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# Optimization of Turning Process during Machining of EN-19 using Grey Relation Analysis

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**ABSTRACT:** Grey Relation Analysis has been recognized as one of the most popular multi-objective optimization techniques. In this work GRA has been used to optimize the CNC turning process parameters. Objective of the present study was to develop empirical models for predicting material removal rate Rise in tool tip temperature and surface roughness in terms of speed, feed rate and depth of cut using multiple regressions modeling method. Experiments were carried out on CNC machine tool by taking EN-19 as workpiece material and TNMG 160408 MC as cutting tool.

**KEYWORDS:** EN-19; Turning; GRA.

## I. INTRODUCTION

Manufacturing industry needs to produce a large number of products within relatively lesser time. However it was observed that reduction in manufacturing time may cause severe quality loss. To deal with such situation of these two conflicting criteria it is necessary to check quality level of the item either on-line or off-line. Turning is a machining process used to obtain the desired dimension of round metal. The main objective in present industrial era is to produce low cost quality product with required dimensions in an optimum time. Therefore the optimum cutting parameters are to be recognized first.

Tosun N. et al [1] made an investigation on the optimisation and the effect of cutting parameters on multiple performance characteristics (the tool life and the workpiece surface roughness) obtained by hot turning operations. A plan of experiments based on the Taguchi method was designed. M20 sintered carbide as tool and the high manganese steel as workpiece material were used in experiments. The workpiece material heated with liquid petroleum gas flame was machined under different settings of feed rate, depth of cut, cutting speed and workpiece temperature on a lathe. The results showed that cutting speed and feed rate were the dominant variables on multiple cutting performance characteristics. An optimum parameter combination was obtained by using statistical analysis. Gaurav Bartarya and S.K. Choudhury [2] used CBN insert (Make: Seco, Type TNGA160408 S01525) of chamfered edge geometry on EN31 bearing steel ( $60\pm 2$  HRC) also called as AISI52100. Effect of cutting parameters on the cutting forces and surface roughness produced is studied. They found depth of cut is the most influential parameter affecting the three cutting forces followed by the feed. Cutting speed is least significant in case of axial and radial force models but was not significant for roughness predictions. Forces first decreased and then increased with increase in cutting speed. The most energy efficient cut can be achieved for relatively lower and moderate cutting speeds with moderate depth of cut in the range of parameters selected for nearly all feed values selected in the range. C.E.H. Ventura et al [3] done investigation of cutting edge preparation of PCBN inserts by grinding and the verification of their applicability in hard turning. Variable micro-geometry of cutting edge has shown its importance in both tool life and surface roughness but it's really a challenging to produce it. Results showed that the used method to prepare edge micro geometries is adequate and asymmetric rounding's can increase tool life and compressive residual stresses.

T. Ozel et al [4] investigated Influence of variable edge micro-geometry insert edge design in hard turning both experimentally and via finite element analysis (FEA). Use of variable micro-geometry in hard turning is very innovative idea is tried by researchers. They used AISI 4340 (40HRC) work material and PcBN (50%CBN+40%TiC+6%WC) inserts of four different microgeometries 1)Uniform chamfer with 0.1mm chamfer height and 20 angle. 2) Uniform hone with  $50\mu\text{m}$ (and  $40\mu\text{m}$ )edge radius 3) Waterfall(WF) hone with  $r_{\text{A}}=30:60\mu\text{m}$  radii 4) Variable hone edge with  $r_{\text{A}}=50\mu\text{m}, r_{\text{B}}=10\mu\text{m}$  radii. They observed variable micro-geometry tool design reduces the heat generation along the tool cutting edge. Variable micro-geometry insert cutting edge induces less plastic strain on the machined workpiece. Tool wear is decreased with the use of a variable micro-geometry insert. Dhiman suresh et al [5] studied effect of cutting parameters (feed, speed, depth of cut) of AISI 1018 steel on various factors (tool tip temperature, surface roughness, and cutting forces) that account for machining costs. A cylindrical bar of AISI 1018 steel (length 125 mm,

diameter 25 mm) was used to carry out experiments on lathe by HSS single point cutting tool without using any coolant. Among the cutting parameters affecting machining variables for AISI 1018 steel, speed has maximum effect & depth of cut has minimum effect. Tool tip temperature increases with increase in cutting speed. At high speeds, surface finish is least affected. Surface finish deteriorates at high feed rates; hence to obtain good surface finish, feed rate may be kept low. Annealing and normalising AISI 1018 steel would improve machinability by coarsening pearlite. At low speeds cutting force are high & tendency of work material to form a built up edge is also stronger. At lower speeds, surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed. Kirby E. Daniel et al [6] presented an application of the Taguchi parameter design method to optimizing the surface finish in a turning operation. The Taguchi parameter design method is an efficient experimental method in which a response variable can be optimized, given various control and noise factors, and using fewer experimental runs than a factorial design. The control parameters for this operation included: spindle speed, feed rate, depth of cut, and tool nose radius. Noise factors included varying room temperature, as well as the use of more than one insert of the same specification, which introduced tool dimension variability. A total of 36 experimental runs were conducted using an orthogonal array, and the ideal combination of control factor levels was determined for the optimal surface roughness and signal to noise ratio. A confirmation run was used to verify the results, which indicated that this method was both efficient and effective in determining the best turning parameters for the optimal surface roughness. Roy Shibendu Shekhar [7] proposed an Adaptive Neuro-Fuzzy Inference System (ANFIS) for predicting the surface roughness in turning operation for set of given cutting parameters, namely cutting speed, feed & depth of cut. The experiment was carried out using a CNC lathe with a tungsten carbide tool & working on S45C steel bars. Cutting speed, feed & depth of cut were selected as the cutting parameters to analyse their effect on surface roughness. By employing the hybrid learning algorithm, ANFIS can obtain the optimal triangular & bell shaped membership functions of fuzzy system. A total of 50 sets of experimental data are used for training in ANFIS. After the training is completed, another 20 sets of data are used as testing data. Surface roughness values predicted by ANFIS are compared with the measurement values derived from 20 data sets in order to determine the error of ANFIS. The bell shaped membership function in ANFIS achieves slightly higher prediction accuracy than triangular membership function. Lanjewar R. W. et al [8] evaluated optimum machining parameters like tool geometry, tool materials, and single or double tithed machining process, feed & cutting speed for minimum vibrations & cutting forces for turning AISI 304 austenitic stainless steel on auto sharpening machine. Taguchi's Parameter optimization Method is used to evaluate best possible combination for minimum cutting force & minimum vibration during machining. Tool material for this study was HSS inserts, carbide inserts. ANOVA-Analysis Of variance Method used suggests that tool shape & fee are the most significant factors for all the three quality characteristics (radial force Y, tangential force Z & tool vibrations) during chasing of CTC rollers. ANOVA-Analysis Of variance Method also suggest that tool material has marginal significance to affect radial force Y & cutting speed has marginal significance on tangential force Z. Radial force Y significantly increases as the cutting points increases; as the material removal was double as compared to that with single point (U & V shaped with one tooth) tool.

Singh Hari and Pradeep Kumar [9] adopted a design of experiments approach to obtain an optimal setting of turning process parameters (cutting speed, feed & depth of cut) that may yield optimal tool wear (flank wear & crater wear) to titanium carbide coated carbide inserts while machining En24 steel (0.45% C). The effects of the selected process parameters on tool wear & subsequent optimum settings of the parameters have been accomplished using Taguchi's Parameter Design Approach. The results indicated the selected process parameters affect significantly the tool wear characteristics of TiC coated carbide tool. Chelladurai H. et al [10] made an attempt to create artificial flank wear using the electrical discharge machining (EDM) process to emulate the actual or real flank wear. The tests were conducted using coated carbide inserts, with and without wear on EN-8 steel, and the acquired data were used to develop artificial neural networks model. Empirical models have been developed using analysis of variance (ANOVA). In order to analyze the response of the system, experiments were carried out for various cutting speeds, depths of cut and feed rates. To increase the confidence limit and reliability of the experimental data, full factorial experimental design (135 experiments) has been carried out. Vibration and strain data during the cutting process are recorded using two accelerometers and one strain gauge bridge. The magnitude of strain and amplitude of vibration depend upon various machining parameters and it is observed that they increase with depth of cut and feed rate, and decrease with cutting speed. Power spectral analysis was carried out to test the level of significance through regression analysis. Experimental results were analyzed with respect to various depths of cut, feed rates and cutting speeds.



## II. EXPERIMENTAL SET-UP

Experiments are carried on Lakshmi Machine Works (LMW), Model- SMARTURN. Experimental set-up is shown in figure 1. EN-19 (length 105 mm, diameter 78 mm) was used as work piece material and TNMG 160408 MC; Grade-TT5100 insert as cutting tool.



Figure 1. Turning set-up

In this study, spindle speed, feed rate and depth of cut were considered as machining parameters and turning was carried out. Experiments were designed using L9 Taguchi orthogonal array. Table 1 shows the machining parameters and their levels.

Table 1. Machining parameters with their levels

	1	2	3
Speed (rpm)	1753	1984	2215
Feed (mm/rev)	0.02	0.03	0.04
Depth of cut (mm)	0.7	1.2	1.7

The weight of specimen is taken before and after the machining process using a digital weighing machine. (Model-SC400, Max wt.: 7000 gm; Min wt.: 1 gm DIGITAL reading electrically operated). To measure the surface roughness of machined work piece the surface tester of Taylor Hobson surtronic 3 series was used. It can evaluate 36 kinds of roughness parameters conforming to the latest ISO, DIN, and ANSI standards, as well as to JIS standards (1994/1982).

Table 2. Experimental run and results

EXPT. No	INPUT PARAMETERS			RESPONSE		
	Speed (RPM)	FEED (MM/REV)	DOC (MM)	MRR (GRAM/SEC)	%RTTT (DEGREE CELSIUS)	Ra $\mu$ m



1	1753	0.02	0.7	0.24	20.40	1.07
2	1753	0.03	1.2	0.79	23.23	1.62
3	1753	0.04	1.7	1.65	75.98	2.12
4	1984	0.02	1.2	0.27	17.44	1.09
5	1984	0.03	1.7	1.34	27.64	0.66
6	1984	0.04	0.7	0.62	23.82	0.71
7	2215	0.02	1.7	0.90	21.94	0.44
8	2215	0.03	0.7	0.50	10.24	0.11
9	2215	0.04	1.2	1.37	26.63	0.16

**III. RESULT AND DISSCUSSION**

**3.1 Multiple regression models:**

The turning experiments were conducted by using the parametric approach of the Taguchi’s method. Regression analysis has been performed to find out the relationship between input factors and responses using Minitab 16 statistical software. During regression analysis it was assumed that the factors and the responses are linearly related to each other. General first order model was developed to predict the material removal rate over the experimental region (equation 1).

$$MRR = - 1.21 + 0.000065 \text{ Speed} + 32.3 \text{ Feed} + 0.843 \text{ DOC} \dots\dots\dots (1)$$

General first order model was developed to predict the surface roughness over the experimental region (equation 2).

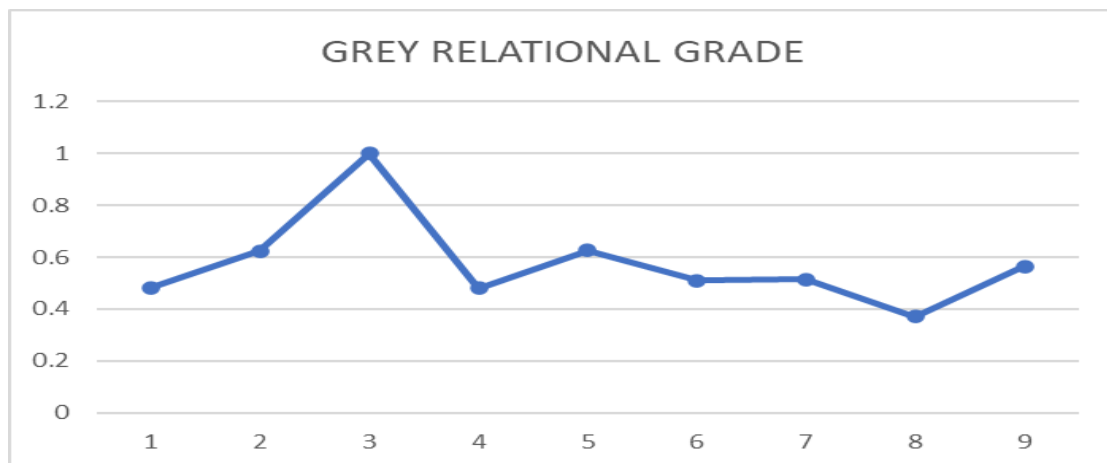
$$Ra = 12.1 - 0.00589 \text{ Speed} + 11.5 \text{ FEED} + 0.893 \text{ DOC} \dots\dots\dots (2)$$

General first order model was developed to predict the RTTT over the experimental region (equation 2).

$$\%RTTT = 58.5 - 0.0439 \text{ Speed} + 966 \text{ FEED} + 23.7 \text{ DOC} \dots\dots\dots (3)$$

**Multiple objective optimization:**

Fig. 2 shows the grey relational grade. The larger the grey relational grade, the better is the multiple performance characteristics. However, the relative importance among the machining parameters for the multiple performance characteristics still needs to be known, so that the optimal combinations of the machining parameter levels can be determined more accurately. From Table 5.4 the optimal parameter combination can be determined as A1 (Speed, 1753 rpm), B3 (Feed, 0.04 mm/rev) and C3 (DOC, 1.7 mm)



**Figure 2. Grey Relational Grade**

### 3.2 Confirmation experiments:

From the regression analysis, randomly run was chosen to verify the prediction of responses (MRR, RTTT and Ra). It was found that validation experiments showed a good agreement with the predicted values of responses with an error less than 5% (table 3).

**Table 3 Validation experiment results based on multi-objective optimization**

	Predicted	Experimental	% Error
MRR (Gram/sec)	1.62	1.64	1.21
% RTTT (Degree Celsius)	60.47	57.5	4.91
Ra ( $\mu\text{m}$ )	2.3	2.2	3.03

## IV. CONCLUSION

In this study turning experiments were conducted by using the parametric approach of the Taguchi's method. Regression analysis has been performed to find out the relationship between input factors and responses using Minitab 16 statistical software. General first order model was developed to predict the material removal rate and surface roughness over the experimental region. Based on multi-objective optimization GRA the best material removal rate obtained was 4.62 gram/sec and the best surface roughness value obtained was 2.3  $\mu\text{m}$  and lowest tool tip temperature is 60.47 Degree Celsius.

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