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Effect of Machining Process Parameters on Surface Roughness of Aluminium Metal Matrix Composites (Al - MMCs)

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Abstract - In the current investigation the influence of drilling process parameters such as cutting speed, feed rate and point angle in affecting the surface roughness of Al Metal Matrix Composites (AA7075 – 5 wt% SiC) was investigated. Al MMC was synthesized using stir casting technique. Experiments (Drilling process) was carried out using taguchi L9 array. Drilling process parameters were considered as the factors in affecting the response (surface roughness). Process parameters were varied at three levels (Cutting speed – 600,900 & 1200 rpm, feed rate -0.5.0.8 & 1.1 mm/rev and point angle - 90^o,115^o & 140^o). Drill diameter was kept constant at 10 mm. Analysis of Variance (ANOVA) indicated that the cutting speed (98.95%) had largely influenced the surface roughness of the composite. Surface roughness found to decrease with increasing cutting speed

Keywords: **Al MMC – SiC- factors – Surface roughness – ANOVA - S/N ratio**

1.INTRODUCTION:

Aluminium Metal Matrix Composites are being widely used in aerospace, automotive and structural applications due to their high strength to weight ratio. Al MMCs consists of Al alloys reinforced with continues fibers/whiskers /particulates. Silicon Carbide (SiC), Alumina (Al_2O_3) and Boron Carbide (B_4C) are some of the widely used particulate reinforcements. Al MMCs exhibit improved strength, wear and other properties than the monolithic alloy. On the other hand machining of the Al MMCs plays a crucial role in applicability of these to numerous applications. Lower surface roughness during machining of Al MMCs is desirable since it makes these composites suitable for aircraft/automotive body works and as well as for having sound mechanical joints. Achieving sound interface and as well as wettability between the reinforcement and matrix is very critical with respect to machining of Al MMCs. MMCs with poor interface and wettability exhibits spalling, delamination, and crack formation owing to their brittleness. Several investigations have been carried out on milling, drilling and turning of Al MMCs. In most of the investigations cutting speed, feed rate and depth of cut were chosen as the factors while surface roughness was the response studied [3,7 &10]. Siva sankar raju et.al [9] studied the effect of factors (cutting speed, feed rate and depth of cut) in turning of Al MMC reinforced with Coconut Shell Ash (CAS) using carbide tool. They carried out the machining operations as per Taguchi L9 orthogonal array by varying the factors at three levels (Cutting speed – 60,120 & 180 m/min, feed (f) – 0.5,1.0 & 1.5 mm/rev, depth of cut – 0.2,0.3 & 0.4 mm) and studied the response surface roughness using statistical analysis such as Analysis of Variance (ANOVA) and Signal to noise ratio (S/N ratio). Feed rate was to have highest influence on the surface roughness in their study and optimum cutting conditions was found to be cutting speed (60 m/min), feedrate (1.5 mm/rev), and depth of cut (0.4 mm) to achieve the minimum surface roughness. Gurprit singh et.al [10] carried out turning operation using tungsten carbide tool on Al hybrid MMC reinforced with 10 weight percentage (wt%) SiC particlulates and 5wt% Graphite at three levels of cutting speed(100,150 & 2000 rpm),feed rate (0.2,0.4 and 0.6 mm/rev) and depth of cut (0.2,0.6 and 1.0 mm) as per Taguchi L9 orthogonal array. Very limited attempts have been made in analyzing the influence of tool tip angle in affecting the surface roughness of the composites. In the present investigation the influence of cutting speed , feed rate and tool point angle on the surface roughness of the Al MMC reinforced with 5wt% SiC particulates was studied by employing Taguchi L9 orthogonal array and as well as ANOVA and S/N ratio analysis.

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2.MATERIALS AND METHODS:

Aluminium alloy 7075 of Aluminium alloy 7xxx series selected as matrix material reason being its good machinability, relatively low cost and also strength is also good. Aerospace, automotive, marine, and sports equipment industries are some of the common applications of Aluminium 7075. Chemical compsosition of Al 7075 alloy is shown in table.1 . Chemical composition was obtained Optical Emission Spectroscopy (OES) – BRUKER (Q4 TASMAN).

Table 1. – Composition of Aluminium alloy 7075 (Wt%)

Elements		Si	Cu	Fe	Mn	Mg	Cr	Zn	Ti	Al
Wt%		0.4	0.5	1.1	0.3	2.45	0.23	0.56	0.2	Balance

Stir-casting technique was used to synthesize Al +5 wt% SiC composite in the present investigation [1,2&6] . Melting of Al alloy was carried out at 750^0 C and preheated reinforcements were added into the Aluminium alloy melt. Stirring of the molten mixture was carried out for 15 minutes. Degassing agent (hexachloro ethane) was used to reduce gas porosities. The molten metal was then poured at 650^0 C into a permanent cast iron mould of diameter 26mm and length 300mm. The dimension of the work piece used in the current investigation was 140 mm X 110 mm X 15 mm . Stir casting setup used for the present investigation is shown in figure.1 and the sample prepared for drilling is shown in figure.2.

Figure.1 Stir casting setup

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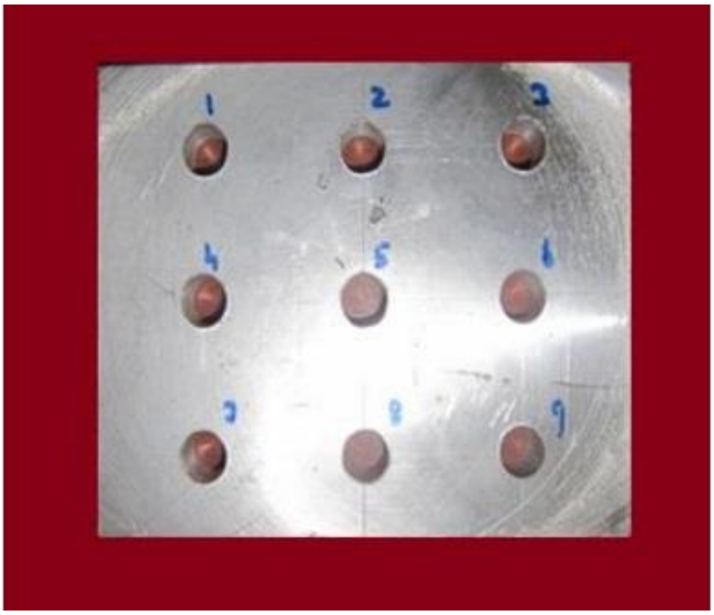

Figure.2 Workpiece for drilling operation

Factors employed in the present investigation for carrying out drilling operations on the composite were cutting speed (rpm), feed rate 9 (mm/rev) and point angle. These factors were varied at three levels as shown in table.2. The drilling operations were performed on the workpiece in the locations marked as per taguchi L9 orthogonal array [4,5&8] (Table.3).

Table.2 Factors used in the present investigation

S.No	Factor designation	Control factor	Level 1	Level 2	Level 3
1	A	Cutting speed (rpm)	600	900	1200
2	B	Feed rate (mm/rev)	0.50	0.80	1.10
3	C	Point angle (θ)	90^0	115^0	140^0

Table .3 Taguchi L9 orthogonal array used in the investigation

Trail .No	Cutting speed	Feed rate	Point angle
1	600	0.50	90^0
2	600	0.80	115^0
3	600	1.10	140^0
4	900	0.50	115^0
5	900	0.80	140^0
6	900	1.10	90^0
7	1200	0.50	140^0
8	1200	0.80	90^0
9	1200	1.10	115^0

Surface roughness (R_a) of all the holes produced was measured by MITUTOYO – SJ201 surface roughness tester. Surface roughness was measured at three spots for all the holes produced and the average reading was taken for the statistical analysis. 'Larger the better' S/N ratio category was chosen for the present investigation since it indicates better performance characteristics [9].

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3. RESULTS AND DISCUSSIONS:

Surface roughness values obtained for the conducted trails of L9 orthogonal array is shown in table.4

Table .4 Surface roughness values

Trail .No	Cutting speed	Feed rate	Point angle	Surface roughness
1	600	0.50	90^0	1.020
2	600	0.80	115^0	1.020
3	600	1.10	140^0	1.022
4	900	0.50	115^0	0.820
5	900	0.80	140^0	0.830
6	900	1.10	90^0	0.820
7	1200	0.50	140^0	0.740
8	1200	0.80	90^0	0.780
9	1200	1.10	115^0	0.780

Main effects plot for mean of surface roughness (figure.3) indicates that surface roughness decreases drastically with an increase in cutting speed whereas surface roughness decreases marginally with an increase in point angle. Surface found to increase marginally with increasing feed rate.

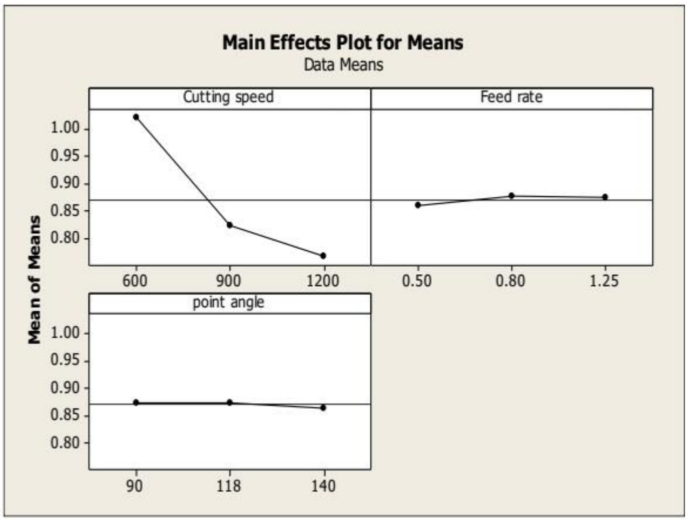

Fig .3 Main effects plot for mean of surface roughness

It can be observed from the ANOVA analysis of mean of surface roughness (table. 5) that cutting speed had the highest contribution of about 98.95% on the surface roughness followed by feed rate (0.446 %) and point angle (0.16 %).

Table. 5 Analysis of Variance for Means of Surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F_o	P	Percentage contribution (Pr%)
Cutting speed	2	0.10668	0.10668	0.053334	221.81	0.004	98.95
Feed rate	2	0.000481	0.000481	0.000240	1.0	0.500	0.446
Point angle	2	0.000174	0.000174	0.000087	0.36	0.734	0.16
Error	5	0.000481	0.000481	0.000240			0.044
Total	11	0.107804					100

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Response table for mean of S/N ratio for surface roughness (table.6) showed that cutting speed had the largest S/N ratio confirming that it had larger influence on surface roughness than other factors.

Table.6 Response table for S/N ratio for Surface roughness

Level	Cutting speed	feedrate	Point angle
1	1.0207	0.8600	0.8733
2	0.8233	0.8767	0.8733
3	0.7667	0.8740	0.8640
Delta	0.2540	0.0167	0.0093
Rank	1	2	3

A linear regression model was developed (equation.1) using statistical software"MINITAB 16". This model gives the relationship between an independent / predicted variable and a response variable by fitting a linear equation to observe data. Regression equation thus generated establishes correlation between the significant terms obtained from ANOVA analysis namely cutting speed, feedrate and point angle.

Surface roughness = 1.26 - 0.000423 Cutting speed + 0.000167 Feed rate - 0.000178-point angle - (1)

Regression equation confirms that surface roughness decreases with increasing cutting speed and it also agrees with trends showed by surface roughness with respect to feedrate and point angle as observed in ANOVA and S/N ratio analysis.

Confirmation experiments were carried out (table.7) to validate the linear regression equation obtained. The experimental value of surface roughness found to be varying from surface roughness calculated in regression equation by error percentage between1.68% - 3.132 %. The results of response generated by regression model and results of confirmation experiments had exhibited a good degree of agreement with each other. Hence the developed regression model was capable of predicting the surface roughness.

Table .7 Confirmation Experiment for surface roughness

Trail.No	Cutting speed	feedrate	Point angle	Experimental value	Regression model value	% Error
1	600	0.5	90	1.020	0.991	2.92
2	900	0.8	140	0.830	0.856	3.132
3	1200	0.5	140	0.740	0.728	1.648

4.CONCLUSION:

Based on the experiments and analysis carried out in the present investigation the following conclusions can be observed.

1. Al MMC was successfully synthesized by adding 5 wt% SiC particles in the AA7075 alloy through stir casting
2. Cutting speed exhibited higher degree of influence (98.95%) on the surface roughness than any other factors
3. Surface roughness found to decrease with increasing cutting speed whereas surface roughness decreases marginally with an increase in point angle and increases marginally with increasing feed rate
4. Regression model developed was in good agreement with ANOVA and S/N ratio analysis. Results of Confirmation experiments and regression model were found to be very close to each other.

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