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Selection of end Milling Parameters on AA7075-15 Wt. % B_4C Metal Matrix Composites

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Abstract : This work was to investigate the effect of CNC end milling process parameters for machining of AA7075-15 wt. % B_4C metal matrix composite by using Taguchi design methodology. The composite was fabricated through stir casting route. Material Removal Rate(MRR) and Surface Roughness (SR) were selected as the output responses. The experiments were carried out based on Taguchi's L9 orthogonal array by choosing various input parameters such as: cutting speed (rpm), feed rate (mm/min) and depth of cut (mm) at three levels. Signal-to-Noise ratios and main effect plots were used to find the optimal levels of parameters in CNC end milling process. Analysis of variance (ANOVA) was used to determine the effects of the machining parameters on material removal rate and surface roughness. From the results observed that the depth of cut is the most influencing factor affecting the material removal rate and feed rate is the most dominant factor affecting the surface roughness.

Keywords : AA7075, B_4C, END milling, MRR, SR, Taguchi method, ANOVA.

1. Introduction

Aluminium and its alloys are widely used as a major engineering material in various industries such as automotive, aerospace, the mould and die components manufacture due to their high strength to weight ratios, good wear resistance and high modulus of elasticity[1].Metal matrix composites (MMCs) are produced by mixing two or more materials that may be discrete in their physical and chemical characteristics. These advanced composite materials obtained at good attention because of their high stiffness, low density and strength[2]. Different kinds of particles such as, TiC, Al_2O_3, TiO_2, B_4C and SiC are used as ceramic reinforcement particles with aluminium alloy as a matrix material[3]. For fabricating a particle-reinforced composite, a few techniques are available namely stir casting, powder metallurgy, infiltration, squeeze casting and compo casting. Among those techniques, stir casting is an accepted processing technique as it is relatively inexpensive, simple, and applicable for mass production[4]. The aluminium matrix composites obtained through the stir casting route has better mechanical properties that allow its use in various industrial applications[5]. Milling process is one of the most essential and frequent metal cutting operations used for machining parts because of its ability to remove materials faster with a reasonably good surface quality. End milling is the extensively used machining operation for metal removal in a variety of manufacturing industries including the automobile and aerospace sector where quality is an important factor in the production of slots, pockets, moulds and dies. The quality of surface is great importance in the functional behaviour of the milled components[6]. Elssawi yahya et al. investigated that the effect of tool flutes, cutting speed, feed rate and depth of cut on SR during end milling of AA6061 using response surface methodology. They reported that cutter flutes has most significant factor on SR followed by feed rate and depth of cut [7]. Puneet kumar et al. reported that the machining of mild steel EN18 on MRR and SR to the various milling parameters such as cutting speed, feed rate and depth of cut [8]. Venkata Vishnu et al. studied CNC milling process of AA6351 and reported that coolant flow is the most significant factor for the SR followed by feed rate. An increase in feed rate and coolant flow will results in better surface finish [9]. Abhishek kumbhar et al. analyzed the influence of cutting speed, feed rate and depth of cut on MRR and SR during milling operation for SS304 using Taguchi method and derived that depth of cut is most significant factor followed by feed rate and cutting speed [10]. Rizwan Anwar et al. studied the effect of cutting speed, feed rate and depth of cut on SR while milling of Aluminium alloy 7075-T6 [11]. Vijaya Krishna Teje et al. optimized the milling parameters of AISI 304 stainless steel using grey Taguchi method and concluded that cutting speed is most influence factor that affects the output responses such as MRR and SR [12]. Chavan et al. analyzed that CNC end milling of Al-Si7Mg aluminium alloy using Taguchi method. The input parameters such as coolant environment, cutting speed and depth of cut. The output responses are SR and MRR [13]. Kannan et al. studied the effect of spindle speed, feed rate and depth of cut on MRR and SR while machining of aluminium alloy [14]. Sidda Reddy et al. optimized the CNC end milling parameters on SR using RSM and genetic algorithm [15]. Ramanathan et al. reported that the influence of milling parameters on MRR and SR while machining of AA6063 using Taguchi design and noticed that feed rate is most dominant factor that affect the SR [16]. Nimas et al. investigated that the influence of spindle speed, feed rate and depth of cut on SR of Al7075 alloy during end milling and concluded that spindle speed and feed rate are the most significant factor affecting the output responses [17].The objective of the present work is to investigate the effect of end milling parameters namely cutting speed, feed rate and depth of cut on material removal rate (MRR) and surface roughness (SR) during machining of AA 7075-15 wt. % B_4C metal matrix composites fabricated by stir casting process. Taguchi technique was used to analyze the experimental results.

2. Experimental Details

2.1 Fabrication of Composites

Aluminium metal matrix composites(AMMCs) were fabricated by using stir casting route. The matrix material used in the present work aluminium alloy AA 7075.B_4C is used as reinforcement particles. The base metal AA 7075was melted at 850°Cinan electric furnace and preheated B_4C particles (15 wt. %) added slowly intothe molten slurry. Then the slurry is stirred at200 rpm for 15 min. After stirring, the crucible was taken outside the furnace and the molten slurry was poured into a preheated metallic mould at a room temperature. The work pieces of AMMCs are cut into rectangular cross sections of dimension 100 mm x 100 mm x 10 mm and the top andbottomfacesoftheworkpiecesaregroundtomakeflatandgoodsurfacefinishpriorto experimentation.

2.2 Design of Experiments

In this study the effect of three machining parameters with three levels are considered and is given in Table 1. The objective of present work is to maximize the MRR and to minimize the SR. The experiment was carried out using L9 orthogonal array and the experimental layout is shown in Table 2. [18]

Table:1Process parameters with their levels

Symbol	Process parameters	Units	Levels		
			1	2	3
A	Cutting Speed	rpm	1000	1500	2000
B	Feed Rate	mm/min	200	300	400
C	Depth of Cut	mm	0.5	1	1.5

Table:2Experimental layout using L9 orthogonal array

Ex. No	A	B	C	Cutting Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)
1	1	1	1	1000	200	0.5
2	1	2	2	1000	300	1
3	1	3	3	1000	400	1.5
4	2	1	2	1500	200	1

5	2	2	3	1500	300	1.5
6	2	3	1	1500	400	0.5
7	3	1	3	2000	200	1.5
8	3	2	1	2000	300	0.5
9	3	3	2	2000	400	1

2.3 Experimental Procedure

The machining was carried out by using CNC vertical milling machine (CNC MILL). The experimental setup is shown in Fig.1. The size of the work piece is 100 mm x 100 mm x 10 mm. The 12 mm HSS end mill cutter was used as a cutting tool. The machining was performed in to rectangular shape of 25 mm breadth and 3 mm depth was maintained at all the experiments. The machined surface was measured at three different locations by using a surface roughness tester and the average surface roughness (SR) value is considered. Material removal rate (MRR) is used as another performance measure to evaluate a machining performance. Material removal rate is expressed as the amount of material removed under a period of machining time.

Fig. 1 CNC milling setup

3. Result and Discussions

In this work, the Taguchi method has been used to design the experimental parameters. The Taguchi technique can be used to reduce the number of experiments required to obtain necessary data for optimization. Generally, there are three types of signal-to- noise ratios such as Larger-the-better(LTB), the Smaller-the-better (STB), and Nominal-the-best(NTB). In this present study, two responses such as material removal rate (MRR) and surface roughness (Ra) are considered. Material removal rate is considered to be maximized and surface roughness is considered to be minimized. The Larger-the-better (LTB) S/N ratio is given by [19]

$$\text{S/N ratio} = -10\log_{10}(1/n)\sum_{k=1}^{n}\frac{1}{Y_{ij}^{2}} \qquad (1)$$

The Smaller-the-better (STB) S/N ratio is given by

$$\text{S/N ratio} = -10\log_{10}(1/n)\sum_{k=1}^{n}Y_{ij}^{2} \qquad (2)$$

Where n – number of replications, Y_{ij} – observed responses value where i = 1, 2, 3…..n; j = 1, 2, 3…….k.

The experimental results for MRR, SR and corresponding signal-to-noise ratio values are given in Table 3.

Table: 3 Experimental results with their calculated S/N ratios

Ex. No	Output responses		Signal- to- Noise ratios	
	MRR (mm^3/min)	**SR (µm)**	**MRR (dB)**	**SR (dB)**
1	17.2605	2.20	24.7411	-6.84845
2	31.0156	1.99	29.8316	-5.97706
3	38.8112	2.57	31.7791	-8.19866
4	29.4387	2.38	29.3784	-7.53154
5	37.4435	1.93	31.4675	-5.71115
6	21.9382	2.19	26.8240	-6.80888
7	33.9407	2.09	30.6144	-6.40293
8	20.7166	2.12	26.3264	-6.52672
9	34.2140	2.14	30.6841	-6.60828

3.1 S/N Ratio Analysis

Table 4 shows the calculated value of S/N ratio for MRR. From the table, it is observed that, depth of cut shows the highest delta value and ranked at 1, i.e. the depth of cut is most significant parameter for MRR followed by feed rate and cutting speed. Fig. 2 shows the main effect plot of S/N ratio for MRR and it is used to determine the value of input process parameters to maximize MRR. The maximum MRR is obtained at level 2 for cutting speed, level 3 for feed rate and level 3 for depth of cut. The optimal level of different input parameters for maximizing MRR is A2B3C3.

Table:4 Response table for S/N ratios (MRR)

Process parameter	Level1	Level2	Level3	Delta	Rank
Cutting Speed (A)	28.78	29.22	29.21	0.44	3
Feed Rate (B)	28.24	29.21	29.76	1.52	2
Depth of Cut (C)	25.96	26.96	31.29	5.32	1

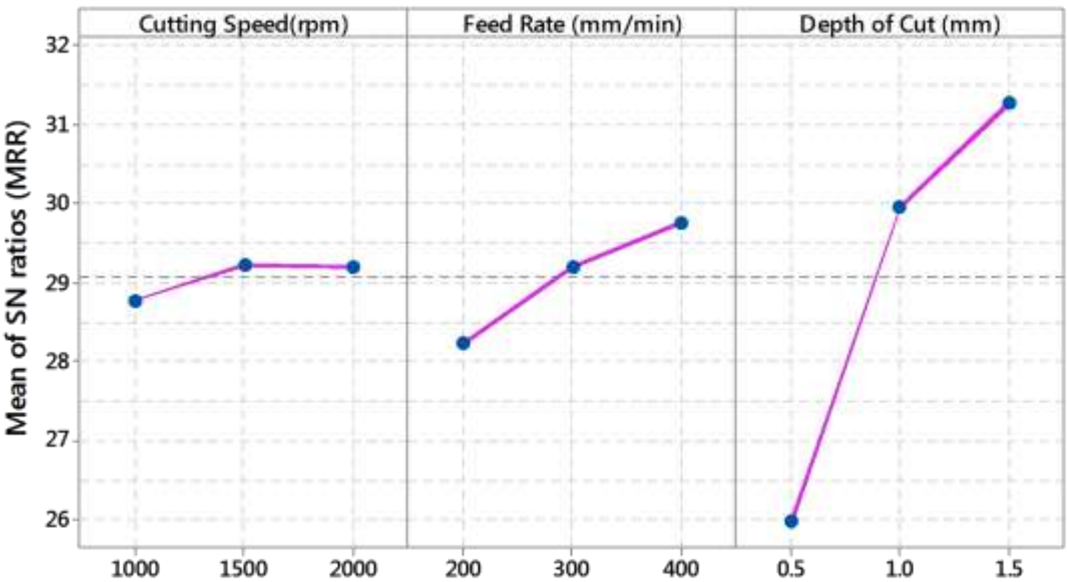

Fig. 2 Main effect plot for MRR

Table 5shows the calculated value of S/N ratio for SR. From the table, it is noticed that, feed rate shows the highest delta value and ranked at 1, i.e. feed rate is most significant parameter for SR followed by cutting speed and depth of cut. Fig. 3 shows the main effect plot of S/N ratio for SR and it is used to determine the value of input process parameters to minimize SR. From the figure, it is clear that minimum SR is obtained at level 3 for cutting speed, level 2 for feed rate and level 2 for depth of cut. The optimal level of different input parameters for minimizing SR is A3B2C2.

Table: 5 Response table for S/N ratios (SR)

Process parameter	Level 1	Level 2	Level 3	Delta	Rank
Cutting Speed (A)	-7.008	-6.684	-6.513	0.495	2
Feed Rate (B)	-6.928	-6.072	-7.205	1.134	1
Depth of Cut (C)	-6.728	-6.706	-6.771	0.065	3

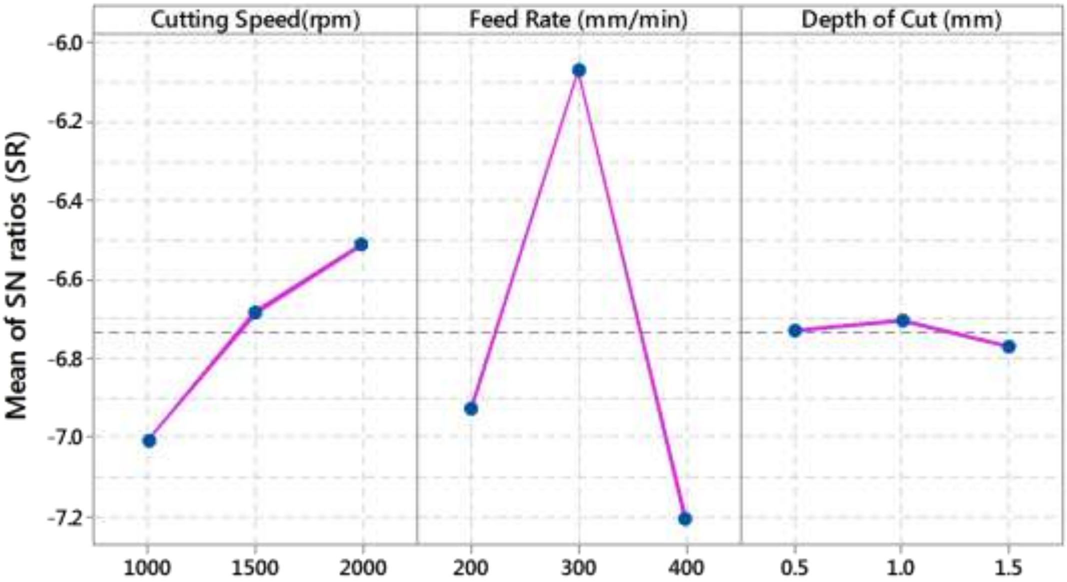

Fig. 3 Main effect plot for SR

3.2 ANOVA Analysis

ANOVA is the statistical method generally used for getting the results of experiments to determine the percentage contribution of each input parameters. The objective of ANOVA is to identify the significant of input process parameters on the MRR and SR with the help of S/N ratio [20]. Table 6 given the ANOVA results for MRR. From the table, it is clearly indicated the depth of cut is found to be most significant factor that affect the MRR followed by feed rate with contributions of 92.42% and 7.23%. The least significant factor is cutting speed with contribution of 0.14%.

Table: 6ANOVA results for MRR

Process parameters	*DoF*	*Adj SS*	*Adj MS*	*F-ratio*	*% of Con*
Cutting Speed (A)	2	0.688	0.344	0.74	0.1438
Feed Rate (B)	2	34.613	17.307	37.13	7.239
Depth of Cut (C)	2	441.883	220.942	474.01	92.421
Residual Error	2	0.932	0.466		0.194
Total	8	478.117			100

Table 7 shows the ANOVA results for SR. From the table, it is clearly noticed that feed rate is found to be most significant factor that affect the SR followed by cutting speed with contributions of 43.40% and 9.42%. Depth of cut is least significant factor that affects the SR with contribution of 0.46%.

Table: 7ANOVA results for SR

Process parameters	*DoF*	*Adj SS*	*Adj MS*	*F-ratio*	*% of Con*
Cutting Speed (A)	2	0.02869	0.01434	0.20	9.422
Feed Rate (B)	2	0.13216	0.06608	0.93	43.403
Depth of Cut (C)	2	0.00142	0.00071	0.01	0.466
Residual Error	2	0.14222	0.07111		46.707
Total	8	0.30449			100

3.3 Interaction Plot Analysis

Figure 3 shows the interaction of cutting speed, feed rate and depth of cut for the response on MRR. It is observed that, while considering the cutting speed and feed rate, the most influencing factor is feed rate. Similarly while considering the cutting speed and depth of cut, the most dominant factor is depth of cut. Similarly while considering feed rate and depth of cut is parallel to each other, there is no interacting effect on MRR.

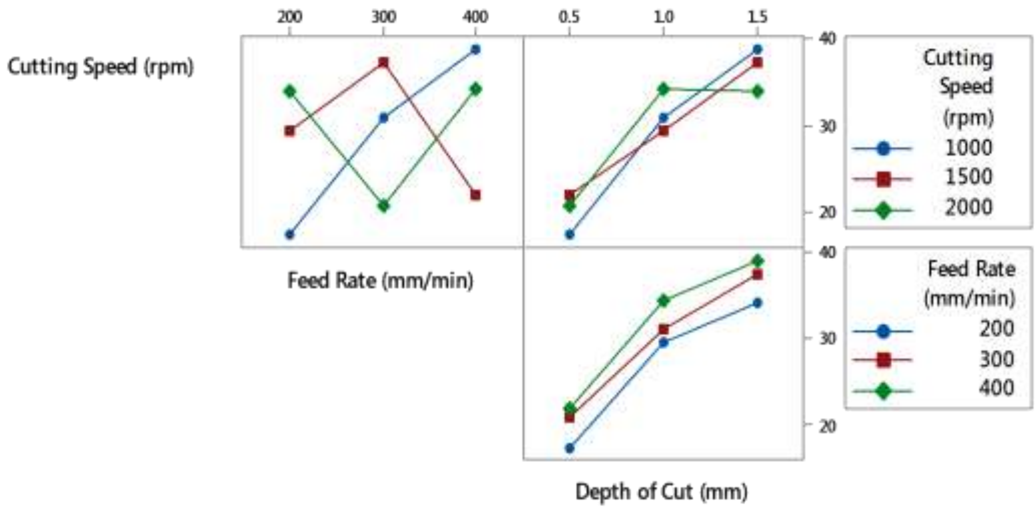

Fig. 4 Interaction plot for MRR

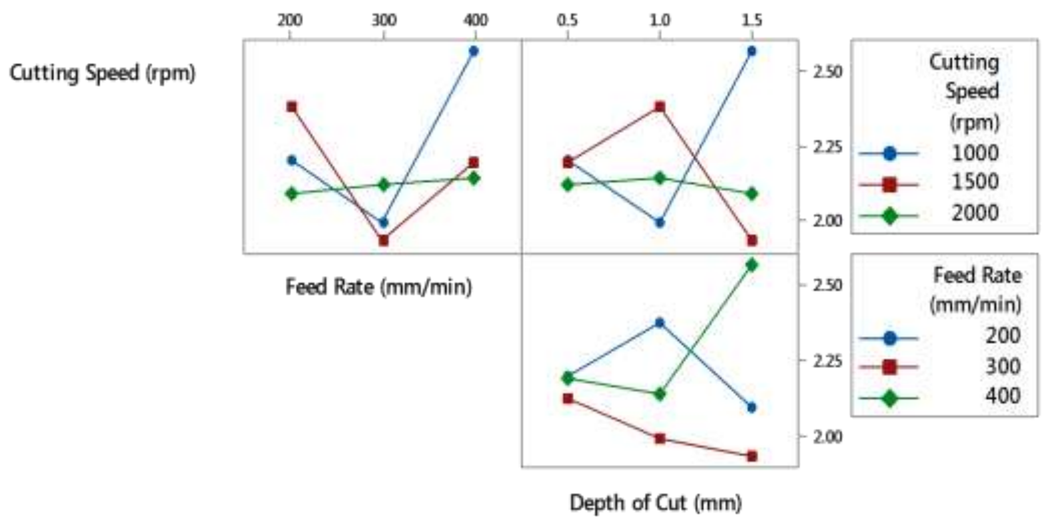

Fig. 5 Interaction plot for SR

Figure 5 shows the interaction of cutting speed, feed rate and depth of cut for the response on SR. It is display that, while considering the cutting speed and feed rate, the most influencing factor is feed rate. Similarly while considering the cutting speed and depth of cut, the most dominant factor is cutting speed. Similarly while considering feed rate and depth of cut, feed rate most important factor for SR.

4. Conclusions

In this work, the effects of cutting speed, feed rate and depth of cut on material removal rate and surface roughness during end milling of AA 7075-15 wt. % B_4C metal matrix composite were investigated using Taguchi's method. The metal matrix composite was successfully fabricated through the stir casting route. Form the S/N ratio analysis optimal process parameter for maximum MRR: Cutting speed (1500 rpm), Feed rate (400 mm/min) and Depth of cut (1.5 mm) and optimal process parameter for minimum SR: Cutting speed (2000 rpm), Feed rate (300 mm/min) and Depth of cut (1 mm). From ANOVA results shows that depth of cut is most influencing factor that affecting the MRR followed by feed rate with contributions of (92.42% and 7.23%) and feed rate is most influencing factor for affecting the SR followed by cutting speed with contributions of (43.40% and 9.42%).

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