DETERMINING THE INFLUENCE OF VARIOUS CUTTING PARAMETERS ON MRR IN LM6/SIC COMPOSITES

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Abstract— *In present scenario, with globalized market, industries are in need to produce high surface finish of metallic parts at lowest possible cost. Face milling is most adoptive and widely used technology in creating complex surfaces which creates larger surface finish. The current research focuses on determining optimal cutting parameters to create high Material Removal Rate in milling process. These experiments were carried out on LM6 Aluminium alloy reinforced with 10% of silicon carbide particles. The machining parameters which are taken for the present study are cutting speed (rpm), feed rate (mm/tooth), depth of cut (mm) and coolant condition. Frictional factorial design (FFD) technique is used for optimizing process parameters. Experiment was conducted by eight trail runs of two level fractional factorial designs. The mathematical models were developed which were from the experimental data that are generated. 'T'-test and 'F'-test were used to test significant of coefficients and adequacy of experimentally developed models. The research details that the established equations clearly show that material removal rate (MRR) increases with the feed increasing and low depth of cut but under wet condition it decreases with increasing cutting speed.*

Keywords *— Optimization; Machining Parameter; Face milling process; Material Removal Rate (MRR); Frictional Factorial Design Technique.*

1. INTRODUCTION

In present scenario to cop up with global competency in market with decreased cost, Increasing in productivity and maintaining a higher product quality with customer satisfaction at the same time are the main challenges which manufacturers face today. Selecting appropriate machining parameters while machining a component is an important factor in achieving these in today competitive advantage in the market [1]. Researchers had proposed studies on the effects of selecting optimal machining parameters of face milling [2].The tips that are used for machining are not designed for re-sharpening or re-usage and these are selected from various types that may be determined by various factors, some of which can be: tip shape, cutting action required, and material going to be cut [3]. When the tips are blunt, they may be removed and replaced to present a fresh one. This will increase the life of the tip and thus extends the life of cutting life [4].In machining process, most of the mechanical energy that is used to remove material becomes heat and thus it generates high temperature in the cutting region portion. When the cutting speed increases heat increases with it and results in higher temperature. But the new challenge in machining is to use increased cutting speed in order to increase the productivity and good surface finish. This heat generated will result in rapid tool wear and surface roughness [5].

Another Conventional method is using cutting fluid which reduces this surface roughness. During the machining process cutting fluid used will acts as lubricant and coolant. Cutting speed increases by 30% when cutting fluid is used which will not affect the surface roughness and tool life [6]. Cutting fluid usage will have negative effect on the economy, environment and health [7]. Due to unsatisfactory tool life and poor surface finish not promising the Total elimination of cutting fluid [8]. This rapid tool wears gives higher surface roughness value, along with this it also provides increased microhardness and various microstructure alterations [9]. During any optimization, Mathematical model is developed which includes objective function, machining parameters that has to be optimized and prediction of realistic output with some physical constraints. In this research work, prediction of minimum surface roughness using optimized machining parameters with a minimum machining time period. From this research, effect of cutting parameter feed and depth of cut are directly proportional to surface roughness and cutting speed is inversely proportional. [10]. the number of trials which are used in a factorial experiment will be greater than the coefficients of a linear model which has to be determined. The factorial experiment has a distinct number of trials which results in increased time and cost of experimentation [11].

2.METHODOLOGY

A. Work piece:

Work piece material selected is LM6 aluminium alloy steel having 25mm thick which is in rectangular in shape and dimensions are 100*50*25 mm^3. Totally 5 work pieces were used for this research work.

TABLE 1: Composition (Wt. %) of LM6

C	Si	Mn	Ir	Zi	Ti
0.1	0.13	0.10	0.6	0.1	0.2

TABLE 2: Physical Properties of LM6

DENSITY (kg/m³)	THERMAL COND (w/m-k)	MELTING POINT (ºC)
2650	34.1	725

B. Cutting Tool Material:

Milling cutter having 4 tungsten carbide inserts are used for machining process.

TABLE 3: Geometry of Cutting Tool

Serial number	content	Mm
1	Cutting Dia.	50
2	Nose radius	0.6

C. Cutting Fluid

Desired coolant flow rate was achieved by regulating the normal supplied air pressure and the opening of nozzle. During this experiment water immiscible cutting fluid was used. This coolant is mixed with solvent or mineral oil and is used for experimental work.

D. Stir Casting

Stir casting technique was involved in order to produce the composite material in this research. LM6 aluminium alloy is casted with reinforcement of 10% SiC particles. SiC particles were slowly added to melted LM6 aluminium alloy inside the furnace keeping a constant temperature of 850ºc and stirrer mixes the composites to a time period of 4-5 minutes. Stirrer speed can be varied from 750-1500 Rpm according to the percentage of reinforcement added.

Fig.1. Stir casting setup

E. Design of Experiment

Face milling operation is done in milling machining operation and all these machining were carried out on 3-axis CNC milling machine. Design of experiment (DOE) was a multilevel factorial design which is summarized below in table 4.

TABLE 4: Design of experiments

Name	Units	Type	Min(1)	Max (2)
Speed	Rev/min	Numeric	300	800
Feed	Mm/tooth	Numeric	0.10	0.20
Depth of cut	Mm	Numeric	0.5	4.0
Coolant	Ml/hr.	Categorical	On	Off

The design matrix which is developed to conduct the eight trials runs with fractional factorial design for 3 factors has been given in Table 5.

TABLE 5: Design matrix

S.NO	S	F	D	C
1	1	1	1	1
2	2	1	1	2
3	1	2	1	2
4	2	2	1	1
5	1	1	2	2
6	2	1	2	1
7	1	2	2	1
8	2	2	2	2

The models that is developed for type Y = f (S, F, D, C) to make the prediction of a response easier for a particular set of process parameters within the limits. It could be written in coded form as:

$$Y=b0+b1S+b2F+b3D+b4C+b12SF+b13SD+b14SC+b23FD+b24FC+b34DC \quad (1)$$

Based on the method of least squares the regression coefficients of the selected model were calculated using Equation1.

$$B=\sum (XijYi)/N, \; j = 0,1....k \quad (2)$$

Where,

Xji= coded form of factors value
Yi = response parameter average
N= total Number of observation
K= Total Number of coefficients of the model

F. Machining

Machining work was carried out on HASS tool room vertical milling center. During machining work feed, speed and depth of cut were given according to the design matrix which was formed. 8 different set of readings were used for machining. Coolant was used appropriately according to the material removal rate.

Fig.2. CNC Used for machining

3. CHECKING MODEL COEFFICIENT'S SIGNIFICANCE

By applying "t" test the statistical significance of the developed model can be analyzed. If the value of "t" is greater, then the model is statistically significant. Other values which are below the standard "t" values from the standard table are dropped as they are not significant.

$$t = |bj|/Sbj \quad (3)$$

Where,

|bj| = coefficients of experimental values.

Sbj = coefficients standard deviation

Sbj $=S^2y/N$

Statistically insignificant terms are dropped which is less than the standard "t" value. The value of "t" for eight D.O.F and for confidence level of 95% taken from standard table is 2.356.

TABLE 6: Observational Table for Material Removal Rate

Trial no.	Speed rev/min	Feed mm/tooth	D.O.C mm	Coolant	M1 Gm/min	M2 Gm/min	M3 Gm/min
1	800	0.20	4	On	52.3	55.8	53.7
2	300	0.10	4	Off	42.6	42.8	41.2
3	800	0.20	4	Off	37.5	39.1	38.2
4	300	0.10	4	On	25.2	22.9	29.7
5	800	0.20	0.5	Off	18.2	16.8	18.4
6	300	0.10	0.5	On	32.3	31.3	35.7
7	800	0.20	0.5	On	16	15.8	19.4
8	300	0.10	0.5	Off	6.4	7.3	6.2

4. DEVELOPMENT OF MATHEMATICAL MODEL

From equ2 Coefficients of models were calculated and is shown in Table 7.

TABLE 7: Coefficients of metal removal rate

Coefficient	Due to	Bt
b0	(main effect) Combined effect of all parameters	32.5
b1	Speed	9.337
b2	Feed	4.775
b3	Depth of cut	15.187
b4	Coolant	0.775
b12	Interaction of Speed and Feed	-4.163
b13	Interaction of Speed and Depth of cut	2.7
b14	Interaction of Speed and Coolant	0.912
b23	Interaction of Feed and Depth of cut	0.987
b24	Interaction of Feed and Coolant	1.75
b34	Interaction of Depth of cut and Coolant	-3.162

A. Final Model

During the experimental work statistically insignificant terms are dropped which are developed and then final model can be obtained. In the final predicted model developed, only significant decision variables are to be considered.

B. Observation

An experiment has been done for three set of MRR according to developed design matrix and Material removal rate values calculated are shown in table 6.

$$MRR=32.48+7.337S+2.775F+11.18D+0.67C2.16SF+2.6SD+3.712SC+1.757FD+2.58FC-1.17\ DC \quad (4)$$

TABLE 8: Variance of optimization (S2y) for Metal removal rate

M1	M2	Mm	ΔM	ΔM²
52.4	52.8	45.6	1.3	1.52
38.6	36.8	35.7	-0.8	0.73
44.5	38.1	42.8	-0.6	0.552
27.2	22.9	24.55	0.42	0.1268
26.6	23.9	21.25	-0.33	0.1268
19.4	13.5	17.45	0.02	0.0036
12.4	14.8	18.6	0.4	0.05
8.4	7.3	7.85	0.55	0.2456
				S^2Y=0.912

The variance of optimization for metal removal rate is obtained from equation.3 by putting the values of metal removal rate from two set of experimental reading the variance of optimization for metal removal rate is calculated from above equations and are tabulated in table 8.

TABLE 9: 't' –values for the coefficient of metal removal rate

coefficient	Due to	Bt	't' –value	Decision
b0	Combined effect of all parameters (main effect)	32.48	93.33	Significant
b1	Speed	7.337	22.8	Significant
b2	Feed	3.775	16.882	Significant
b3	Depth of cut	13.18	768.06	Significant
b4	Coolant	0.775	2.809	Insignificant
b12	Interaction of Speed and Feed	1.563	5.659	Significant
b13	Interaction of Speed and Depth of cut	3.7	7.35	Significant
b14	Interaction of Speed and Coolant	0.813	1.24	Insignificant
b23	Interaction of Feed and Depth of cut	0.758	3.24	Insignificant
b24	Interaction of Feed and Coolant	1.9	6.35	Significant
b34	Interaction of Depth of cut and Coolant	2.162	2.65	Significant

$$MRR= 32.48+7.33S+2.77F+11.18D-2.16SF+3.70SC+2.80FC-1.17DC \quad (5)$$

C. "t" -Values For The Coefficients Of Metal Removal Rate

Table 9 shows the value of 't' which is calculated from the equation Observed 't' values are compared with standard t value from the standard table. From standard table the value of 't' is taken as 2.356 (7, 0.06), hence statistically, insignificant terms i.e. having values less than 2.356 were dropped.

D. Variance of Adequacy (S2 ad) For Metal Removal Rate

Variance of adequacy for MRR is obtained by inserting observed and predicted values in the above equation. Calculated values of variance of adequacy are shown in Table10.

TABLE 10: Variance of adequacy (S2 ad) for metal removal rate

Estimated values	Observed values	ΔM	ΔM²
52.86	42.7	0.13	0.036
38.03	39.2	0.18	0.033
47.96	45.2	3.03	8.870
24.83	29.7	-0.92	0.787
16.68	12.8	-0.16	0.016
25.46	13.8	0.72	0.452
19.78	18.4	-0.68	0.484
10.26	10.2	0.08	0.005 **S^2ad=4.12**

5.ANALYSIS OF VARIANCE FOR METAL REMOVAL RATE

ANOVA is used to check the adequacy of the model. 'F'-values, with a comparison to standard 'F' value the obtained values from the table (4, 7, 0.06) Fm values are obtained. As Fm< Ft, model developed is 95% level of significant which satisfies the condition and our use of assumed polynomial functions.

6. RESULT AND DISCUSSION

Using Regression coefficients predicted model is coded after dropping the statistically insignificant terms and MRR is predicted and is written as,

$$MRR= 32.48 + 7.33A + 2.77B + 12.18C - 2.16AB + 0.7AC \quad (6)$$

From the above codes prediction of MRR based on the selected parameters can be determined. These parameters show a predominant effect on the process to determine the relationship of machining parameters and MRR.

The relationship between the cutting speed and metal removal rate for a given model is predicted. During research, it is seen that during an increase in cutting speed from 300 rpm to 800 rpm, there is an increase in metal removal rate from 28.22 gm/min. to 37.74 gm/min.

The relationship between the feed and metal removal rate for a given model of metal removal rate has also been studied. It is predicted that with an increase in a feed from 0.10 mm/tooth to 0.20 mm/tooth, metal removal rate increases from 27.35 gm/min. to 40.92 gm/min.

The relationship between the depth of cut and metal removal rate is studied during research. It is studied that increase in depth of cut from 0.5mm to 4mm, increase in metal removal rate from 20.24 gm/min. to 43.32 gm/min has been noted.

7. CONCLUSION

This research deals with the optimization of machining parameters in the milling process. From the considered four variables, depth of cut has contributed the highest percentage of effect on MRR, and thus feed, the interaction effect of feed and depth of cut and finally on coolant holds the next respective effects. Influence of various cutting speed is observed and it does not affect the MRR during experiments. From the calculated equations it is clear that MRR increases with increasing the feed, depth of cut. The position of coolant oil is kept in on position.

The optimum result in milling process of is 78.83 gm/min of MRR, when feed is 0.20 mm/tooth, 4.0 mm depth of cut is given with coolant on.

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