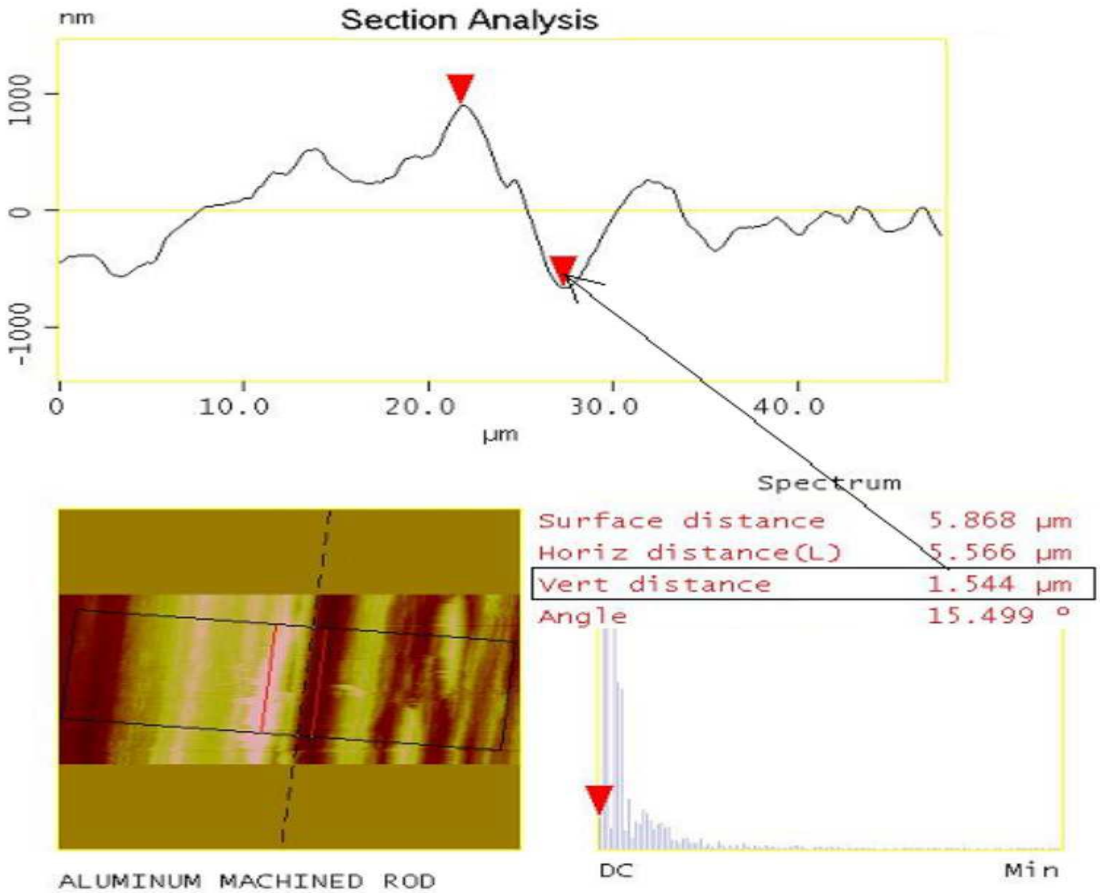

Figure 7 AFM graph of machined surface

IV. CONCLUSIONS

In this present work, the aluminum metal matrix composites were developed successfully by the stir casting route. The surface roughness and isanalyzed as response factors and feed rate, depth of cut androtational speed are termed as input parameters. RSM method is employed successfully to analyses the influence of machining parameters on the aluminum composites. The following conclusions are drawn as follows.

1. The stir casting equipment is capable of producing the aluminum metal matrix composites which has homogeneous mixing of reinforcement.
2. SEM image of fabricated sample shows the uniform distribution with negligible defects like porosity.
3. All three process parameters have significant effect on surface roughness during machining of Al7075/B_4C.
4. For AA7075/B_4C composite CBN inserts is suitable for machining.
5. SEM image of machined surface shows the small scale porosity on the machined surface due to dislodgment of reinforcement particles during machining operation.

6. AFM results revealed that the minimum surface roughness of 1.544 μm can be achieved by the machining process on the developed MMC.

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