"OPTIMIZATION OF MACHINING PARAMETERS IN FACE MILLING PROCESS USING FRICTIONAL FACTORIAL DESIGN"

B.Logesh*

*M.E Industrial Engineering Scholar, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore-641049
Email:btplogesh@gmail.com

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 (MRR) in milling process. These experiments were carried out on LM6 Aluminium alloy reinforced with 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. Tungsten coated face mills with lager rake angles are used in machining of LM6 aluminium alloy and frictional factorial design technique is used for optimizing process parameters. Experiment was conducted by eight runs of two level of 24-1 fractional factorial design. The mathematical models were developed from the data generated. 'T'-test and 'F'-test were used to test coefficients and adequacy of developed models. The research details that the established equations clearly show that surface roughness increases with the feed increasing and 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.

I. INTRODUCTION

In present scenario to cop up with global market decreased cost, Increasing in productivity and maintaining high product quality with customer satisfaction at the same time are the main challenges which manufacturers face today. The proper selection of machining parameters is an important factor in achieving these in today competitive advantage in the market [1]. Many researchers had made 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 a range of 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 [1]. Cutting fluid usage will have negative effect to the economy, environment and health [3]. Due to unsatisfactory tool life and poor surface finish not promising the Total elimination of cutting fluid [6]. This rapid tool wears gives higher surface roughness value, along with this it also provides higher micro hardness and major microstructure alteration [7]. Optimizing the variable parameters such as coolant flow rate, cutting

ISSN 2229-5518

speed, feed rate and depth of cut for the tool life to increase the productivity and with a good surface finish. Full factorial design technique is used for optimization of machining parameter in which the number of trials increases with number or levels of the factors increases. Increased number of that is because of higher order interactions in most cases which do not affect the response [8]. 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. Factorial experiment has distinct number of trials which results in increased time and cost of experimentation [9].

II. METHODOLOGY

A. Work piece:

Work piece material selected is high carbon alloy steel having 25mm thick plate which is in rectangular in shape and dimensions are 100*50*25 mm^3. Chemical composition and physical properties were determined by spectrometer and were tabulated in table1 and table2.

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

THERMAL CONDUCTI -VITY (w/m-k)	DENSITY (kg/m^3)	MELTING POINT (°C)
34.1	2650	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 supplied air pressure and the opening of nozzle. During this experiment water immiscible cutting fluid was used. This coolant is miscible with solvent or mineral oil.

D. Design of Experiment

Face milling operation is done in machining operation and all these machining were carried out on 3-axis CNC milling machine. Design of experiment (DOE) was 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 developed to conduct the eight trials runs fractional factorial design as 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 could be developed of the type Y = f (S, F, D, C) to facilitate the prediction of a response a particular set of direct process parameters within the specified dimensional tolerance. It could be written as:

Y=b0+b1S+b2F+b3D+b4C+b12SF+b13SD +b14SC+b23 FD+b24FC+b34DC ...[Equ.1]

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

Bi=∑(XijYi)/N, j = 0,1….k **…[Equ.2]**

Where,

Xji= Value of a factor or interaction in coded form

Yi = Average value of response parameter

N= Number of observation

K= Total Number of coefficients of the model

III. CHECKING THE SIGNIFICANCE OF COEFFICIENTS OF MODEL

By applying ‘t’ test the statistical significance of the coefficients can be tested, from the magnitude of the‘t’ value The level of significance of a particular parameter can be assessed which is associated with it. Values with higher value of ‘t’ are more significant. ‘t’ value can be attained from the below equ.

t = |bj|/Sbj **...[Equ.3]**

Where,

|bj| = coefficients of absolute 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 95% confidence level taken from standard table is 2.306.

A. Final Model

Statistically in-significant terms are dropped from developed model final model can be obtained. In the final model only significant decision variables are to be considered.

B. Observation

Experiment has been done for three set of MRR according to design matrix and surface roughness value is shown in table 7.

Table 7: Observational Table for Material Removal Rate

Trial no.	Speed rev/min	Feed mm/tooth	D.O.C mm	Coolant	Set-1 M1 Gm/min	Set-2 M2 Gm/min	Set-3 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

IV. DEVELOPMENT OF MATHEMATICAL MODEL

From equ2 Coefficients of models were calculated and is shown in Table 8.

Table 8: 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

MRR=32.48+7.337S+2.775F+11.18D+0.67C 2.16SF+2.6SD+3.712SC+1.757FD+2.58FC-1.17 DC ...[Equ.4]

By putting the values for MRR in above equ Variance of optimization (S2y) for metal removal rate is obtained from two set of reading in Equations. The value of variance of optimization for metal removal rate is shown in table 9.

Table 9: Variance of optimization (S2y) for Metal removal rate

M1	M2	Mm	ΔM	ΔM^2
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

Variance of optimization (S2y) for metal removal rate is obtained by putting the values of metal removal rate from two set of reading in Equations 3. Table 10 shows the variance of optimization for metal removal rate.

A. 't' -Values For The Coefficients Of Metal Removal Rate

Table 10 shows the value of 't' which is calculated from the equ. Observed 't' values are compared with standard t value from the std table. From standard table the value of 't' is taken as 2.356 (7,0.07), hence statistically in significant terms i.e. having values less than 2.356 were dropped.

Table 10: '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 ...[Equ.5]

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

From the above equ by inserting the observed and estimated values of metal removal rate the Variance of adequacy value for metal removal rate can be determined.

Table 11: Variance of adequacy (S2 ad) for metal removal rate

Estimated values	Observed values	ΔM	ΔM^2
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**

V. ANALYSIS OF VARIANCE FOR METAL REMOVAL RATE

'F'-values, with an comparison to standard 'F' value the obtained values from the table (4,7,0.06) Fm values are obtained. As Fm< Ft, model is 95% level of significant which justifies the use of our assumed polynomial functions.

VI. RESULT AND DISCUSSION

Coded form for the proposed models for the prediction of MRR after the statistically insignificant terms are dropped is written as,

MRR= 32.48 + 7.33A + 2.77B + 12.18C - 2.16AB + 0.7AC …[Equ.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.

VII. CONCLUSION

This study deals with the optimization of machining parameters in milling process. From the considered four variables, depth of cut has contributed the highest percentage of effect on MRR, and thus feed, interaction effect of feed and depth of cut and finally on coolant holds the next respective effects. Influence of cutting speed is insignificant on the MRR. The established equations clearly show that MRR increased with increasing the feed, depth of cut under wet condition.

The optimum result in milling process of is 78.83 gm/min of MRR, when feed is 0.22 mm/tooth, 4.0 mm depth of cut is given with coolant on.

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