Analysis of effect of cutting parameters on responses Surface Roughness and Material Removal Rate for En 19 work-pieces material with and without heat treatment

Roopa K Rao, Asst Professor
Dept. of Industrial and Production Engineering
KLS Gogte Institute of Technology
Belgaum, India
rooparao@git.edu

Vinay Murgod, Asst Professor
Dept. of Industrial and Production Engineering
KLS Gogte Institute of Technology
Belgaum, India

Dr. A S. Deshpande, Principal
KLS Gogte Institute of Technology
Belgaum, India
principal@git.edu

Dr K K Jadhav,
Joint Director(ER), Union Director,
UPSC New Delhi--69

Abstract— This paper provides an insight to the effect of cutting parameters on surface roughness & material removal rate for turning operation. In any machining process, apart from obtaining the accurate dimensions, achieving a good surface quality and maximization of metal removal are of utmost importance. The objective of this paper is to provide the of effect of varying cutting parameters like Cutting Speed, Feed & Depth of cut over Surface Finish and Material Removal Rate on En 19 type steel with and without heat treatment.

EN 19 materials is widely used in manufacturing machinery parts, gear wheels, tie rods, bolts, pins and shaft requiring high resistance also in the manufacturing of automobile and machine tool parts such as shafts, spindles, etc. Because of special properties of EN19 steel, like low specific heat, and tendency to strain-harden and diffuse between tool and work material, give rise to certain problems in its machining such as large forces, high cutting-tool temperatures, poor surface finish and built-up-edge formation hence it is essential to conduct experimentation on En 19 material.

Key words— Cutting Speed, Depth of cut and Feed, MRR, Surface Roughness, ANOVA

I. Introduction

Machining has become indispensable to the modern man. It is used directly or indirectly in the production of almost all the goods and services being created all over the world. It is the basis of everything manufactured [1]. Metal cutting is the time honored activity having a rich literature much of which goes back well before the work of F. W. Taylor at the turn of 20th century [2]. The traditional machining operations include turning, boring, planing, shaping, drilling, reaming, milling, broaching, honing and lapping[1].Out of these machining processes, turning still remains as the most important operation used to shape metal, because in turning the condition of operation are most varied. Increasing productivity and reducing manufacturing cost has always been the primary objective of any organization. Since material removal is a workshop related activity where very strong economic or production rate constraints pertain, it is to be noted that the selection of tools, fluids, operating conditions etc. are of paramount importance. The ultimate objective of the science of metal cutting is to solve practical problems associated with efficient material removal in the metal cutting process.

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:- • With the work piece rotating, • With a single-point cutting tool, and • With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

ISSN 2229-5518

Objective the of research work is to study the effect of cutting parameters i.e. speed, feed and depth of cut in turning En 19 medium carbon steel with change in hardness of material by subjecting it to heat treatment.

- To plan experiments using design of experiment (DOE) technique.
- To develop a Linear Regression model for Surface Roughness and Material Removal Rate.
- To compare the experimental and predicted values of Material Removal Rate and Surface Roughness for two different kind of En 19 work material

II. LITERATURE REVIEW

Dr. Philip Selvaraj, P. Chandramohan, [3] developed a surface roughness model for AISI 304 Austenitic stainless steel that has excellent corrosion resistance specially used in piping components in boiling water in nuclear reactors. Taguchi techniques were employed to find optimum process parameters which minimize the Surface Roughness during the dry turning. ANOVA results showed that the Feed, Cutting speed, Depth of Cut affect the SR by 51.84%, 41.99%, 1.66% respectively.

Jitendra Verma, Pankaj Agarawal, Lokesh Bajpai, [4] demonstrated a systematic procedure using Taguchi method to analyze the surface roughness in turning ASTM A242 Type 1 alloy steel. The paper focused on use of ANOVA analysis to determine the influence of cutting parameters such as Cutting Speed, Feed, Depth of cut on Surface Roughness. The major contributing factors to Surface Roughness were Cutting Speed by 57.47% followed by Feed rate about 16.27% and Depth of Cut has a lesser role on surface roughness.

S.Tamizhmanii, S.Saparudin, S.Hasan, [5]conducted experiments using SCM440 alloy steel, a dry turning process and Taguchi method were employed to determine Speed, Feed, Depth of Cut to obtain lowest surface roughness. A golden coated Al2O3 + TiC cutting tool were used. The investigation proposed that Depth of Cut as the major contributing factor which effects the Surface Roughness by 14.467% and then by feed 9.764%. Cutting speed has very little role to play.

Hardeep Singh, Rajesh Khanna, M.P.Garg [6] carried out an experimental study on dry turning of En-8 a dry turning process, to optimize the cutting parameters like Cutting Speed, Feed, Depth of Cut on Surface Roughness as well as Material Removal Rate. The results showed that the cutting speed contributed towards 63.90%, Depth of Cut is the second significant factor and contribution of feed rate was least with 8.3% for surface roughness. The ANOVA results for MRR showed that the contribution of feed and cutting speed was 60.9% & 29.3% respectively, whereas Depth of Cut contributes only 7%. The results of the experimental work propose that the increase in spindle speed results in decrease in surface roughness value up to 1600 rpm. RPM of 800 produces highest roughness and 1260 RPM produces the lowest i.e. the best surface finish. The optimum value for feed was 0.2 mm/ rev and depth of cut was 2mm. The paper also provides information on MRR where in increase in spindle speed, feed, and depth of cut increases Material Removal rate i.e. high production rate. It was observed that maximum Material Removal rate is obtained at 2000 RPM spindle speed, 0.3mm/rev of feed & 2mm of depth of cut.

Upinder Kumar Yadav, Deepak Narang, Pankaj Sharma Attri, [7] predicted the value of Surface Roughness at the optimum conditions. The best result of Surface Roughness would be achieved when AISI 1045 is machined at 264 m/ min cutting speed, depth of cut of 1.5 mm, feed rate of 0.1mm/rev. The feed rate has the most significant factor for Surface Roughness. The experimental design was according to Taguchi method and ANOVA to investigate the cutting parameters affecting the surface roughness.

Ishwer Shivakoti ,Sunny Diyaley,Golam Kibria, B.B.Pradhan, [8] applied genetic algorithm (GA) for optimizing machining parameters during turning operation for maximizing Material Removal Rate. Cutting speed, feed, DOC has been considered as the machining parameters to obtain its influence for Material Removal Rate. The experimentation proposed that Material Removal Rate increases with increased feed rate. A regression equation for Material Removal Rate has been developed helped in validating the comparative results. Optimization results of Material removal rate achieved in Genetic algorithm is for Spindle speed 891.50 rpm, cutting speed 25.580 m/min and feed 0.582mm/rev. The best fitness of Material removal rate is 51247.549 mm^3/sec.

M Kaladhar,K.V.Subbaiah,Ch.Srinivas Rao and K.Narayana Rao, [9] evaluated the process parameters like speed, feed, depth of cut and nose radius for solving multi objective problem in turning AISI 202 Austenitic stainless steel with the application of Taguchi method and utility concept. Experimental analysis shows that the maximum Material Removal Rate is obtained at 200 m/min of cutting speed, 0.25 mm / rev of feed, 0.75 mm depth of cut and minimal effect of nose radius. The feed (61.428%) is the most significant parameter followed by cutting speed (20.697%) for Surface Roughness. The depth of cut (63.183%) is the most significant parameter followed by cutting speed (20.697%) for Material Removal Rate response. The analysis showed that the combination of higher levels of cutting speed, depth of cut and nose radius and lower level of feed is essential to achieve simultaneous maximization of Material Removal Rate and minimization of Surface Roughness. The following figure shows the optimum level of process parameters for the multi response optimization of Material Removal Rate & minimization of Surface Roughness.

Ashish Kabra et al. [10] Conducted an experimental study to optimize and study the effects of process parameters in CNC turning on Surface roughness, feed and radial forces of EN19/AISI4140 (medium carbon steel) work material in dry environment conditions. The orthogonal array, signal to noise ratio and analysis of variance are employed to study the performance characteristics in CNC turning operation. Three machining parameters are chosen as process parameters: Cutting Speed, Feed rate and Depth of cut. The experimentation plan is designed using Taguchi's L9 Orthogonal Array (OA) and Minitab-16 statistical software is used. Optimal values of process parameters for desired performance characteristics are obtained by Taguchi design of experiment. Prediction models are developed with the help of regression analysis method using Minitab-16 software. The cutting tool selected for machining EN19 steel is uncoated carbide inserts. Results showed that Depth of Cut represents the largest influence on surface roughness, feed and radial forces followed by feed rate, and finally Cutting Speed.

Sajeev A , Dr.Binu C Yeldose , Susan Rose.[11] Made an attempt to develop and compare Regression (linear and nonlinear) and Artificial Neural Network (ANN) models for prediction of surface roughness with independent variables cutting speed, feed rate and depth of cut. Turning was conducted on EN19 steel. The measured surface roughness was used to develop Regression and ANN models. The regression models were validated using Chi-square test and Coefficient of Determination. All the models were compared with Root Mean Square Error (RMSE) and the best model was selected based on the least error. ANN models were found to have least RMSE and hence were adopted as the best model.

Daniel Kirby. [12] Investigated into the use of Taguchi Parameter Design for optimizing surface roughness generated by a CNC turning operation. This study utilizes a standard orthogonal array for determining the optimum turning parameters, with an applied noise factor. Controlled factors include spindle speed, feed rate and depth of cut; and the noise factor is slightly damaged jaws. The noise factor is included to increase the robustness and applicability of this study. After experimentally turning sample workpieces using the selected orthogonal array and parameters, this study produced a verified combination of controlled factors and a predictive equation for determining surface roughness with a given set of parameters. The work pieces selected for this experiment were cut from 1-inch diameter 6061-T6511 Aluminum Alloy rod, per ASTM B221.

H. K. Dave, L. S. Patel and H. K. Raval [13] focused on the analysis of optimum cutting conditions to get the lowest surface roughness and maximum material removal rate in CNC turning of different grades of EN materials by Taguchi method. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in dry turning operation. ANOVA has shown that the depth of cut has significant role to play in producing higher MRR and insert has significant role to play for producing lower surface roughness. Turning tests were performed on different grades of EN materials using two different inserts of coated carbide cutting tools. The influences of cutting speed, tool inserts type and work piece material were investigated on the machined surface roughness. The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by depth of cut. It is found that if speed is increase then MRR would increase and positive inserts are superior as compare to negative inserts for more MRR. Analysis of Variance suggests the insert is the most significant factor for surface roughness.

Ravinder Tonk and Jasbir Singh Ratol [14] Conducted experiments to obtain an optimal setting of turning process parameters –cutting speed, feed, depth of cut, cutting tool and cutting fluid which may result in optimizing the thrust force and feed force encountered during machining of EN31 alloy. EN31 is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance, but is usually known to create major challenges during its machining. Turning is the process known for its capabilities in providing machining efficiency in terms of higher machining rate low tool wear apart from reasonably good surface quality. The study was aimed to investigate the effect of several input parameters of turning operation (cutting tool, cutting oil, cutting speed, feed and depth of cut) on the different response parameters such as thrust force and feed force in turning process on EN31. The result showed that the response variables were strongly influenced by the input parameters. The experiments were performed on conventional lathe machine. Taguchi's robust design methodology has been used for statistical planning of the experiments. Experiments were conducted on conventional lathe machine in a completely random manner to minimize the effect of noise factors present while turning EN31 under different experimental conditions. Two type of tools and three types of coolant were used with three different values of machining parameters (speed, feed and depth of cut).

Krishankant, Jatin Taneja, Mohit Bector, Rajesh Kumar [15] Reported on an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate. The bars used are of diameter 44mm and length 60mm. There are three machining parameters i.e. Spindle speed, Feed rate, Depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Operating range is found by experimenting with top spindle speed and taking the lower levels of other parameters. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 15. In the first run nine experiments are performed and material removal rate (MRR) is calculated. When experiments are repeated in second run again MRR is calculated. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of "the larger-the-better". The S/N ratio for the larger-the-better Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration with the help of software Minitab 15.

III METHODOLOGY AND DATA COLLECTION

ISSN 2229-5518

The experiments are performed on a high precision conventional lathe machine. Experimental set-up used for the present set of turning operation of hardened steel En 19. A single point Carbide tip tool has been used as the cutting tool. The round bar of dimensions 25 mm in diameter and 70mm in length is used as the work piece. The chemical composition of the En 19 is as given in the table 3.1

C	Mn	Si	S	P	Cr	Mo
0.35-0.45%	0.50-0.80%	0.10-0.35%	0.040 %	0.040%	0.90-1.40%	0.20-0.40%

TABLE 3.1: CHEMICAL COMPOSITION OF EN 19 STEEL, % BY WEIGHT

IV. CHOICE OF FACTORS LEVELS AND RANGE

The experiments were conducted for two sets of workpieces, each set there are 27 workpieces and experimentation is planned using **3^3 full factorial design** method. In first set tests are carried out using workpieces that are not heat treated. In second set machining is done on tempered En19 bars. The control parameters and their levels are indicated in Table 2.2.

TABLE 4.1: CONTROL PARAMETERS AND THEIR LEVELS

Code	***Levels***	**Cutting Parameters**		
		Speed (RPM)	***Feed (mm/rev)***	***Depth of cut (mm)***
		A	*B*	*C*
1	Low	420	0.04	0.04
2	Medium	630	0.048	0.08
3	High	1000	0.054	0.12

V PERFORMING THE EXPERIMENT AND DATA COLLECTION

- Measuring the hardness of each workpiece using Rockwell hardness C scale.
- Checking and preparing the Centre Lathe ready for performing the machining operation.
- Performing initial turning operation to get desired dimension of the work pieces.
- Measuring weight of each specimen by the digital balance meter before machining.
- Performing straight turning operation on specimens with cutting involving various combinations of process control parameters like: spindle speed, feed and depth of cut.
- Using stop watch machining time is noted down.
- Weight of each machined En 19 bar is measured using digital balance.
- Calculating MRR using following formula

$$\frac{\text{Weight before machining} - \text{Weight after machining}}{\text{Machining time} \times \text{Density of the material}}$$

Density ρ of En19 is 7.8×10-3 gm/mm3

- Measuring surface roughness with the help of a portable stylus-type Talysurf (Taylor Hobson, Surtronic 3+, UK)

VI EXPERIMENTAL VALUES

TABLE 6.1: EXPERIMENTAL VALUES OF SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE FOR EN19 WORKPIECES WITHOUT HEAT TREATMENT. (22 to 26 HRC)

Spindle speed rpm	**feed mm/rev**	**DOC mm**	**MRR mm^3/min**	**Surface roughness Ra µm**
420	0.04	0.04	50.725	3.394
420	0.04	0.08	56.8273	3.91
420	0.04	0.12	60.907	4.7818
420	0.048	0.04	54.27	3.41
420	0.048	0.08	59.422	4.105
420	0.048	0.12	67.86	4.8392
420	0.054	0.04	63.108	3.68
420	0.054	0.08	68.95	4.256
420	0.054	0.12	75.85	4.998
630	0.04	0.04	70.97	3.1325
630	0.04	0.08	74.1875	3.75
630	0.04	0.12	80.5133	3.915
630	0.048	0.04	78.043	3.2702
630	0.048	0.08	82.446	3.8039
630	0.048	0.12	88.28	4.7951
630	0.054	0.04	89.136	3.35
630	0.054	0.08	91.778	3.975
630	0.054	0.12	128.89	4.255
1000	0.04	0.04	93	3.003
1000	0.04	0.08	104.88	3.6275
1000	0.04	0.12	142.515	3.995
1000	0.048	0.04	129.232	3.215
1000	0.048	0.08	145.84	3.8275
1000	0.048	0.12	188.268	4.5225
1000	0.054	0.04	223.9698	3.4275
1000	0.054	0.08	230.875	4.2625
1000	0.054	0.12	249.73	4.9817

TABLE 6.2: EXPERIMENTAL VALUES OF MATERIAL REMOVAL RATE AND SURFACE ROUGHNESS FOR EN19 WORKPIECES AFTER HEAT TREATMENT.(36 to 39 HRC)

Spindle speed rpm	**feed mm/rev**	**DOC mm**	**MRR mm^3/min**	**Surface roughness Ra µm**
420	0.04	0.04	47.35	2.5675
420	0.04	0.08	52.1873	3.385
420	0.04	0.12	56.18	4.105
420	0.048	0.04	51.05	3.025
420	0.048	0.08	55.55	3.7225
420	0.048	0.12	65.03	4.1525
420	0.054	0.04	53.94	3.294
420	0.054	0.08	60.57	3.722
420	0.054	0.12	69.67	4.197

630	0.04	0.04	66.069	2.8232
630	0.04	0.08	71.5159	3.198
630	0.04	0.12	77.328	3.325
630	0.048	0.04	75.8636	2.985
630	0.048	0.08	80.6072	3.2675
630	0.048	0.12	84.019	3.975
630	0.054	0.04	83.73	2.8925
630	0.054	0.08	87.099	3.05
630	0.054	0.12	122.465	4.0135
1000	0.04	0.04	88.624	2.1907
1000	0.04	0.08	96.04	2.8225
1000	0.04	0.12	130.6743	3.27
1000	0.048	0.04	123.38	2.4025
1000	0.048	0.08	138.47	3.1727
1000	0.048	0.12	178.508	3.7575
1000	0.054	0.04	190.89	2.6775
1000	0.054	0.08	196.549	3.74
1000	0.054	0.12	200.72	4.002

VII RESULTS AND DISCUSSION

The data collected is used to obtain analysis of variance (ANOVA) table for 90% confidence level using Minitab-15 statistical analysis software and coefficients obtained through ANOVA are used to develop a linear regression prediction model for the responses, material removal rate and surface roughness Ra. Effect of cutting parameters Speed, Feed and Depth of cut on Material Removal Rate and Surface roughness Ra is discussed with the help of interaction and main effect plots.

A. *MRR Before Heat treatment*

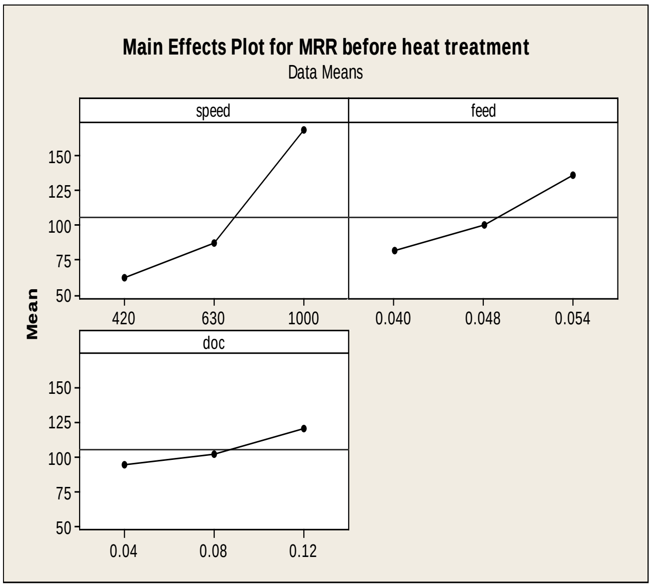

Fig 7.1: Main effect plot for material removal rate for workpieces without heat treatment

The main effect plot reveals that during machining of En 19 on conventional lathe machine, MRR is affected by all the process parameters viz. spindle speed, depth of cut and feed rate. The MRR is increased by increasing any of the process parameters. The effect of variation in spindle speed and feed rate is more as compared to depth of cut.

From ANOVA table it is found that for MRR contribution of speed is 63.97% and contribution of feed is 16.06% followed by depth of cut, contributes by 3.50%.

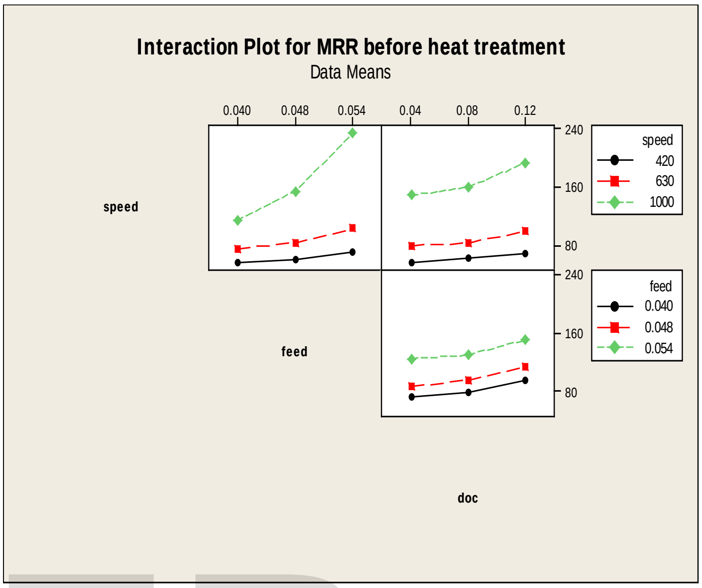

Fig 7.2: Interaction plot for material removal rate for workpieces without heat treatment

From the interaction plot it is found that speed is significant factor which affects material removal rate. Using combination of higher speed and lower feed higher MRR can be achieved when compared to combination of higher speed and higher depth of cut. Plot shows increasing trend for MRR with increasing depth of cut as well as feed.

Linear Regression model for material removal rate before heat treatment can be written as follows by using coefficients obtained from ANOVA table.

MRR=213.18 - (0.40027*speed) - (4543*feed) + (10.868*speed*feed) + (0.7185*speed*DOC)

B. *MRR After Heat treatment*

ISSN 2229-5518

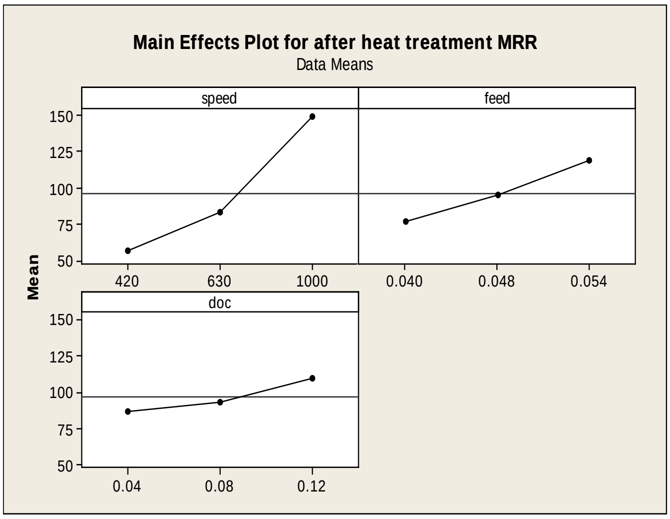

Fig 7.3: Main effect plot for material removal rate for workpieces subjected to heat treatment

The main effect plot for material removal rate for heat treated workpieces reveals that during machining of tempered En 19 bars on conventional lathe machine, MRR is affected by all the process parameters viz. spindle speed, depth of cut and feed rate. The MRR is increased by increasing any of the process parameters. The effect of variation in spindle speed and feed rate is more as compared to depth of cut. From ANOVA table it is found that for MRR contribution of speed is 69.38% and contribution of feed is 13.76% followed by depth of cut, contributes by 3.94%.

Fig 7.4: Interaction plot for material removal rate after heat treatment

From the interaction plot for Material Removal Rate for heat treated workpieces it is found that speed is significant factor which affects material removal rate.Using combination of higher speed and lower feed higher MRR can be achieved when compared to combination of higher feed and depth of cut. Plot shows increasing trend for MRR with increasing speed, depth of cut as well as feed.

Linear Regression model for material removal rate after heat treatment can be written as follows by using coefficients obtained from ANOVA table.

MRR=144.08 – (0.26835*speed) – (3153.7*feed) – (70.3*DOC) + (8.016*speed*feed) + (257*feed*DOC) + (0.4985*speed*DOC)

C. *Surface Roughness for workpieces Before Heat treatment*

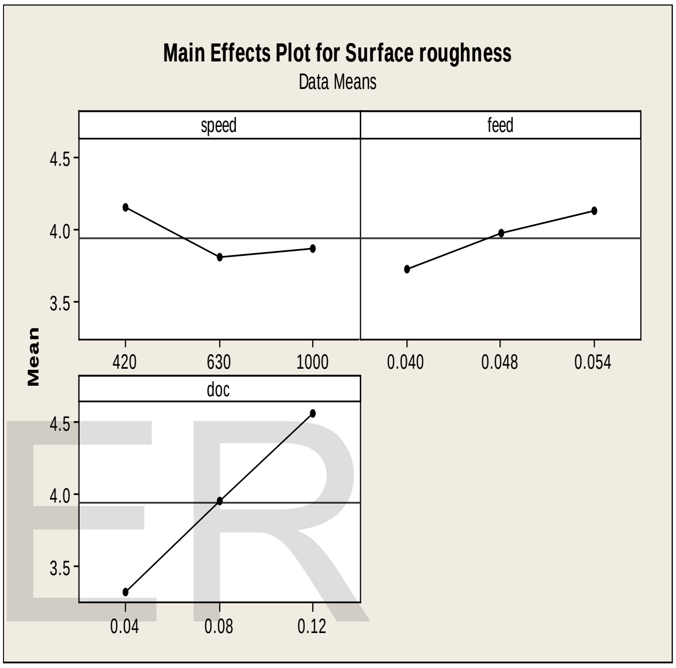

Fig 7.5: Main effect plot for surface roughness for workpieces without heat treatment

Main effect plot for surface roughness for workpieces without heat treatment indicates that depth of cut has direct and significant effect on surface roughness. Increasing depth of cut increases surface roughness. Increase in feed also results in higher surface roughness. Surface roughness reduces with increasing spindle speed up to 630 rpm after that increasing speed results into increasing surface roughness. Also higher feed gives higher surface roughness. From ANOVA table it is found that for surface roughness Ra contribution of depth of cut is 76.98% followed by feed which contributes by8.114% and contribution of speed is 2.81%.

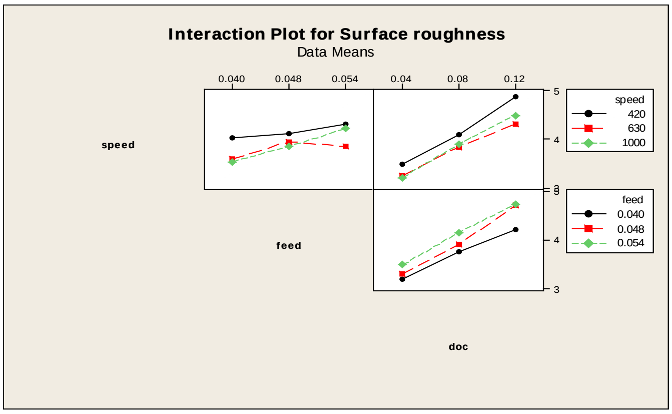

Fig 7.6: Interaction plot for surface roughness for workpieces without heat treatment

Interaction plot for surface roughness Ra for workpieces without heat treatment interprets that minimum surface roughness can be obtained at higher spindle speed of 1000 rpm and lower depth of cut of 0.04 mm. Increasing feed from 0.04 mm/rev to 0.054 mm/rev results into increasing surface roughness. Higher speed of 1000 rpm gives better surface finish at lower feed of 0.04 mm/ rev and lower depth of cut of 0.04 mm.

Linear Regression model for surface roughness before heat treatment can be written as follows by using coefficients obtained from ANOVA table.

Surface roughness Ra = 0.986 – (0.003892*speed) + (114.56*feed) + 35.75*DOC) – (0.02088*speed*feed) – (401.3*feed*DOC) – (0.03868*speed*DOC) + (0.7749*speed*feed*DOC) + (0.000003*speed*speed) – (896.4*feed*feed)

D. Surface Roughness for workpieces after Heat treatment

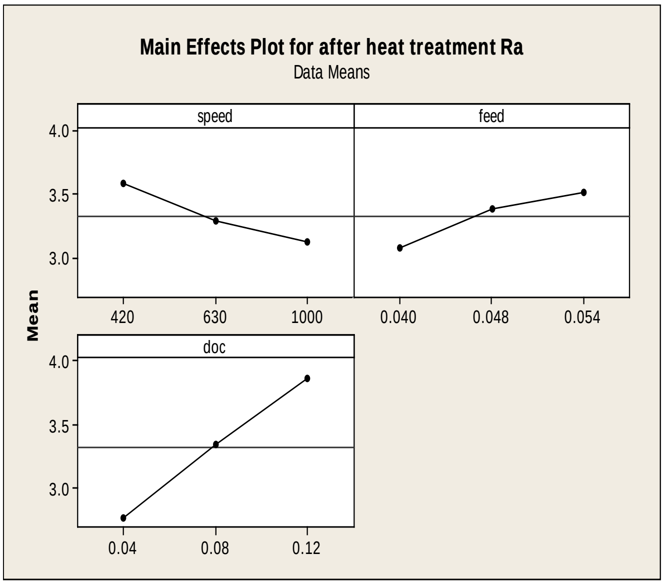

Fig 7.7: Main effect plot for Surface Roughness Ra after heat treatment

Main effect plot for Surface Roughness for heat treated workpieces which are subjected to tempering indicates that depth of cut has direct and significant effect on surface roughness. Increasing depth from of cut 0.04 mm to 0.12 mm increases surface roughness. Increase in feed also results in higher surface roughness. Surface roughness reduces drastically with increasing spindle speed up to 630 rpm. From ANOVA table it is found that for surface roughness Ra contribution of depth of cut is 66.63% followed by speed which contributes by 10.68% and contribution of feed is 9.90%.

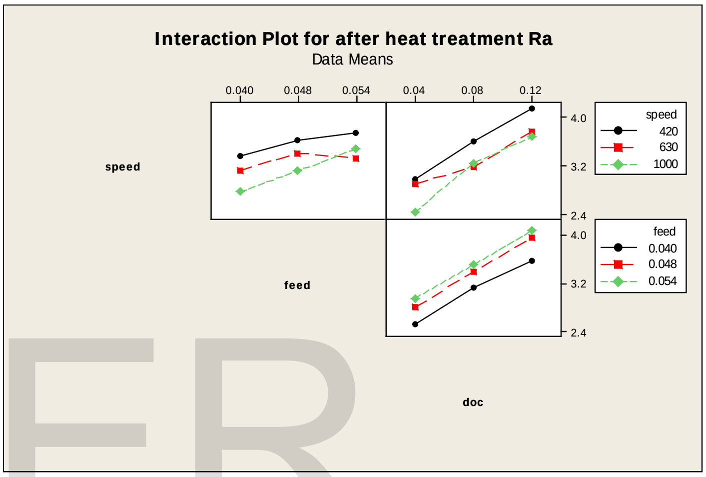

Fig 7.8: Interaction plot for surface roughness Ra after heat treatment

Interaction plot for surface roughness Ra after heat treatment shows that minimum surface roughness can be obtained at higher spindle speed of 1000 rpm and lower depth of cut of 0.04 mm. Increasing feed from 0.04 mm/rev to 0.054 mm/rev results into increasing surface roughness from 2.4 micro meters to 3.5 micro meters.

Linear Regression model for surface roughness after heat treatment can be written as follows by using coefficients obtained from ANOVA table.

Ra=0.504 – (0.005138*speed) + (136.2*feed) + (9.586*DOC) +(0.03717*speed*feed) + (48.9*feed*DOC) + (0.002690*speed*DOC) + (0.000002*speed*speed) – (1443*feed*feed)

VIII CONFIRMATION EXPERIMENTS

The confirmation experiments were conducted to check the percentage error in the experimental and predicted values. It was found that the results obtained are within the acceptable limits.

TABLE 8.1: CONFIRMATION EPXERIMENTS FOR MATERIAL REMOVAL RATE (MRR)

Sl no	Speed	Feed	DOC	MRR mm3/rev		% error
	rpm	*mm/ rev*	*mm*	*experimental*	*predicted*	
1	540	0.045	0.06	79	79.971	-1.21%
2	840	0.05	0.1	165.986	166.613	-0.38%
	After heat treatment					
1	540	0.045	0.06	66.28	64.6706	2.43%
2	840	0.05	0.1	131.672	133.782	-1.60%

TABLE 8.2: CONFIRMATION EPXERIMENTS FOR SURFACE ROUGHNESS- Ra (SR)

sl no	Speed	Feed	DOC	Surface roughness Ra (microns)		percentage error
	rpm	*mm/rev*	*mm*	*experimental*	*predicted*	
1	540	0.045	0.06	3.365	3.5297	-4.896%
2	840	0.05	0.1	4.0021	4.0175	-0.385%
	After heat treatment					
1	540	0.045	0.06	3.312	3.217	2.86%
2	840	0.05	0.1	3.87	3.7919	2.018%

IX CONCLUSION

The research work was carried out to study the effect of cutting parameters on the surface roughness and material removal rate for heat treated and without heat treated En19 steel. The following conclusions have been drawn from the study:

MRR- For En19 steel without heat treatment Speed is significant factor which influences MRR by 63.97% followed by feed which contributes by 16.06% and contribution of depth of cut is 3.50%.Maximum MRR of 249.73 mm3/min for given range can be obtained at 1000 rpm speed ,0.054 mm/rev feed,0.12 mm depth of cut.

MRR- For En 19 steel subjected to heat treatment Speed is significant factor which affects MRR by 69.38% followed by feed which contributes by 13.76% and contribution of depth of cut is 3.94%. Maximum MRR of 200.72 mm3/min for given range can be obtained at 1000 rpm speed ,0.054 mm/rev feed,0.12 mm depth of cut

Surface Roughness- For En19 steel without heat treatment depth of cut is a significant factor which affects surface roughness by 76% followed by feed which contributes by 8.114% and contribution of speed is by 2.81%.Good surface roughness of 3.003 microns for given range can be obtained at 1000 rpm speed,0.04mm feed and depth of cut of 0.04mm.

Surface Roughness- For En19 steel subjected to heat treatment depth of cut is significant factor which affects surface roughness by 66.63% followed by speed which contributes by 10.68% and contribution of feed is 9.90%.Good surface roughness of 2.1907 microns for given range can be obtained at 1000 rpm speed,0.04mm feed and depth of cut of 0.04mm.

REFERENCES

[1] B.L.Juneja, G.S.Sekhon, Nitin Seth, “Fundamentals of Metal cutting & Machine tools”, 2nd Edition, New age international publishers.

[2] Milton C. Shaw, “Metal Cutting Principles”, 2nd edition, Oxford series on “Advanced manufacturing”

[3] Dr. Philip Selvaraj, P. Chandramohan, “Optimization of Surface Roughness of AISI 304 Austenitic Stainless Steel in Dry Turning Operation Using Taguchi Design Method”- “Journal of Engineering Science and Technology, Vol.5,No3(2010) 293-301”.

[4] Jitendra Verma, Pankaj Agarawal, Lokesh Bajpai, “Turning Parameter Optimization for Surface Roughness of ASTM A242 Type-1 Alloys steel By Taguchi Method”- “International Journal of Advances in Engineering and Technology March 2012”.

[5] S Tamizhmanii, S.Saparudin, S.Hasan, “ Analysis of Surface Roughness By Turning Process Using Taguchi Method”- “Journal of Achievements in Materials and Manufacturing Engineering, Vol. 20, pp. 503-506, 2007”.

[6] Hardeep Singh, Rajesh Khanna, M.P.Garg, “Effect of cutting parameters on Material Removal Rate and Surface Roughness in Turning En-8”- “Current Trends in Engineering Research Vol.1, No.1 (Dec.2011)”.

[7] Upinder Kumar Yadav, Deepak Narang, Pankaj Sharma Attri, “ Experimental Investigation and Optimization Of Machining Parameters for Surface Roughness in CNC Turning By Taguchi Method”- “International Journal of Engineering Research and Applications Vol.2, July-August 2012,pp.2060-2065”.

[8] Ishwer Shivakoti ,Sunny Diyaley,Golam Kibria, B.B.Pradhan, “Analysis of Material Removal Rate using Genetic Algorithm Approach”- “International Journal of Scientific & Engineering Research Volume 3,Issue 5,May-2012”.

[9] M Kaladhar,K.V.Subbaiah,Ch.Srinivas Rao and K.Narayana Rao, “ Application of Taguchi Approach and Utility concept in Solving the Multi-objective Problem when turning AISI 202 Austenitic Stainless Steel” - “ Journal of Engineering Science and Technology Review 4(1) (2011) 55-61”.

[10] Ashish Kabra, Amit Agarwal, Vikas Agarwal, Sanjay Goyal, Ajay Bangar, “Parametric Optimization & Modeling for Surface Roughness, Feed and Radial Force of EN-19/ANSI-4140 Steel in CNC Turning Using Taguchi and Regression Analysis Method”, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622

[11] Sajeev A , Dr.Binu C Yeldose , Susan Rose, “Surface Roughness Prediction Based on Cutting Parameters in Turning Operation”

[12] E. Daniel Kirby, "A parameter design study in a turning operation using the Taguchi method" , the Technology Interface/Fall 2006

[13] H. K. Dave, L. S. Patel and H. K. Raval, "Effect of machining conditions on MRR and surface roughness during CNC Turning of different Materials Using TiN Coated Cutting Tools – A Taguchi approach" International Journal of Industrial Engineering Computations 3 (2012) 925–930

[14] Ravinder Tonk and Jasbir Singh Ratol, "Investigation of the Effects of the Parametric Variations in Turning Process of En31 Alloy"-"International Journal on Emerging Technologies 3(1): 160-164(2012)"

[15] Krishankant, Jatin Taneja, Mohit Bector, Rajesh Kumar "Application of Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012

.