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Optimization of Dry Turning Process Parameters using Taguchi and ANOVA Technique for MRR of EN8 Steel

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Abstract*: Turning operation is a material removal process generally used to remove the material from the surfaces to achieve the desired dimension of the product. An L_9 orthogonal array, S/N ratio and ANOVA are employed for analysis the MRR characteristic for turning operations. In the present study, Taguchi method or Design of experiments has been used to optimize the effect of turning parameters such as cutting speed (m/min), feed (mm/rev) and depth of cut (mm) on the Material Removal Rate of EN8 steel. Material removal rate measurements were carried out during the machining process on the work piece. EN8 is generally known medium strength steel has good tensile strength and consists of higher machinability. It has several industrial applications in manufacturing of shafts, stressed pins, studs, keys etc. The results indicated that feed rate and depth of cut and cutting speed were the significant factors for the material removal rate. The optimized parameters for material removal rate are cutting speed 200 m/min, feed 25 mm/rev. and depth of cut 14 mm.
Keywords: Turning, Taguchi method, EN8 steel, Orthogonal Array, ANOVA, MRR

I. INTRODUCTION

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact [1].

In many industrial applications such as bearings, transmission shafts, axels, and engine components, flap gears, landing struts and aerospace engine components, the replacement of slow and cost intensive grinding process with the finish hard turning have been implemented [2]. In comparison between grinding and hard turning, turning can machine complex work piece in just one set up. Besides, turning cycle time is three times faster than grinding. It consumes less energy per unit volume of metal removed than grinding and remains friendlier to the environment due to dry cutting. For successful implementation in hard turning, the machining criteria of material removal rate are studied in this paper & optimized the controlled parameters for its effectiveness application [3]. Taguchi and ANOVA can conveniently optimize the input cutting parameters with several experimental runs well designed. ANOVA was employed to find out significance of the different parameters on MRR [4].

II. WORK MATERIAL AND METHODS

Turning operation was performed on centre lathe machine made by OSWAL MACHINERY & TOOLS CORP LUDHIANA PUNJAB at Rajat Engineering Works, Panki Industrial Area Kanpur.

A. *Work Piece Material*

EN8 which is also known as medium carbon mild steel was used as work piece. A rod of 200 mm in length and the diameter was 50 mm.

TABLE I
CHEMICAL COMPOSITION OF EN8 STEEL

Standard	Grade	C	Mn	P	S	Si
BS970	EN8/080M40	0.36-0.44	0.60-1.00	0.05	0.005	0.10-0.40

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TABLE II
PHYSICAL PROPERTIES OF EN8 STEEL

Physical Properties	Value
Melting point	1450 - 1510°C
Density	$7850 kg/m^3$
Tensile strength	850 MPa
Yield strength	$465 n/mm^2$
Impact (Izod)	25 ft.lb
Hardness (Brinell)	201 - 255

Fig. 1 After turning operation EN8 material piece

B. Cutting Tool

Carbide tool (Single point) was used for turning operation. The Cutting tool used was coated and having combination of Al_2O_3 + TiC with tin coating (Golden) manufactured by PRIME PRECISIONS PVT LTD.
The insert was rigidly mounted on a tool holder

Fig. 2 A single point carbide cutting tool

C. Digital Weighing Machine

Material removal rate (MRR) of work piece was calculated by weighing the work piece after machining period. For this, DJ 300S model weighing machine was used with an accuracy of 0.001 gram. That machine capacity was 300 gram and accuracy is 0.001 gram. Weighing machine was manufactured by SHINKO DENSHI Co. LTD, JAPAN

D. Process Parameters

Turning tests were performed on centre lathe machine and carbide cutting tool was used for machining. Different process parameters of turning operation i.e. cutting speed, feed rate and depth of cut were selected. The other parameters are kept constant.

TABLE III

PROCESS PARAMETERS OF TURNING OPERATION

Factors	Level A	Level B	Level C
Cutting Speed	20	40	60
Feed Rate	0.1	0.2	0.3
Depth of Cut	0.3	0.6	0.9

III.DESIGN OF EXPERIMENT AND MEASUREMENT

A. Taguchi Method

It is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions [5]. Steps of Taguchi method are as follows:

1) Identify the main function, side effects and failure mode.
2) Identify the noise factor, testing condition and quality characteristics.
3) Identify the main function to be optimized.
4) Identify the control factor and their levels.
5) Proper selection of orthogonal array and matrix experiment.
6) Carefully conducting the matrix experiment.
7) Analysing the data, prediction of the optimum level and performance.
8) Performing the verification experiment and planning the future action. [6]

B. Design of Experiments

The study of most important variables affecting quality characteristics and a plan for conducting such experiments is called the Design of Experiments [7].

C. Taguchi Orthogonal Array

If there is an experiment having 3 factors which have three values, then total number of experiment is 27. Then results of all experiment will give 100 accurate results. In comparison to above method the Taguchi orthogonal array make list of nine experiments in a particular order which cover all factors. These nine experiments will give 99.96% accurate result. By using this method number of experiments reduced to 9 instead of 27 with almost same accuracy [8].

TABLE IV

TAGUCHI L9 ORTHOGONAL ARRAY

Sr. No.	Cutting speed	Feed Rate	Depth of Cut
Unit	(m/min)	(mm/rev)	(mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

D. Optimization by Taguchi Method

For optimization firstly the Signal to Noise (S/N) ratio was calculated, actually it represents the total amount of input signal that is converted into noise during machining operation. Because whole input signal can never be converted into output some of its part is always wasted as noise. Its unit is decibel. There are three types of S/N ratios,

1) Smaller the Better
2) Nominal the Better and,
3) Larger the Better [9]

For MRR Larger the Better is used

$$S/N_{LTB} = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{yi^2}\right) \quad \text{.................} (1)$$

Where yi is the performance response to the ith setting of the parameter combination, and n is the number of samples.

IV. RESULT AND DISCUSSIONS

After performing the experiments, the output responses (MRR) values were calculated by equation 2, and the results were tabulated for carbide tool.

$$MRR\ (mm^3/min) = \frac{[\text{Initial Weight of Work piece (gm)} - [\text{Final Weight of Work piece (gm)}]}{\text{Density }(gm/mm^3)\times\text{Machining Time (min)}} \quad \text{......} (2)$$

The density of the mild steel is taken as 7.87 x 10^{-3} gm/mm^3 [10]

TABLE V
EXPERIMENTAL TABLE WITH S/N RATIO

S. no.	Cutting Speed	Feed Rate	Depth of Cut	MRR	S/N Ratio
Unit	(m/min)	(mm/rev)	(mm)	gm/mm^3	db
1	20	0.1	0.3	86173.25	98.707
2	20	0.2	0.6	74500.64	97.443
3	20	0.3	0.9	93011.46	99.371
4	40	0.1	0.9	114649.68	101.187
5	40	0.2	0.3	18048.41	85.129
6	40	0.3	0.6	21569.43	86.677
7	60	0.1	0.6	83731.72	98.458
8	60	0.2	0.9	52738.85	94.443
9	60	0.3	0.3	5847.13	75.339

TABLE VI
RESPONSE TABLE FOR S/N RATIO

Level	Cutting speed	Feed Rate	Depth of Cut
1	98.51	99.45	98.33
2	91.00	92.34	86.39
3	89.41	87.13	94.19
Delta	9.09	12.32	11.94
Rank	3	1	2

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TABLE VII

RESPONSE TABLE OF MEAN

Level	Cutting speed	Feed Rate	Depth of Cut
1	84562	94852	86800
2	51423	48429	36690
3	47439	40143	59934
Delta	37123	54709	50110
Rank	3	1	2

TABLE VIII

ANOVA TABLE

Source	DF	Seq SS	Adj MS	F	P	% of Contribution
Cutting speed	2	141.60	70.802	10.20	0.089	23.38
Feed Rate	2	229.56	114.782	16.54	0.057	37.90
Depth of Cut	2	220.61	110.305	15.90	0.059	36.43
Residual Error	2	13.88	6.938			2.29
Total	8	605.65				100

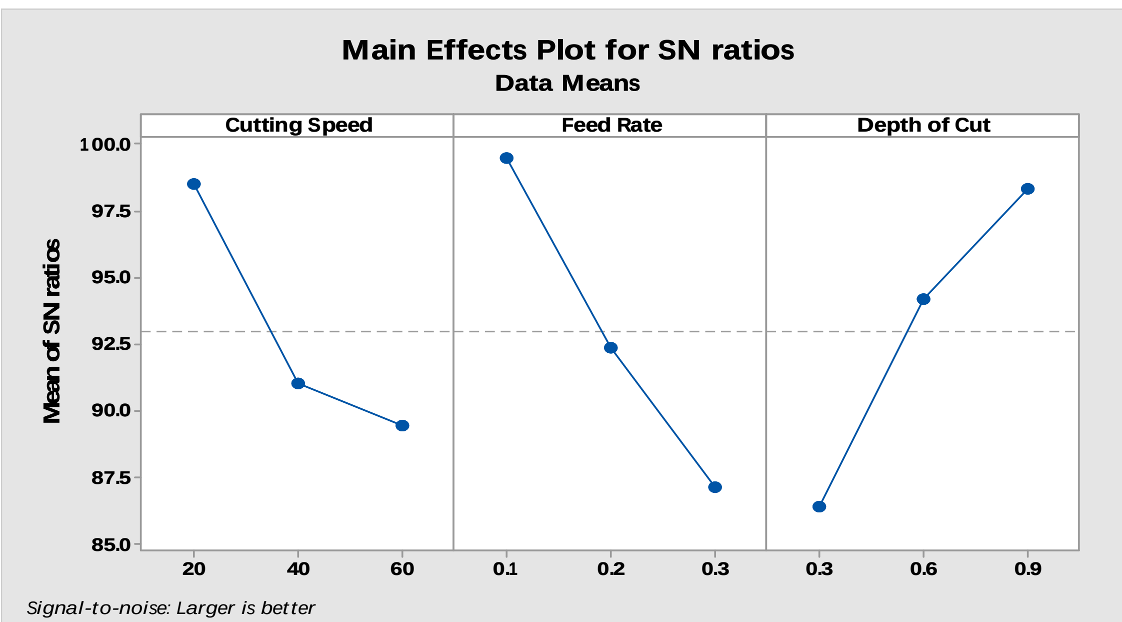

Fig. 3 Main effects plot for SN ratio

Above graph is between SN ratio of MRR and the three different levels (A1,B2,C3) of the input parameters i.e. Cutting Speed, Feed Rate and Depth of Cut A greater value of S/N ratio is always considered for better performance. This graph shows that which level of the parameter results in maximum material removal rate. According to this graph, first level of Cutting Speed results in maximum material removal rate. Similarly, the first level of feed rate, third level of Depth of cut results in maximum material removal rate.

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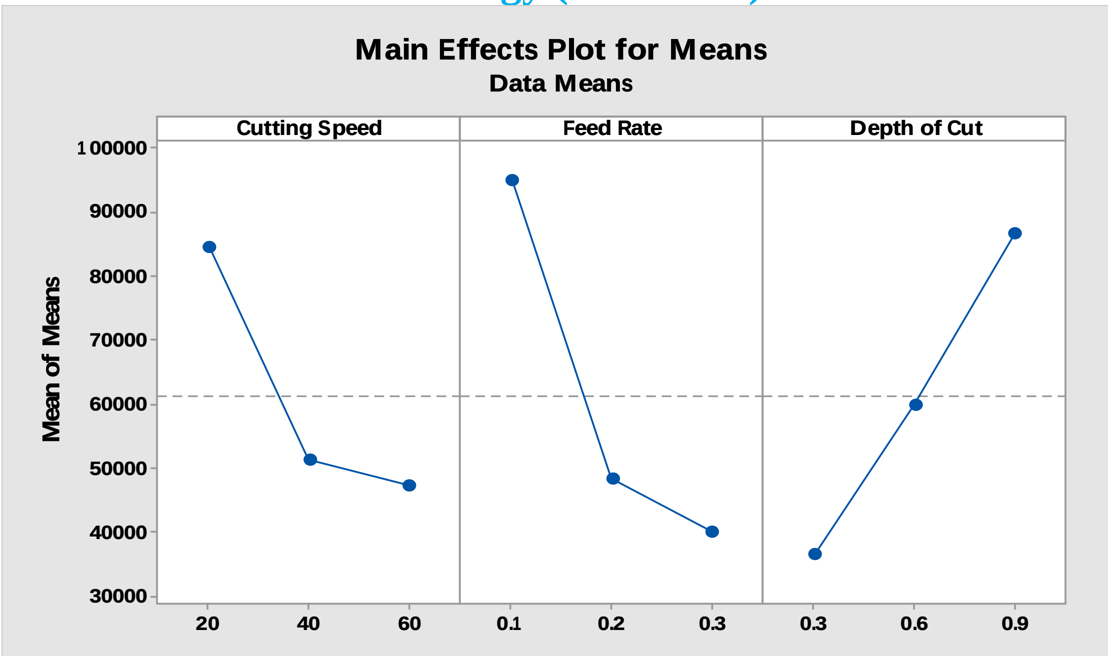

Fig. 4 Main effect plot for means

Above graph is between the means of MRR and three levels (A1, B2, C3) of input parameters i.e. cutting speed, feed rate, and depth of cut. This graph shows that maximum value of the means results in maximum material removal rate. Hence, first level of cutting speed, first level of feed rate and third level of depth of cut results in maximum material removal rate.

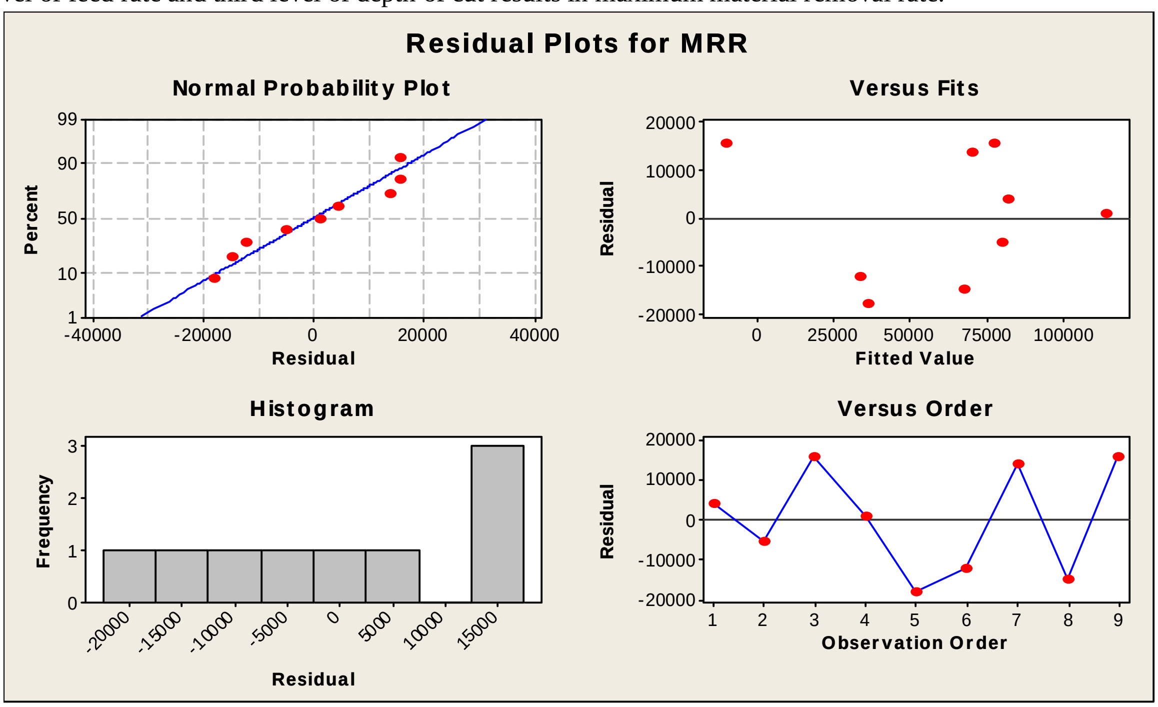

Fig. 5 Residual plot for MRR

In the above figure residuals follow an approximately straight line in normal probability plot and approximate symmetric nature of histogram indicates that the residuals are normally distributed. Residuals possess constant variance as they are scattered randomly around zero in residuals versus the fitted values. Since residuals exhibit no clear pattern, there is no error due to time or data collection order.

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V. CONCLUSIONS

The experimental study has focused on application of the Taguchi method for the optimization of input process parameters of dry turning operations. As discussed earlier, the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for the optimization of the cutting parameters. Except machining time, cutting parameters such as cutting speed, feed rate, and Depth of cut mainly influenced the MRR of EN8 steel rod. The optimal combination of turning parameters and their levels for the MRR of the turning process are A1B1C3 (i.e. cutting speed- 20 m/min, feed rate- 0.10 mm/rev and depth of cut- 0.9 mm). The percentage contributions of cutting speed, feed rate and depth of cut for carbide tool are 23.28%, 37.90% and 36.43% respectively.

Hence, significant improvements in MRR can be obtained using this approach. Finally, it can be a very useful technique for use to the industries to optimize the machining performance with minimum cost and loss of time.

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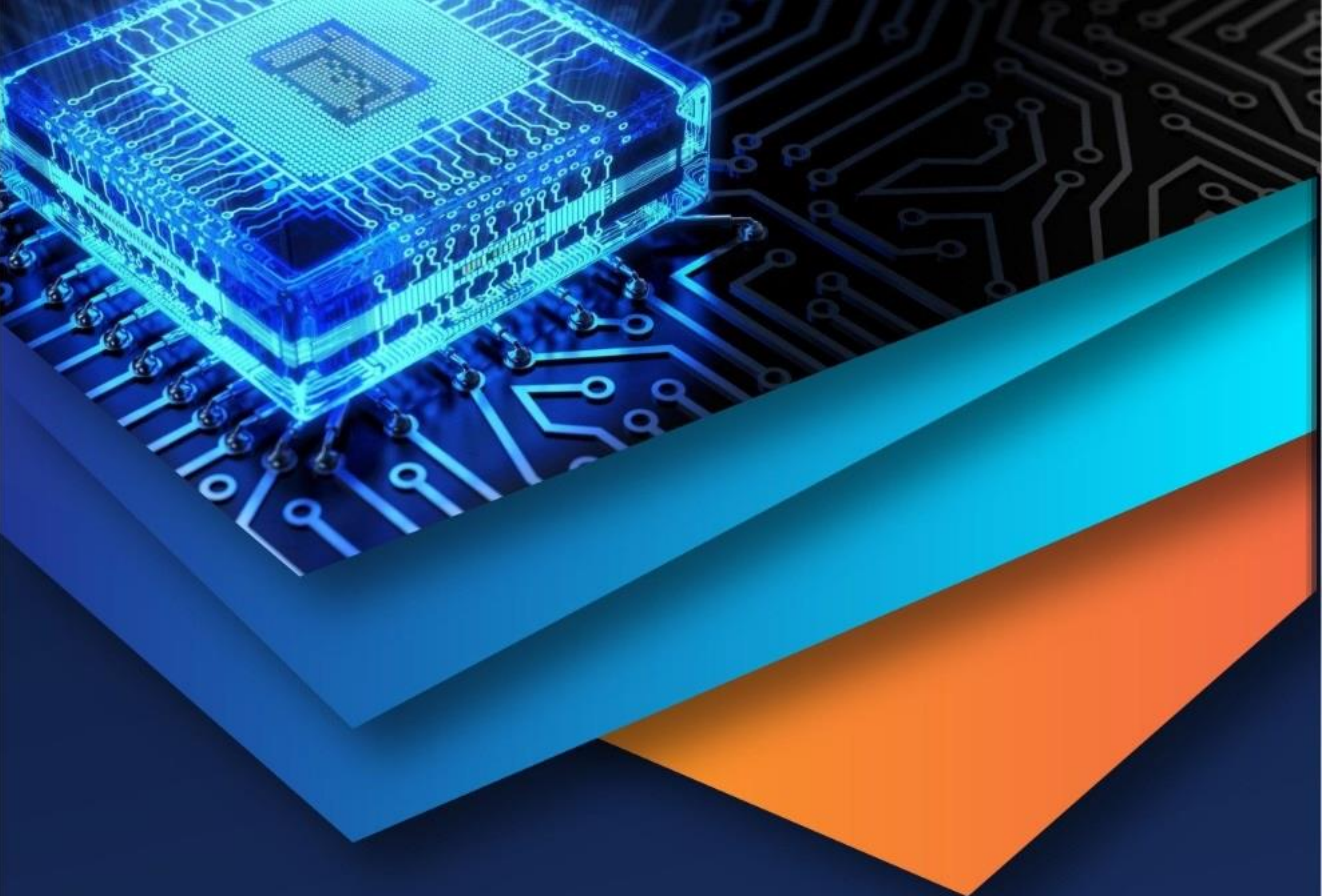

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