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Optimisation of Process Parameters in Hard Turning of Aisi 5150 Steel by Anova

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Abstract*: In the present study, an attempt has been made to hard turn AISI 5150 steel using uncoated TiC inserts. Round bar stock of AISI 5150 steel was hardened to 48 HRC by oil quenching. Three different process parameters Speed, feed and depth cut were chosen at three different levels. The parameter combinations were chosen according to L9 orthogonal array to limit the number of experiments to nine instead of twenty seven. ANOVA is performed on the results of surface finish obtained for 9 experiments parameter combination chosen. The percentage contribution of the factor feed towards the response i.e., surface roughness is 51.19%, followed by depth of cut 24.07% and finally by speed 15.01%.The main effect plots for means were generated between process parameters and surface roughness an optimum process parameters were chosen and confirmation experiment was performed on the selected optimum process parameters.

Index Terms*: AISI 5150 steel, ANOVA, Hard turning, Surface roughness.

I. INTRODUCTION

Hard turning is turning of work pieces with hardness greater than 45 HRC. The main advantage of hard turning is standard off the shelf cutting tool can be used for turning instead of special form grinding wheel which will reduce the cost of machining. The surface roughness values obtained in the hard turning process are comparable to that of conventional cylindrical grinding process [1]. Proper selection of cutting tool and process parameters is important in hard turning process as the tool material and process parameters have direct effect on tool life [2]. If improper process parameters were selected it will seriously affect the tool life and hard turning may not be a viable option if the tool wear rate is high and the cost of machining will be much more when compared to grinding. Generally hard turning is performed in dry conditions but some researchers have used different coolant feeding techniques namely flood lubrication, minimum quantity lubrication [3]. Although the surface roughness values obtained by using coolants are not better than dry condition but average flank wear of the cutting tool decreased with use of cutting fluids [3]. Some researchers have used depth of cut as high as 1.5 mm but at low speeds 45 m/min to 90 m/min (286 rpm to 573 rpm) [4] where as some researchers limited the depth of cut to 0.6 mm [5].

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Generally experimental design involves three kinds of test strategies. Typical test strategy, better test strategy and efficient test strategy [7]. Typical test strategy involves testing effect of one parameter on the response or taking several factors one at a time or several factors all at the same time by changing all the parameters at the same time with a hope that at least one of these changes improves the situation sufficiently. Better test strategy involves all the available parameter combinations. There will be equal number of test data points under each level of each factor. Although better test strategy uses full factorial experiments with all possible parameter combinations the resources required to experiment will increase with respect to number of factors or number of levels of factors. For example an experiment with four factors each at two levels will result in total of 128 experiments. Efficient test strategies or more commonly referred as fractional factorial experiments uses only a portion of total possible combinations and still used to estimate the effect of pameters on the response. As quoted earlier a four factor two level experiment will result in 128 combinations but the number of combinations can be scaled down to 1/2 FFE or 1/4FFE or even 1/16 FFE in which the number of experiments will be just 8.

Analysis of variance (ANOVA) developed by Sir Ronald Fischer is a statistically based, objective decision making tool for detecting any differences in average performance of the group of items tested [7]. The decision, rather than using pure judgment, takes variation in account. There are different types of ANOVA and the selection is dependent on the number of controlled factors. As the number of controlled factors selected for the experiment are three, a three way ANOVA is performed on the L9 orthogonal array which was obtained by scaling down L27 orthogonal array to 1/3 size. Ilhan [5] has taken speed range of 90 mm/min to 150 mm/min for 110 mm diameter stock

(260 rpm to 434 rpm) got least surface roughness values ranging from of 1.17 µm to 4.22 µm whereas Dipti [6] performed experiments with speed ranges of 50 – 130 m/min for 45 diameter stock (354 rpm to 920 rpm) got surface roughness values of range 0.42 – 1.17 µm indicate increase in speed decreases the surface roughness.

II. EXPERIMENTAL PROCEDURE

Round bar stock of AISI 5150 Chrome steel of 50 mm diameter and 150 mm length was oil quenched to a hardness of 48 HRC. Cutting tool inserts chosen are DNMG 110408 TiC with Nickel as binder in uncoated condition.

The tool insert holder used was DDJNR – 2020 – 15.

Turning was performed on CNC lathe with spindle motor of capacity 2.2KW and maximum spindle speed of 3000 rpm.

Three different process parameters were chosen: speed, feed, depth of cut at three different levels.

Table1: Process Parameters and their Levels

Level	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	990	0.04	0.10
2	1320	0.08	0.15
3	1650	0.12	0.20

The total number of possible experiments with the above stated parameters is 27. In order to reduce the numbers of experiments, 9 experiments according to L9 orthogonal array were selected. The parameter combination is given in table:2.

Table2: Process parameters arranged according to L9 orthogonal array layout

Sl. No	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	990	0.04	0.10
2	990	0.08	0.15
3	990	0.12	0.20
4	1320	0.04	0.15
5	1320	0.08	0.20
6	1320	0.12	0.10
7	1650	0.04	0.20
8	1650	0.08	0.10
9	1650	0.12	0.15

Hard turning was performed on the stock material with the selected process parameter combination. Since the work pieces were turned in hardened condition wear is expected on the cutting tool edge and therefore each experiment was performed with a new cutting edge to avoid cutting tool wear playing a role in experimental process.

III. EXPERIMENTAL RESULTS

The surface roughness vales of the turned work pieces by taking the above said process parameter combination is given in table:3.

Table3: Process Parameter Combinations

Sl. No	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Surface roughness (µm)
1	990	0.04	0.10	0.64
2	990	0.08	0.15	0.38
3	990	0.12	0.20	0.82
4	1320	0.04	0.15	0.42
5	1320	0.08	0.20	0.44
6	1320	0.12	0.10	0.58
7	1650	0.04	0.20	0.86
8	1650	0.08	0.10	0.39
9	1650	0.12	0.15	0.70

The analysis of variance (ANOVA) is performed and the results were tabulated in the table4.

Factor	Degree of freedom	Sum of squares	Variance	Percentage contribution	F_{cal}	$F_{table\ (0.05,\ 2,\ 8)}$	Significant Yes/No
Speed	2	0.048	0.024	15.01	7.179	4.46	Yes
Feed	2	0.1476	0.0738	51.19	22.0697	4.46	Yes
Depth of cut	2	0.073	0.036	24.07	10.907	4.46	Yes
Error	2	0.00668	0.00334	9.72			
Total	8	0.2753		100			

Table4: Analysis of variance for means

The percentage contribution was calculated to understand to what extent each parameter is contributing towards the response i.e., surface roughness. The $F_{tabulated}$ value is taken from F- distribution table with α = 0.05 or 95 % confidence level and degrees of freedom 2 and 8 for factors and total respectively which is equal to 4.46. the $F_{calculated}$ values obtained for all the three factors are greater than $F_{tabulated}$ values indicating that all the three factors i.e., Speed, Feed and Depth of cut are contributing significantly towards the response i.e., surface roughness.

Summary of means

Table5: Main Effects of Surface Roughness (Means)

Level	Speed	Feed	Depth of Cut
1	0.6133	0.64	0.5367
2	**0.48**	**0.4033**	**0.5**
3	0.65	0.7	0.7067

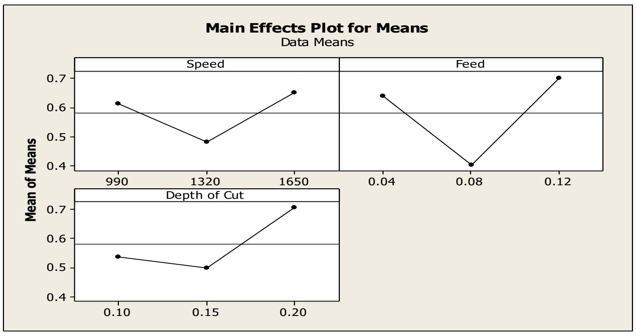

Figure1: Main effects plot for Means of surface roughness (X - axis: Factor levels; Y - axis: surface roughness)

IV. SELECTION OF OPTIMUM SET OF PROCESS PARAMETERS

In order to determine optimum set of process parameter combination, two possibilities exist. In a full factorial experiment the optimum set of parameters will be identical to those in the experiment, but if a fractional factorial experiment is selected, the optimum condition of parameter combination may or may not be included in the experiment. The optimum set of process parameters were taken from the main effects plots for means and as the response is surface roughness the level of parameter at which the surface roughness is least is selected.

The factor levels for predictions are given below

Table6: Selected Process Parameter Combination

Speed	Feed	Depth of Cut
1320	0.08	0.15

The above selected process parameter combination is not present in the experiments conducted. The value of the surface roughness for the above selected optimum set of process parameter combination can be calculated as

Surface roughness predicted = y + (N2 - y) + (F2 - y) + (D2 - y)

= N2 + F2 + D2 - 2y

= 0.48 + 0.4033 + 0.5 - (2 * 0.5811)

= 0.22 µm

Where y = overall mean of surface roughness values

V.CONFIRMATION TEST

The verification of the predicted result can be done by performing the confirmation test using the optimum process parameter combination set which is speed at level 2, feed at level 2 and depth of cut at level 2. The surface roughness obtained 0.32 µm.

VI. CONCLUSIONS

The following conclusions are drawn based on the experiments conducted on turning of AISI 5150 Chrome steel stock of 50 mm diameter.

1. From ANOVA, feed rate is the primary significant factor which contributes to surface roughness with a percentage contribution of 51.19%, followed by depth of cut 24.07% and finally by speed 15.01%.

2. The surface roughness decreased as the feed rate is increased from 0.04 mm/rev to 0.08mm/rev but increased drastically as the feed rate increased to 0.12mm/rev.

3. Optimum cutting conditions taken from main effects plot for means are speed 1320 rpm, feed rate 0.08 mm/rev and depth of cut 0.15mm.

4. The surface roughness value obtained from predictor equation by taking optimum cutting conditions is 0.22 µm. Confirmation test is performed taking optimum cutting conditions and surface roughness value obtained is 0.32 µm.

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