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TO STUDY THE INFLUENCE OF MILLING PARAMETERS ON MATERIAL REMOVAL RATE OF AISI H13 BY ANOVA

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ABSTRACT : *Metal machining has been a very important activity in manufacturing. Machining conditions play a significant role in governing the performance of machining operations. It has long been recognized that the machining conditions, such as cutting speed, feed and depth of cut affect the performance of the operation to a greater extent. These parameters should be selected to optimize the quality of machining operation. This can be achieved using design of experiments (DOE). The objective of the present work is to assess the effects of the machining parameters in milling on the material removal rate of AISI H13 steel. This material is used in the manufacturing industries for making die casting moulds, extrusion dies, moulds for glass industry, punches, piercing tools, mandrels etc. In the present study the machining experiments were conducted on CNC vertical milling machine. Design of experiments based on Taguchi grey relational analysis with three independent factors (cutting speed, feed rate and depth of cut), three levels L27 orthogonal array has been used to develop relationships for predicting material removal rate. The material removal rate is calculated by formula. Model significance tests were conducted using ANOVA techniques and effects of various parameters were investigated This research paper would be beneficial for manufacturing industry where metal removal rate plays very vital roles like in die casting, and other manufacturing operations.*

I. INTRODUCTION

Milling parameters such as speed, feed rate and depth of cut play an important role in milling the given work piece to a finished product. These have a major effect on the quality, cost of production and production rate; hence their proper selection is important. The selected milling parameters should yield desired material removal rate on the milling surface while utilizing the milling resources to the fullest extent possible, consistent with the constraints on these resources.

End milling is one of the important machining operations, widely used in most of the manufacturing industries because complex geometric surfaces with good accuracy and surface finish can be produced by this operation. However, with the invention of CNC milling machine, the flexibility has been adopted along with versatility in end milling process. In order to build up a bridge between quality and productivity and to achieve the same in an economic way, the present study highlights optimization of CNC end milling process parameters to provide good surface finish.

The material removal rate of the machined surface refers to production rate attribute. Attempt has been made to study the significance of various input parameters on material removal rate (productivity).

Usually machine operators make use of ‘trial and error’ method to set up machining conditions in milling. This method is not efficient and time consuming and thus achievement of desired value is a repetitive and very time consuming process.

work piece

The milling experiments were performed on AISI H13 steel alloy plates. All the plates used in the experimentation were 117 mm in length with 80 mm width and 20 mm in thickness as shown in Figure 1.

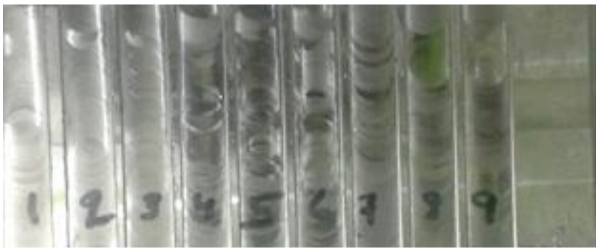

Figure 1. work piece

The chemical composition of AISI H13 was obtained by spectro test and summarized in Table 1. All the work from initial preparation of work piece to final machining experiments was done at R AND D Centre for Bicycle and Sewing Machine, Ludhiana.

Table 1 Chemical composition of AISI H13, % weight

ELEMENT	C	Mn	Si	Cr	Mo	V	P	S
PERCENTAGE	0.40	0.36	0.95	5.28	1.25	0.92	0.011	0.010

II. EXPERIMENTAL DESIGN

Number of experiments required for any experimental work, mainly depends on the approach adopted for design of experiment. Thus it important to have a well designed experiment so that no. of experiments required can be minimized. In the present study, ANOVA has been adopted to analyze the effect of three independent variables for milling i.e. cutting speed, feed rate and depth of cut on material removal rate. The process control parameters and their levels are given in Table 2. Complete design matrix for performing experimentation is given in Table 3 and corresponding experimental results are summarized in Table 4. This demonstrates a total number of 27 experiments for the complete experimentation.

Table 2 Process control parameters and their levels according to TGRA

Parameter	Units	Symbols	Level 1	Level 2	Level 3
Speed	(rpm)	A	3500	4000	4500
Feed	(mm/tooth)	B	0.01	0.03	0.05
Depth of cut	(mm)	C	0.20	0.35	0.50

Experimental Procedure

End milling operation was carried out on a BFW SURYA VF 30 CNC VS in dry conditions.

The CNC milling machine equipped with AC variable speed spindle motor up to 6000 rpm and 3.7 KW motor power was used for the present experimental work. The cutter used in this work was end mill with mechanically attached carbide insert having

Figure 2 Photo of CNC Milling machine

Figure 3 Photo of milling cutter

16 mm diameter. Commercially accessible carbide end mill cutter with two cutting flutes is used in this research for end milling. The cutting inserts used in the machining test was WIDAX PA120 5575 (0.8 mm nose radius) and the cutter used was WIDAX XPHT 09 end milling cutter of 16 mm diameter.

Steps followed for ANOVA is given flowchart:

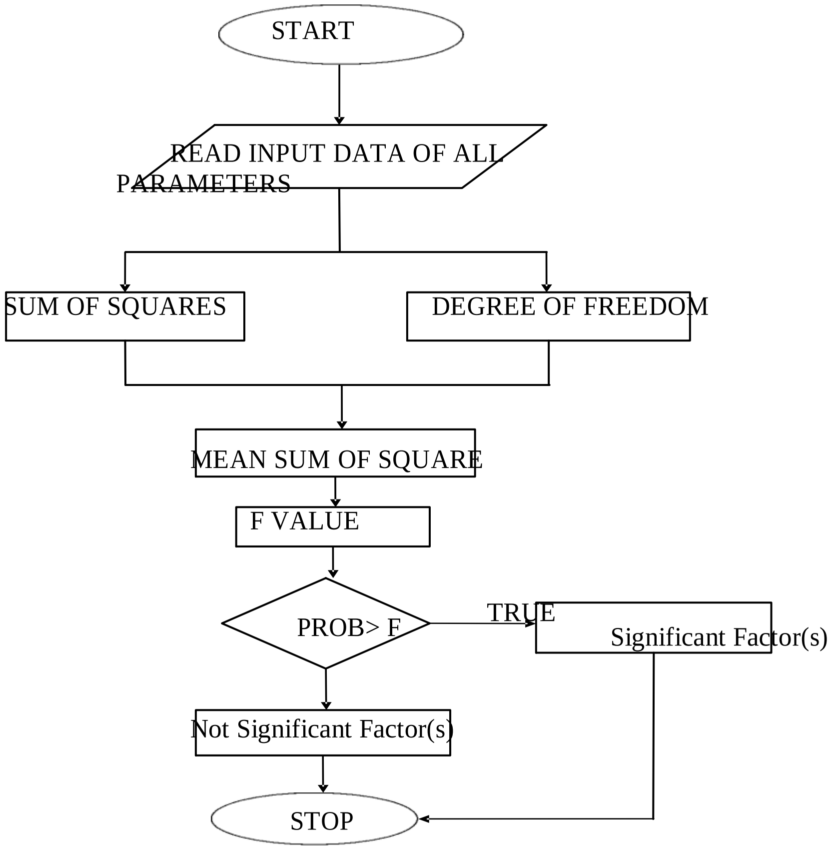

Figure 4 Flowchart showing general steps of ANOVA (Singh, 2012)

Calculation Of Metal Removal Rate

The metal removal rate can be calculated according to line diagram as shown in Figure 5.5 and the terms used are
W = Width of cut
T = Depth of cutter V =
Cutting speed
N = RPM of Cutter
n = Number of Teeth on Cutter
L = Length of pass or cut
f_m =Table(machine) Feed
f_t= Feed/tooth of cutter D = Cutter Diameter

Cutting time:

$f_m = f_t \times N \times n$

CT = $\frac{L}{f_m}$

Metal Removal Rate for end milling is calculated as follows:

$$MRR = \frac{\text{Volume removed}}{\text{Cutting time}} = \frac{L \times W \times t}{CT} = w \times t \times f_m$$

Figure 5 Material removal rate calculation

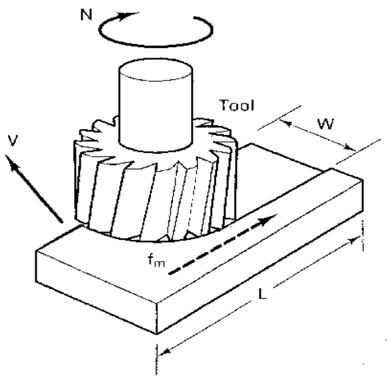

Table 3 Experimental results using L27 orthogonal array

Expt. No.	Parametric combination (Design of experiment)			Response features
	Speed (A) (rpm)	Feed (B) (mm/tooth)	Depth of cut (C) (mm)	MRR (mm^3/sec)
1	3500	0.01	0.20	3.73333
2	3500	0.01	0.35	6.53333
3	3500	0.01	0.50	9.33333
4	3500	0.03	0.20	11.2000
5	3500	0.03	0.35	19.6000
6	3500	0.03	0.50	28.0000
7	3500	0.05	0.20	18.6667
8	3500	0.05	0.35	32.6667
9	3500	0.05	0.50	46.6667
10	4000	0.01	0.20	4.26667
11	4000	0.01	0.35	7.46667
12	4000	0.01	0.50	10.6667
13	4000	0.03	0.20	12.8000
14	4000	0.03	0.35	22.4000
15	4000	0.03	0.50	32.0000
16	4000	0.05	0.20	21.3333
17	4000	0.05	0.35	37.3333
18	4000	0.05	0.50	53.3333
19	4500	0.01	0.20	4.80000
20	4500	0.01	0.35	8.40000
21	4500	0.01	0.50	12.0000
22	4500	0.03	0.20	14.4000
23	4500	0.03	0.35	25.2000
24	4500	0.03	0.50	36.0000
25	4500	0.05	0.20	24.0000
26	4500	0.05	0.35	42.0000
27	4500	0.05	0.50	60.0000

III. RESULTS AND CONCLUSIONS

Methodology is a powerful approach to improve product design or improve process performance, where it can be used to reduce cycle time required to develop new product or processes. It is a test or series of test where changes are made in the input variable (parameter) of a process for observing and identifying corresponding changes in the output response. The result of the process is analyzed to find the optimum value of input parameters that have most significant effect on the process. The objectives of the experiment may include (Montgomery, 2005)

1) Determination of input parameters that have an influential effect on the response variable.
2) Determination of the appropriate settings of the influential parameters for optimization of the desired response.
3) Determination of the appropriate settings of the influential parameters for minimization of the response's variability.

There are several statistical tools available in design of experiments for the optimization i.e Factorial designs, Taguchi method, Response Surface Methodology, six sigma etc.

Maximization of MRR

The mean of the material removal rate value for each level of the milling parameters was calculated using the average method and presented in Table 4. The second last row presents the difference between maximum and minimum value of material removal rate at particular level of factor. Hence feed is the most effecting factor on material removal rate amongst the three machining parameters. The order of importance of the controllable factors for maximization of material removal rate, in sequence is: feed, depth of cut, speed (i.e. 29.866 > 19.2 > 5.59).

Table 4 Mean effect on material removal rate

Level	speed (A) (rpm)	Feed (B) (mm/tooth)	Depth of cut (C) (mm)
1	19.60001	7.46667	12.8000000
2	22.39999	22.4000	22.4000000
3	**25.20000**	**37.33333**	**32.00000333**
Average	22.40000	22.40000	22.40000111
Max. - Min.	5.59999	29.86666	19.20000333
Rank	**3**	**1**	**2**

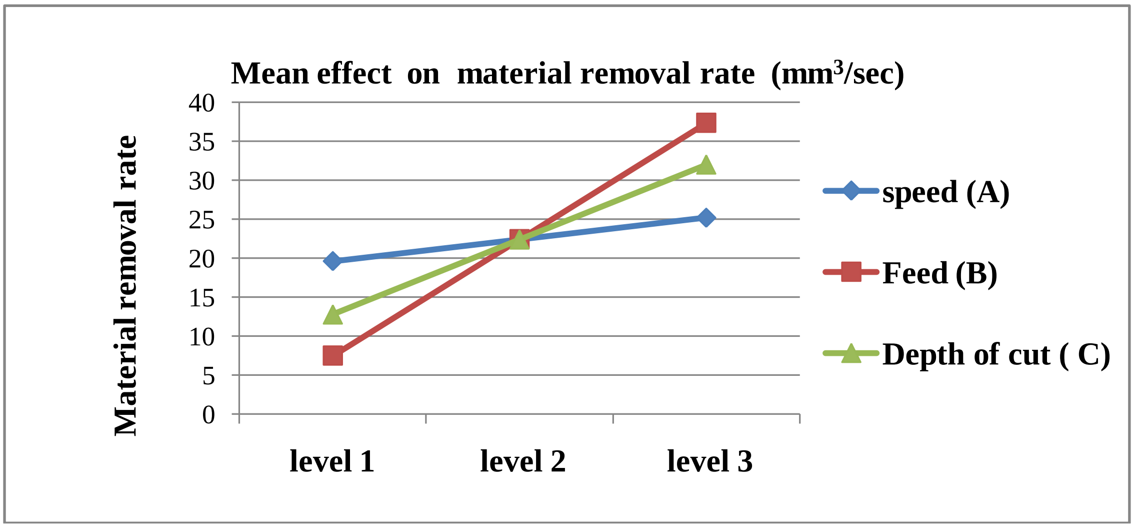

Figure 6 Graphical representation of mean effect on material removal rate

Analysis of variance (ANOVA)

The main purpose of the analysis of variance (ANOVA) is the application of a statistical method to identify the effect of individual parameters and their significance for the response variable. Results from ANOVA can determine very clearly the impact of each parameters on the process results at desired confidence level.

Table 5 Results of ANOVA for material removal rate

FACTOR	D.F	SUM OF SQUARE	MEAN SQUARES	F-RATIO	PERCENT CONTRIBUTION	F>F TABLE
SPEED (s)	2	141.119496	70.55974800	2.012927112	2.215442188	Insignificant
FEED (F)	2	4014.079104	2007.039552	57.25678512	63.01723322	Significant
DEPTH OF CUT (D)	2	1658.880576	829.440288	23.66225633	26.04285103	Significant
S X F	4	20.90633067	5.226582667	0.149103848	0.328209555	
F X D	4	245.759744	61.43993600	1.752757293	3.858194795	
S X D	4	8.640024	2.160006000	0.061620609	0.135640179	
ERROR	8	280.42644	35.05330500			
TOTAL	26	6369.811715	244.9927583			
$F_{0.05}(2,8)$	=4.459					
$F_{0.05}(4,8)$	=3.837					

IV. CONCLUSION

The important conclusions drawn from the present work are summarized as follows:

1.Feed and depth of cut are the significant milling parameters for material removal rate.

2.With the increase in feed material removal rate increases. The material removal rate is increases as the level of feed increase. And as depth of cut from level 1 to 3, material rate also increases subsequently. Seed has less significance on the material removal rate.

3.For high productivity machining conditions the significant parameter are feed and depth of cut.

4. From Table 4 it is clear that desired optimum condition for MRR is ‘B3, C3, A3’.

5. Table 5 shows the ANOVA results for the response material removal rate. Feed seems to be the most significant factor followed by the depth of cut and their percentage contribution are 63.01% and 26.04%.

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