

Improvisation of Machining Parameters for Better Surface Finish of MMC Material using Taguchi Method



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Abstract: Metal matrix composite is used in engineering applications due to its superior mechanical properties. MMC's are reinforced with particle fiber, whisker, and particulate. The size of particulates used is classified as micro, nano, and macro. The particulate reinforced MMC's have excellent form-ability compared to fiber and whisker composite. Metal matrix composite has outstanding wear, heat resistance, and excellent mechanical properties. Many authors have been stated the property as its ability of workpiece material to be machined or it refers to workpiece response to machining or it is normally applied to the machining properties of work material or it indicates how easily and fast a material can be machined. MMC materials are difficult to machine with a superior surface finish. In this study Al6061 with Silicon Carbide and Graphite are fabricated with 5 weight % using squeeze casting route. Tensile strength and hardness are tested according to ASTM standards and as a result, there was an increase in tensile strength and hardness of MMC. Machining process parameters plays a vital role in defining surface roughness. This machining parameters are to be optimized to get the better surface finish results. Taguchi techniques is used. To optimized the machining parameters affecting machining of MMC for surface roughness are identified. Orthogonal array L9 was selected based on three parameters with three levels. There is a vital role played by the feed rate in increasing the surface roughness of the material. Relevant process parameters considered for a better roughness of the surface are, cutting speed 300RPM, the rate of feed 0.13 mm/rev, and the depth of cut 0.4mm.

Keywords: Squeeze Casting, Machining, and the Surface Roughness

I. INTRODUCTION

Now a day the MMC's are used in marine, automobile, and aerospace industries due to their superior properties. Fabrication technique plays an important role in the

distribution of reinforcement [1]. Squeeze casting is a new & simple casting method that is economical, with the excellent ability in automatic operation at high rates of production. Mechanical properties are improved of the cast products produced from the squeeze casting operation. The refinement of the microstructure of products made by squeeze casting can be used for several critical applications. [1].

In-car businesses, head of the barrel, liners, cylinders, rotors of brakes, and its calipers [3– 4] are models where MMCs materials are used to accomplish better wear resistance. In any case, the use of MMCs in the automobile industries isn't constrained to previously mentioned parts. Car and railroad enterprises use MMCs in various assortments. The Toyota diesel motor is a car manufacturing industry that uses MMC. It had alumina-silica fiber joined in the ring notch of the cylinder amid the weight casting of aluminum [2].

Ajay R. Bhardwaj [4] has discussed several machining ability aspects of MMCs. Machine operations performed on composite materials depend upon the properties and relation satisfied by the reinforcements & matrix of the materials and their response to machining operations. The material performance in machining depends on the properties of the matrix and the volume of reinforcement of the material. While the machining of composite materials, extra forces are acting on the geometry of the cutting tool simultaneously wear of tool due to expansion should be considered during the selection of the cutting tool.

The work of A.R. Chambers [5] is worried about estimate some of the operation parameters which affect the machine-ability of aluminum-based metal matrix composites. The terms considered for machining composites are the wear of the tool, the life of the tool, surface quality, forces acting during cutting, and cutting parameters. In this paper, evaluation of the machining ability of two test materials Al-5 Mg which is reinforced with 15% Silicon Carbide and 5% Saffil, and 15% Silicon Carbide is reinforced in Duralcan and is carried out by machining with KIO make cemented carbide and PCD turning tools. While tool wear, cutting speed was the most important process parameter while the rate of feed and depth of cut were kept constant. The flank wear controlled the wear of KIO for both composite materials. Wear of a tool positively gives details of the (Al-5Mg hybrid) that increase the force through cutting speed reinforced by KIO. The force measurement of the tool and workpiece during the machining process increases the value of the wear of tool. Thus, as a result, force measurements of the tool can provide an effective measure of the tool condition while machining alloys of the said type.

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Due to the addition of reinforcing materials in the samples, which were having properties like hardness and stiffness than the matrix composite, machining of these MMC materials become significantly more demanding than those of conventional materials. Machining becomes difficult due to the non-homogeneous and anisotropic nature associated with abrasive reinforcement of the material. The wear rate experienced by the cutting tools can damage the material, which results in uneconomical machining and the poor surface finish of the material.

II. EXPERIMENTAL PROCEDURE

A. MMC fabrication

Samples will be fabricated as per table 1. An increase in 10% by weight there is an increase in accumulation due to the dislocation density of reinforcement material. Homogenous mixture production is no possible due to the increasing % weight of reinforcement, as the reinforcements settle down due to higher density as compares to the matrix phase (Al6061).

Table- I: Material segregation

	AL6061	Silicon Carbide	Graphite
Sample 1	90%	5%	5%

For the sample Al6061, rods are purchased from the market. Silicon Carbide and Graphite particles are purchased from Mumbai. Silicon carbide and graphite having a size of particles as 30µm. Samples will be segregated as per table I. Above 10% by the weight of reinforcement the agglomeration increases, this is due to the dislocation density of reinforcement. An Increase in % weight of reinforcement material added also increases the density of reinforcement due to which homogenous mixture production is not possible due to an increase in % weight of reinforcement, as reinforcements settle down due to higher density as compares to the matrix phase (Al6061).

In a crucible furnace, the desired amount of Al6061 is melted. The melting temperature of Al alloy was 700°C. To remove impurities, Silicon Carbide and Graphite reinforcement particles having the size of 30 microns are pre-heated till 500°C temperature. This pre-heated reinforcement is added into the melted Al6061 and stirred for 5 minutes at 500rpm, further it is transmitted to die through a pre-heater, which was set for 300°C. To keep the mixture in a liquid phase the pathway is maintained at some temperature. At last, the liquid metal is pressurized in the die cavity. The applied pressure for this study was taken is 100 MPa. For completely solidifying the material the process is carried out very quickly, providing solidification of the molten metal under pressure. This increases the rate of heat flow and simultaneously removes macro or micro shrinkage porosity. The porosity which is formed due to dissolved gases in the molten metal is minimized. At last, the punch is withdrawn and the component is ejected.

B. Machining of MMC

The Silicon Carbide metal removing operation used broadly in industries managing metallic slicing is the turning operation. For the turning operation, a precise single point cutting tool is fed into the rotating workpiece, with a constant feed excess material is removed in the form of chips from the material and desired product can be manufactured. The

operator performs this operation on the lathe machine with the help of a computer-controlled application.

The type of machine can be used for fabricated MMC turning with high rigidity. A dry cutting environment was selected for performing the turning operation due to concern regarding the safety of the environment. In the dry cutting process is coolant was not used during themachining of the material, in turn, was a benefit that the cost of cutting fluid was eliminated.

The study shows, considering three levels of the process parameter as shown in table 2, for turning of MMC, DLC coated tool is used. The cuttingspeed, the rate of feed, and depth of cut are varying from low level to highlevel. Therange from low to high was considered from 200rpm to 600rpm. The machining of MMC material of Al6061/Silicon Carbide/Graphite is conducted on the lathe machine for measuring the surface roughness of the sample. The effect of the turning parameters like the depth of cut, spindle speed, and feed on surface roughness is investigated.

Table- II: Process parameters for turning

Sr. No	Particulars	Speed (RPM)	Feed (mm/rev)	Depth of cut (mm)
1	Low	200	0.1	0.2
2	Medium	400	0.13	0.4
3	High	600	0.15	0.6

The quality of the product is determined by the surface roughness of the product which is measured by the surface texture. MITUTOYO Model -SJ211 is used to examine the surface roughness. The roughness of the surface is measured by moving the probe which is made of hard material on the surface of the product. The average surface roughness (Ra), which is mostly used in industries, is taken for this project. The surface roughness was measured at three positions spaced at 120° intervals around the rod circumference with the cut-off length of 0.8mm using SURFTEST SJ-211. Readings at three different locations were taken and then compiled to form one reading and this reading is used for analysis as shown in table III.

C. Design of experiment (DOE)

The Taguchi technique is influential and used where variables having a variety of ranges say (3 to 50), few interactions among variables, and when only some variables contribute drastically. The stages of freedom of three parameters in each of the three ranges are six. Then, a three-degree orthogonal array (L₉3³) with 9 runs of the experiment will be [degrees of freedom = 9-1 = 8] are chosen for studies.

Table- III: Surface roughness value

Sr. no.	Reading 1 (µm)	Reading 2 (µm)	Reading 3 (µm)	Average Reading (µm)
1	0.382	0.379	0.383	0.381
2	0.365	0.351	0.367	0.361
3	0.534	0.545	0.527	0.535
4	0.393	0.391	0.379	0.388
5	0.378	0.407	0.441	0.409

6	0.529	0.532	0.531	0.531
7	0.465	0.451	0.461	0.459
8	0.468	0.469	0.469	0.469
9	0.535	0.541	0.524	0.533

L9 is sufficient for this study. Taguchi's experimental design of experiments suggests L9 orthogonal array. To improvise the parameters, 9 experiments are enough. At columns, assigned variables are based on the main factor, as stipulated by the orthogonal array.

Table- IV: Process parameters and their particulars

Process Parameters	Particular 1	Particular 2	Particular 3
Cutting Speed (RPM)	300	500	700
Feed rate (mm/rev)	0.1	0.13	0.15
Depth of cut (mm)	2	4	6

Table- V: Results of Surface roughness (µm) as per DOE

Sr. No	Speed (RPM)	Feed (mm/rev)	Depth of cut (mm)	Roughness Value (µm)
1	300	0.1	0.2	0.381
2	300	0.13	0.4	0.361
3	300	0.15	0.6	0.535
4	500	0.1	0.4	0.388
5	500	0.13	0.6	0.409
6	500	0.15	0.2	0.533
7	700	0.1	0.6	0.459
8	700	0.13	0.2	0.469
9	700	0.15	0.4	0.533

According to the design of experiments surface roughness readings are shown in table V.

MINITAB 18 was used to analyze the process parameters and was arranged in an L9 orthogonal array. Responses for the S/N ratio for surface roughness are shown in table 6 while the control factor effects on the surface roughness concerning Signal to Noise proportion are shown in table 7. The results showed that feed rate has linked to surface roughness. For better performance, it showed a higher S/N ratio. Parameters having a maximum level of S/N value show the optimum level of process parameters.

Mean & variability of the experimental result is responsible parameter considered in signal to noise proportion. The quality and characteristics of the product/process to improvise rely on the S/N proportion. The analysis of characteristics concerning Signal to Noise proportion can be done by three categories; that are, the lower-the-better, the higher-the-better, and the nominal-the-better. A Signal-to-Noise proportion is a term of strength, which is used to detect control factor settings that reduce the noise effect of the response and MINITAB is used to calculate signal-to-noise proportion for each set of control factor levels in the design.

Table- VI: S/N proportion for surface roughness for smaller is better

Orth. No	Cutting Speed (RPM)	Feed Rate (mm/rev)	Depth of cut (mm)	Roughness Value (µm)	S/N Ratio
L1	300	0.1	0.2	0.381	8.3815
L2	300	0.13	0.4	0.361	8.849856
L3	300	0.15	0.6	0.535	5.432924
L4	500	0.1	0.4	0.388	8.223365
L5	500	0.13	0.6	0.409	7.765534
L6	500	0.15	0.2	0.533	5.465456
L7	700	0.1	0.6	0.459	6.763746
L8	700	0.13	0.2	0.469	6.576543
L9	700	0.15	0.4	0.533	5.465456

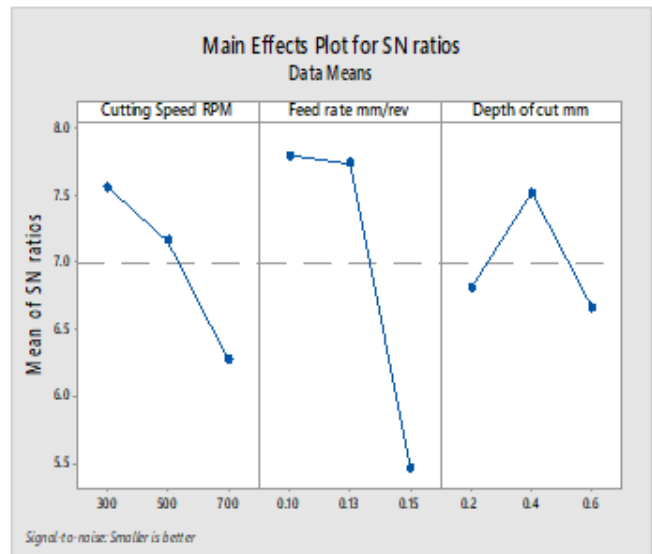


Table- VII: Taguchi Analysis: Roughness Value versus Cutting speed, Rate of feed and Depth of cut smaller is better

Particular	Cutting Speed (RPM)	Feed Rate (mm/rev)	Depth of cut (mm)
1	7.555	7.79	6.808
2	7.151	7.731	7.513
3	6.269	5.455	6.654
Delta	1.286	2.335	0.859
Rank	2	1	3

Fig.1.S/N ratio response curve of surface roughness

The ANOVA results for surface roughness are shown in table 8 which decides the F-ratio. In determining the surface finish properties as compared to all the process parameters Feed Rate plays a vital role. The values of surface roughness are varied depending on the rate of feed. The rate of feed was 75.81% which represents the highest contribution, cutting speed and depth of cut were 15.10% and 7.08% contributions for Surface roughness. It is seen from the ANOVA table that the rate of feed is the major factor to control the value of surface roughness.

Table- VII: ANOVA Variance table for surface roughness

Source	DF	Contribution %	Adj SS	Adj MS	F Value	P Value
Cutting Speed (RPM)	2	15.10	0.005981	0.00299	7.49	0.118
Feed Rate (mm/rev)	2	75.81	0.030033	0.015016	37.63	0.026
Depth of cut (mm)	2	7.08	0.002805	0.001402	3.51	0.222
Error	2	2.01	0.000798	0.000399		
Total	8	100	0.039616			

The rate of feed mostly plays a vital role in the surface roughness. At a lower Feed Rate, the surface roughness was at a low level. An increase in the feed rate affects the surface roughness which increases the temperature of the tip of a tool and MMC interface. Higher roughness results are due to an increase in temperature which generates friction. The rate of feed-in machining MMC using a cutting tool influenced the surface roughness. The rate of feed plays a major role in determining the final component surface roughness. Increasing the rate of feed also produces more vibration which leads to poor surface roughness.

D. Regression analysis

MINITAB 18 software was used to complete the model of regression. In this present study, three levels and three operational parameters were considered. Equation 1 shows the complete regression and by using it the result shows the relationship between the machining and calculated parameters.

$$\text{Surface roughness} = 0.077 + 0.000153 \text{ Cutting Speed RPM} + 2.300 \text{ Feed rate mm/rev} + 0.017 \text{ Depth of cut mm}$$

III. CONCLUSION

With the use of using squeeze casting route, Al6061/5wt%SiC/5wt%Gr was successfully fabricated. The addition of reinforcement shows improvement in mechanical properties compared to Al6061; this improvement is due to hard ceramic particles. Taguchi method is used to improvise the machining parameters for better surface finish. Orthogonal array L9 was selected based on three parameters with three levels. The increase in the rate of feed resulted in a decrease in surface roughness. Optimized process parameters with good surface finish are cutting speed of 300RPM, rate of feed 0.13 mm/rev, and depth of cut 0.4mm. From ANOVA the percentage of contribution of feed rate was 75.81% which was more compared to other parameters hence, the feed rate is more significant parameter for machining MMC and minimizing surface roughness. Second most impact parameters is cutting speed having contribution of 15.10%.

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