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Effect of Machining Parameters on Temperature at Cutter-Work Piece Interface in Milling

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Abstract— in this paper the experiment were conducted to study experimentally the influence of depth of cut, cutting speed, feed and work piece material type on cutter temperature during milling process. Few experiments per material type are to be performed in order to measure the cutter temperature. The data used for this investigation is derived from the experiment conducted on milling machine to observe the effect of each factor level on the process performance. The Taguchi technique is used for selecting arrays L18. From the Data analysis using response graph method, the cutting speed is most contributory factor, work material is second important factor and Feed rate is third important factor. Experimental results will provide to confirm the effectiveness of this approach.

Keywords: **Machining optimization, Response graph method, Taguchi technique,**

I. INTRODUCTION

The influence of cutting parameters on cutter temperature to find out optimal operating conditions of cutting speed, feed, depth of cut and work piece material for achieving minimum temperature and hence maximum cutter life. It also includes the development of mathematical model in terms of machining parameters for cutter temperature predication. Cutter life which affects the productivity. This begins with the the right machine, properly applied tooling and keeping the proper machining parameters. Productivity gains through the innovative application of tooling and processes that will lower the overall machining cost. The objective of this study is to investigate the influence of cutting parameters on cutter temperature to find out optimal operating conditions of cutting speed, feed, depth of cut and work piece material for achieving minimum temperature and hence maximum cutter life. It also includes the development of mathematical model in terms of machining parameters for cutter temperature predication. Reducing the machining time through higher speeds and feeds means that you are considering the tool life. This begins with the right machine, properly applied tooling, setup for the application, and ends by directly reducing the cycle time to produce a greater number of parts over the same amount of time. The results are a reduction in fixed costs as they are now shared across a greater number of parts, in addition to opening up the shop for more capacity. The machine, labor and overhead costs previously incurred by the job now decrease through improved productivity. In the end, the only way to compete with the excess loss is by achieving significant productivity gains through innovative applications of tooling and processes that will lower overall machining cost. The objective of this study is to investigate the influence of cutting parameters on cutter temperature to find out optimal operating conditions of cutting speed, feed, depth of cut and work piece material for achieving minimum temperature and hence maximum cutter life.

II. METHODOLOGY

Before starting the machining process the milling machine is prepared for machining and then the tool is prepared to measure the temperature on cutter. We used the radiation pyrometer. It is kept at a distance of not more than 30 cm. A pyrometer has an optical system and detector. The optical system focuses the thermal radiation onto the detector and temperature is recorded. The radiation pyrometer uses the concept of infrared radiant energy to measure the temperature of objects from the distance. After determining the wavelength of the energy being emitted by an object, the sensor can use integrated equations that take into account the body's material and surface qualities to determine its temperature, as the temperature of the object varies, the frequency at which the wave are emitted also changes. The advantage of using a radiation temperature sensor is that it does not make contact with the material it is measure.

Fig 1. Milling Machine

II. TAGUCHI METHOD

TAGUCHI METHOD: Dr. Taguchi has developed a method based on "ORTHOGONAL ARRAY" experiments which gives reduced "variance" for the experiment with "optimum setting" of control parameter. Thus the merging of Design of Experiment with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. " Orthogonal Arrays (OA) provides a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to – Noise ratios (S/N), which are log functions of desired output, serve as objective functions for the optimization, help in data analysis and prediction of optimum result. In Taguchi Method, the word "optimization" implies "determination of BEST levels of control factors". In turn, the BEST levels of control factors are those that maximize the Signal-to-Noise

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ratios. The Signal-to-Noise ratios are log functions of desired output characteristics. The experiments, that are conducted to determine the BEST levels, are based on "Orthogonal Arrays", are balanced with respect to all control factors and yet are minimum in number. This in turn implies that the resources (material and time) required for the experiments are also minimum [14].

Steps of Taguchi

1) Decide the variables or factors like Cutting speed, Depth of cut & feed rate
2) Choose the factor for safety:-
   One parameter varies while remaining is kept constant. After deciding the effect of various machining parameters on cutter-work piece (temperature should be minimized),by comparing the different optimization method, it was found that Taguchi optimization method is best and therefore the design of experiment were performed.
3) Selection of no. of levels(working range):-
4) Select the experiment levels.
5) Choose an orthogonal array for experiments run the experiments as per design.
6) Analyses the experiment results for the objectives of the results. Draw conclusion and verify them with the objectives.
7) If results do not seems to be meeting to the objectives of the study then it would be owing to inappropriate factors considered in the study, then having two options either, start the experiments all over with different factor or process design should be modified. Select another optimization technique.

III. EXPERIMENT DETAIL

1) Selection of parameters work piece, cutting speed, depth of cut, feed rate, and Total number of parameters is 4. Out of which work piece has 2 levels while the remaining has 3 levels.
2) Calculation of feed rate
   Rpm of arbor is measured =159 rpm
   The rpm is measured with contact and non contact type tachometer then automatic feed rate lever is placed on three different position and movement of tool post is measured for 1 minute and then feed rate is calculated using the formula,

$$\text{Feed Rate} = \frac{\text{movement/min}}{\text{Revolution/min}} = \text{mm/teeth}$$

   3 levels of feed rate are = 0.004 mm/teeth, 0.008 mm/teeth, 0.01 mm/teeth
3) Feed rate is found out, preparation of cutting tool angle is done as per the machine data and experiments were performed.
4) Calculation of Degrees of freedom
   Overall mean = 1
   One factor (work piece) with 2 levels = 1*(2-1) = 1
   Three factor with 3 levels = 3*(3-1) = 6
   Total = 8
   Minimum no. of experiments to perform at least = 8
5) The Taguchi design of experiments done by using Minitab 14 Statistical software.
   From the machine data, feed all the values according to select no. of levels.
6) Selection of array variable
   Selected array is L18 as per the Taguchi design of experiments method.
7) Perform design of experiments.
8) Then S/N ratio is found out, then find most influencing parameter.
   Test 1 Evaluating the experiments using lower and higher value of the most influencing parameter
   Test 2 Evaluate the prediction given by Taguchi.

Test 1.

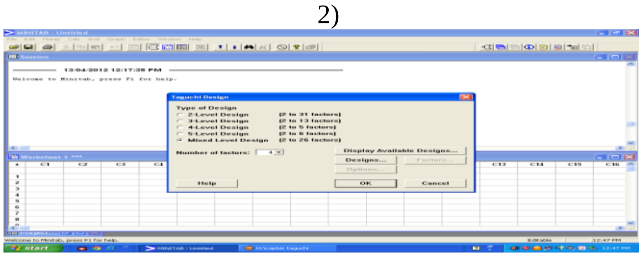
The higher and lower values selected for cutting speed as per the most influencing parameters are 16.58, 29.31, 85m/min

Test 2.

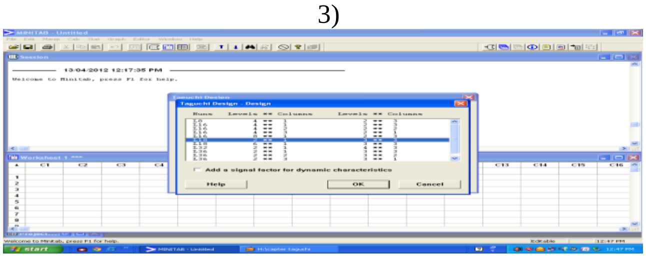
According to the best combination the predicted values are

Material	:	C.I.
Cutting speed	:	16.58 m/min
Feed rate	:	0.008 mm/teeth
Depth of cut	:	0.5 mm

2)



3)

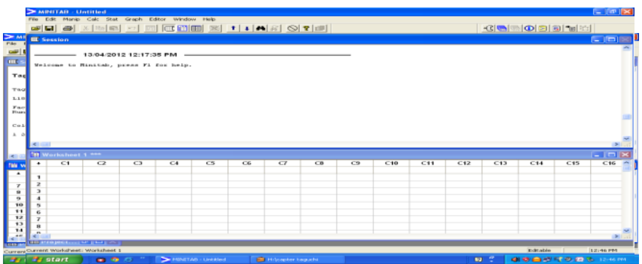


4)

5)

Fig 2),3), 4), 5) : Minitab 14 Statistical Software

Taguchi Orthogonal Array Design
L18 (2**1 3**3)
Factors: 4
Runs: 18



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Columns of L18 (2**1 3**7) Array
1 2 4 5

Table I

Taguchi Design

Taguchi Orthogonal Array Design
L18 (2**1 3**3)
Factors: 4
Runs: 18
Columns of L18 (2**1 3**7) Array
1 2 4 5
Executing from file: C:\Program Files\MTBWIN\MACROS\ROBUST.MAC

Main Effects for S/N Ratios: T1-T2

Main Effects for Means: T1-T2

Response Table for Signal to Noise Ratios

Smaller is better

Level	WM	CS	FR	DOC
1	-35.2666	-33.3484	-34.8046	-34.0875
2	-33.4679	-34.3935	-33.7821	-34.5082
3		-35.3598	-34.5150	-34.5059
Delta	1.7987	2.0114	1.0225	0.4207
Rank	2	1	3	4

Response Table for Means

Level	WM	CS	FR	DOC
1	58.8228	47.0325	55.7825	51.4317
2	47.2494	52.7742	49.1175	53.7917
3		59.3017	54.2083	53.8850
Delta	11.5733	12.2692	6.6650	2.4533
Rank	2	1	3	4

Executing from file: C:\Program Files\MTBWIN\MACROS\ROBUST.MAC
Executing from file: C:\Program Files\MTBWIN\MACROS\PREDICT.MAC

Predicted values

S/N Ratio	Mean
-31.5842	35.7228

Factor levels for predictions

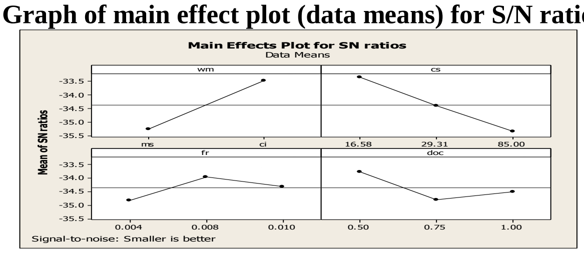
WM	CS	FR	DOC
CI	16.58	0.008	0.5

5. Observation of the experiment

1) The output data of Taguchi design of experiments, using **Minitab 14** statistical software:

a) **Minitab session**

b) **Graph of main effect plot (data means) for S/N ratio**



Graph 1:. Main Effects Plot for SN Ratio Graph

Inner/outer OA; smaller-the better type of quality characteristic:

We use smaller-the better quality characteristic to compute S/N ratios. That is

$$\eta = -10\log [1/n^* (\sum T_i^2)]$$

The S/N ratios are given in the table II.

Table I

Trail No.	WM	CS	FR	DOC	T1	T2	η
1	MS	16.58	0.008	0.5	39.44	42.22	-32.22
2	MS	16.58	0.004	0.75	54.44	47.77	-34.19
3	MS	16.58	0.01	1	57.77	68.88	-36.06
4	MS	29.31	0.008	0.75	48.88	56.66	-34.47
5	MS	29.31	0.004	1	65.55	68.33	-36.52
6	MS	29.31	0.01	0.5	46.11	50	-33.64
7	MS	85	0.004	0.5	93.33	57.77	-37.8
8	MS	85	0.01	0.75	71.11	76.66	-37.38
9	MS	85	0.008	1	54.45	59.44	-35.12
10	CI	16.58	0.01	1	36.11	42.77	-31.95
11	CI	16.58	0.008	0.5	46.11	40.55	-32.75
12	CI	16.58	0.004	0.75	42.22	46.11	-32.91
13	CI	29.31	0.004	1	45.55	48.33	-33.43
14	CI	29.31	0.01	0.5	49.44	52.22	-34.13
15	CI	29.31	0.008	0.75	50	52.22	-34.17
16	CI	85	0.01	0.75	50.55	48.88	-33.93
17	CI	85	0.008	1	46.11	53.33	-33.95
18	CI	85	0.004	0.5	48.88	51.11	-33.98

Data analysis using response graph method:

The level total of the S/N ratios are given in table II

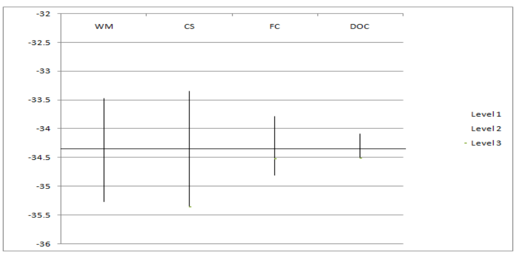
Table II

FACTOR	LEVEL 1	LEVEL 2	LEVEL 3
WM	-317.399	-301.211	
CS	-200.09	-206.361	-212.159
FR	-202.693	-208.827	-207.09
DOC	-204.525	-204.525	-204.525

The grand total is -623.774 and the grand mean is -34.654(623.774/18). TableIV given below show the factor affect and their ranking

Table IV

Factor	WM	CS	FR	DOC
Level 1	-35.2666	-33.3484	-33.7821	-34.09
Level 2	-33.4679	-34.3935	-34.8046	-34.51
Level 3		-35.3598	-34.515	-34.51
Difference	1.798732	2.011382	1.022479	0.4207
rank	2	1	3	4



Graph 2: Response Graph

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Predicting optimum condition:

From table, it can be seen that factors CS, WM and FR are significant (first three ranks). Hence the predicted optimum response in terms of S/n ratio (η_{opt}) is given by

$$\eta_{opt} = \eta_{mean} + (CS_1 - \eta_{mean}) + (WM_2 - \eta_{mean}) + (FR_1 - \eta_{mean})$$

=-34.3672+(-33.3484-(-34.3672))+(-33.4679-(-34.3672))+(-33.784-(-34.3672))
= -34.3672+1.0188+0.8993+0.5851
= -32.5834

It is observed from table that the maximum S/N ratio is -32.5834 and it corresponds to the experimental Trail no. 11. The optimum condition found is WM_2, CS_2, and FR1. And the experimental Trail mo. 11 includes this condition with a predicted yield of -32.5834. From this we can conclude that the optimum condition obtained is satisfactory. However, this has to be verified through a confirmation experiment.

IV. RESULTS

From the Data analysis using response graph method, it is .found that the factor cutting speed is most contribution factor. It indicates that the feed rate is the most influencing factor in this experimentation. Whereas Depth of cut contributes is least important factor in the whole experimentation. Further it is also observed that work material is second important factor and Feed rate is third important factor. From the main effect plots graphs, it is observed that the highest variation in SN ratio is for cutting speed. SN values for cutting speed ranges from -35.3598 to -33.3484, which clearly indicates that this factor plays very important role in this process. It is found that for factor (depth of cut) SN ratio for second level (depth of cut =1.0mm) is, better than the first level that is .5mm.

V. CONCLUSION

From the experimentation it is found that the cutting speed plays a crucial role in controlling the cutter temperature. It is proved by using both theoretical designs of experiments and Taguchi Minitab software that cutting speed is important parameter. For the best level setting the higher point of the graph is referred. From the Taguchi prediction for best optimum factor levels is found to be 43.33^0C. The same was confirmed by using confirmative test at the optimum factor levels was found to be 46.85^0C. It confirms that the optimum level settings are correct.

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