Experimental Investigations on CNC Turning of EN-36 Material Using Taguchi Method

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ABSTRACT

In the present work, by using Taguchi methodology, the Turning of EN-36Alloy is carried out in order to optimize the turning process parameters. The present paper deals with the optimization of selected process parameters, i.e. Type of Lubricant, Cutting Speed, Feed rate and Depth of cut. The experiments are carried out using L_9 (3^4) orthogonal array. Taguchi method stresses the importance of studying the response variation using the Analysis of Variance (ANOVA) and signal to noise (S/N) ratio, resulting the minimization of quality characteristic variation due to uncontrollable parameter. The Cutting temperature is considered as the quality characteristic in the concept of "the smaller the better". The Cutting temperature measured from experiment and their optimum value for Cutting temperature are calculated. Analysis of Variance suggests that the selected cutting parameters are significant for the Cutting temperature.

Keyword: - *Taguchi Method, EN-36 Alloy, Turning, Cutting Temperature, Analysis of Variance (ANOVA), Signal to noise (S/N) ratio etc.*

1. INTRODUCTION:

The objective of the work is to find out the set of optimum values for the selected control factors in order to decrease cutting temperature. In the present work, Taguchi methodology is used to determine the optimum cutting conditions more efficiently. Four control factors viz. type of lubricant; cutting speed; feed rate and depth of cut are investigated at three different levels. The work piece material used is EN 36 Alloy. Taguchi methodology is used to optimize the process parameters using signal-to-noise ratio for turning process of the work piece material. Experiments are carried out using L_9 (3^4) orthogonal array [1-14].

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear [1]. Turning machines used in manufacturing are classified as engine, automatics, and computer numerical control etc. The Turning used for machining in this work is CNC Turning machine. Basically Turning machines are classified according to the operation required [2].

In this work, the output parameter is cutting temperature. Robust design is an engineering methodology for improving productivity during design and development so that high quality products can be produced at low cost.

EN 36 is nickel- chromium high hardenability, case hardening (carburizing) steel, generally available in the annealed condition with a maximum brinell hardness of 255, characterized by high core strength, excellent toughness and fatigue resistance in relatively large sections with case hardness upto RC62 when carburized, hardened and tempered. EN 36 can also be used (uncarburized) as high tensile steel which when suitably hardened and tempered can be utilized for various applications requiring good tensile strength and excellent toughness [1][6].

2. EXPERIMENTAL SETUP AND DESIGN:

The aim of the work is to find out the set of optimum conditions for the selected cutting conditions in order to decrease cutting temperature using Taguchi's robust design methodology. The turning operations are carried out on CNC Lathe machine shown in Fig No. 1. The work material selected is EN-36 steel alloy with the dimensions of

28mm dia X 110mm long and the cutting insert used is TNMG UNCOATED carbide tool of KORLOY Company. The machining are conducted under- Dry Condition (Without Lubricant), With Lubricant using Veg oil and Using Veg oil + Boric Acid. The machining tests are also conducted under the different Cutting speed, Feed rate and Depth of cut with respect the Type of Lubricant.

Fig. No. 1: CNC Lathe

Fig. No. 2: EN36 Alloy Steel

The four control factors Type of Lubricant (A), Speed (B), Feed Rate (C) and Depth Of Cut(D) are selected with three levels and the corresponding orthogonal array $L_9(3^4)$ is chosen with respect to its degrees of freedom[1] and are tabulated in Table No.1. Steel bars of 28mm diaX110mm length are prepared for conducting the experiment. Using different levels of the process parameters as per the experimental design shown in table no.2, the specimens have been machined in CNC Lathe Machine accordingly, the Cutting Temperature is measured precisely with the help of a portable Digital Thermometer tester.

Table No. 1: Control Factors & Levels

Factors /Levels	**Type of Lubricant (A)**	**Speed (B) (rpm)**	**Feed (C) (mm/min)**	**Depth Of Cut (D) (mm)**
1	Without Lubricant	350	0.4	5
2	Veg Oil	500	0.5	7.5
3	Veg Oil+ Boric Acid	650	0.6	10

Table No. 2. Experimental Design

EXPERIMENT NO.	**TYPE OF LUBRICANT**	**SPEED**	**FEED**	**DEPTH OF CUT**
1	WITHOUT LUBRICANT	350	0.4	5
2	WITHOUT LUBRICANT	500	0.5	7.5
3	WITHOUT LUBRICANT	650	0.6	10
4	VEG OIL	350	0.5	10
5	VEG OIL	500	0.6	5
6	VEG OIL	650	0.4	7.5
7	VEG OIL+BORIC ACID	350	0.6	7.5
8	VEG OIL+BORIC ACID	500	0.4	10
9	VEG OIL+BORIC ACID	650	0.5	5

Fig. No. 3: Machining of EN36 Alloy Steel in CNC Lathe

3. RESULTS & DISCUSSIONS:

The Cutting Temperature is measured precisely with the help of a portable Digital Thermometer tester and the experiments results are tabulated in table no. 3 for two trails in ^{0}C i.e. at two positions while machining. For each experiment the corresponding S/N values at smaller the better are also tabulated. Optimization of Cutting Temperature is carried out using Taguchi methodology. Confirmatory test have also been conducted to validate optimal results.

Table No.3. Experimental Results of Cutting temperature with the corresponding S/N Ratio's

EXP NO.	CUTTING TEMPERATURE			S/N RATIO
	TRAIL1	TRAIL2	MEAN	
1	64.2	53.9	59.05	-35.4244
2	106.2	105.2	105.7	-40.4815
3	133.3	125.2	129.25	-42.2286
4	70.7	71.2	70.95	-37.019
5	36.1	41.2	38.65	-31.743
6	73.2	70.2	71.7	-37.1104
7	50	52.8	51.4	-34.2193
8	50.7	40.6	45.65	-33.1888
9	50.9	47.5	49.2	-33.8393

Table No 4: Summary of S/N Ratios

Factor	Level 1	Level 2	Level 3
Type of Lubricant(A)	-39.378	-35.291	**-33.749**
Speed(B)	-35.554	**-35.138**	-37.726
Feed(C)	**-35.241**	-37.113	-36.064
Depth of Cut(D)	**-33.669**	-37.27	-37.479

The best condition for Type of Lubricant factor is level 3 (Veg Oil+ Boric Acid), for Speed is level 2 (500rpm), for Feed is Level 1 (0.4 mm/min) and Depth of Cut is level 1 (5mm). Thus, the optimum conditions chosen were: **A3-B2-C1-D1**. A confirmation test is performed with the obtained optimum cutting, the Cutting temperature is measured and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 6 & 7.the corresponding ANOVA table no in 8.

Table No 5: Optimum Set Of Control Factors

Factors /Levels	**Type of Lubricant (A)**	**Speed (B) (rpm)**	**Feed (C) (mm/min)**	**Depth Of Cut (D) (mm)**
Optimum Value	Veg Oil+ Boric Acid	500	0.4	5

Table No 6. Conformation results

Cutting Temperature			S/N RATIO
1	2	Average	
34.6	32.1	33.35	-30.4619

Table No 7. Comparison of S/N ratios

η predicted	-29.3789
η conformation	-30.4619

Table No. 8: Analysis Of Variance

FACTOR	**S.S**	**D.O.F**	**M.S.S**	**F-RATIO (DATA)**	**F-RATIO (TABLE)**	**RESULT**
TYPE OF LUBRICANT	7946.634	2	3973.317	193.0142	4.26	Significant
SPEED	1870.788	2	935.3939	45.43918	4.26	Significant
FEED	961.9144	2	480.9572	23.36374	4.26	Significant
DEPTH OF CUT	3730.981	2	1865.491	90.62103	4.26	Significant
ERROR	164.685	9	20.58563			
MEAN	85849.87	1				
ST	100524.9	18				

3.1. Effect of Cutting Parameters on Cutting Temperature:

Taguchi's methodology has been successfully implemented to identify the optimum settings for control parameters in order to decrease Cutting temperature of the selected work piece material for their improved performance, after analysis of data from the design of experiments the optimum setting are found. These optimum settings combination is validated by conducting confirmation test, which concluded that the results were within the acceptable limits of the predicted value and can be implemented in the real time application.

From Figure No 4, it is observed that, the Cutting Temperature is high in the Dry environment and certainly decreasing from Dry Condition to Veg oil and certainly from using Veg oil to Veg oil +Boric acid where it further decreases.

From Figure No 5, it is observed that, the cutting temperature is low at low Speed conditions and certainly increasing from low Speed to moderate and from moderate to high Speed, the Cutting Temperature increases.

From Figure No 6, it is observed that, the cutting temperature is low at low Feed conditions and certainly increasing from low Feed to moderate Conditions and from moderate to high Feed, the Cutting Temperature decreases.

From Figure No 7, it is observed that, the cutting temperature is low at low depth of cut conditions and certainly increasing from low depth to moderate and from moderate to high Depth, the Cutting Temperature increases.

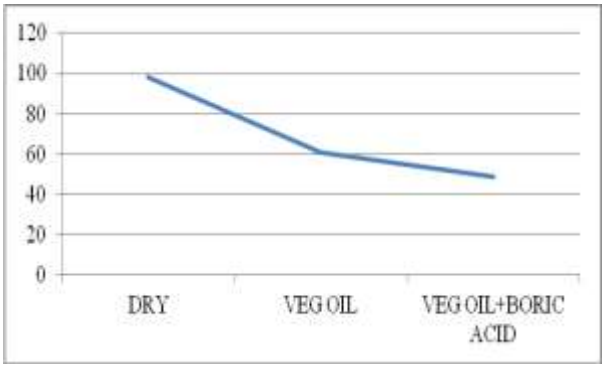

Fig. No. 4: Cutting Temperature V/s Type of Lubricant

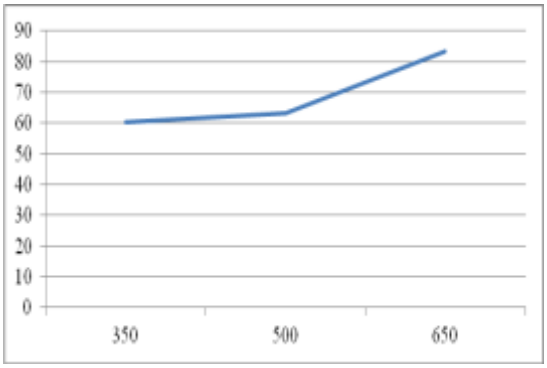

Fig. No. 5: Cutting Temperature V/s Speed

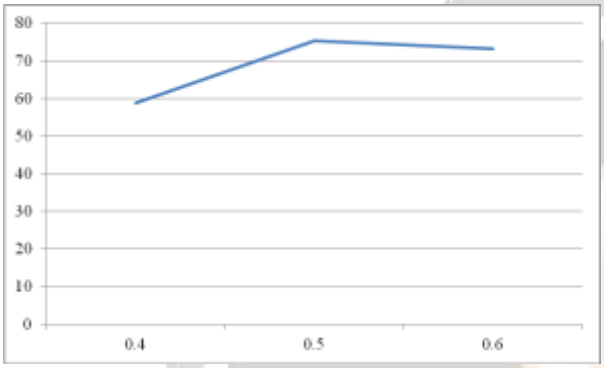

Fig. No. 6: Cutting Temperature V/s Feed

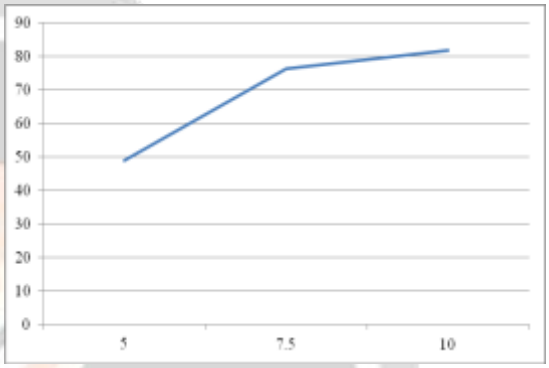

Fig. No. 7: Cutting Temperature V/s Depth of Cut

4. CONCLUSIONS

The objective of the work is to find out the set of optimum values for the selected factors in order to decrease cutting temperature. Taguchi methodology is successfully implemented, to determine the optimum cutting conditions more efficiently considering the control factors viz. type of lubricant; cutting speed; feed rate and depth of cut are investigated at three different levels for EN 36 Alloy

- Analysis of Variance suggests that the selected control factors are significant for the Cutting Temperature.
- In the present experimentation the optimum Type of environment obtained using Taguchi Robust Design Methodology is Veg oil + Boric Acid. Similarly the results obtained for speed and feed are 500m/min and 0.4mm/min respectively. The optimum Depth of cut obtained is 5mm.
- Hence it can be concluded that the control factors obtained are valid and within the range of EN 36 machining standards.
- The S/N ratio of predicted value and verification test values are valid when compared with the optimum values. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled

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