Journal Of Harmonized Research (JOHR)

Journal Of Harmonized Research in Engineering
2(2), 2014, 301-316

ISSN 2347 – 7393

Original Research Article

# EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETER IN TURNING OPERATION USING FULL FACTORIAL DESIGN

**Mohit Kumar Sahu, Manish Verma and Ashish Kumar Khandelwal**

Department of Mechanical Engineering Chouksey Engineering College Bilaspur, INDIA

**Abstract:**
The purpose of this paper is to study the effect of speed, feed and depth of cut on Material Removal Rate(MRR) and cutting force (F c) in turning mild steel using high speed steel cutting tool. Experiments were conducted on a centre lathe and the influence of cutting parameters was studied using analysis of variance (ANOVA) based on adjusted approach. Based on the main effects plots obtained through full factorial design use Design expert Software, optimum level for surface roughness and cutting force were chosen from the three levels of cutting parameters considered. Linear regression equation of cutting force has revealed that speed, feed, and depth of cut significantly influenced the variance. In case of material removal rate, the influencing factors were found to be feed and the interaction of speed and feed. As turning of mild steel using HSS is one among the major machining operations in manufacturing industry, the revelation made in this research would significantly contribute to the cutting parameters

Keywords: Cutting Force; MRR; HSS Tool; Full Factorial Methodology; ANOVA; Design Expert Software

## 1. Introduction

Metal cutting process forms the basis of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every product of our modern civilization.

**For Correspondence:**
mksahu0ATgmail.com
Received on: June 2014
Accepted after revision: June 2014


The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. An area of research interest in metal cutting is the analysis of cutting force, as minimum power consumption is a never ending endeavor. Among the Cutting force, Thrust force and Feed force the former prominently influences a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece. The cutting tool is fed linearly in a direction parallel to the axis of rotation. Turning is carried on lathe that provides the power to turn the work piece at a given rotational speed and feed to the cutting tool at specified .

Turning is a very important machining process in which rate and depth of cut. Therefore three cutting parameters namely cutting speed, feed rate and depth of cut need to be optimized in a turning operation. Turning operation is one of the most important operations used for machine elements construction in manufacturing industries i.e. aerospace, automotive and shipping. Turning produces three cutting force components as shown in fig.1,(the cutting force i.e. thrust force, (FZ), which acts in the cutting speed direction, feed force, (FX), which acts in the feed rate direction and the radial force, (FY), which acts in radial direction and which is normal to the cutting speed.

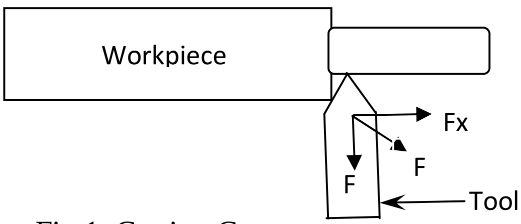



Fig.1. Cutting Component

Tugrul O zel et al [1] presented the effects of cutting edge preparation geometry, workpiece surface hardness and cutting conditions on the surface roughness and cutting forces in the finish hard turning of AISI H13 steel. They have found that the cutting forces are influenced not only by cutting conditions but also the cutting edge geometry and workpiece surface hardness. The lower workpiece surface hardness and small edge radius resulted in lower tangential and radial forces. Cutting force is classified among the most important technological parameter to control in machining process. It is the background for the evaluation of the necessary power machining (choice of the electric motor). It is also used for dimensioning of machine tool components and the tool body. It influences machining system stability. In hard turning, cutting forces have been found to be influenced by a number of factors such as depth of cut, feed rate, cutting speed, cutting time, workpiece hardness, etc. Yallese et al [2] confirmed that in hard machining of hardened bearing steel using cubic boron nitride tool, the radial force is dominating especially when machining is within the limit of tool nose radius. Such finding is in contradiction with what is known from conventional turning as radial force is about 30 to 50% from the tangential cutting force. Consequently, the radial force cannot be neglected in characterizing static and dynamic behaviors of such machining system. J.G. Lima et al [3] have evaluated the mach inability of hardened steels at different levels of hardness and using a range of cutting tool materials. They have proved in their result that turning of AISI 4340 steel using low feed rates and depths of cut, the forces were higher when machining the softer steel and that surface roughness of the machined part was improved as cutting speed was elevated and deteriorated with feed rate. Vishal S Sharma et al [4] investigated the machining AISI 52100 steel using a carbide-coated tool. It was found that the cutting force increases with the feed rate and depth of cut. The approach angle has little effect on the cutting force, and increasing the speed causes the cutting force to decrease slightly. The feed force increased with increasing depth of cut and decreased with increasing approach angle, speed, and feed rate. D.I. Lalwani, N.K. et al [5] investigated the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness in finish hard turning of MDN250 steel using coated ceramic tool. They have used response surface methodology (RSM) and sequential approach using face centered central composite design. Astakhov and Shvets et al [6] studied force variations and their effects in metal-deforming technological processes. They suggest that interaction of the energy waves propagating in the medium might affect the cutting force. They experimented and studied on the interaction between the deformation and the heat waves. The conclusions drawn from this paper reveals that the study of cutting force and the interaction between the deformation and heat waves can be very helpful in adopting the process which involves the least energy consumption. Having realized the importance of the choice of most appropriate cutting conditions in metal cutting, this research primarily focuses on machining mild steel using HSS owing to its lower cost, ready availability, and a wide range of applications from automotives to domestic goods to constructional steel and many other machine elements such as keys, rings, fence posts etc. The influence of cutting parameters on cutting force and surface roughness can be studied effectively using Adjusted statistical approach

The aim of the present study is, thus, to develop a statistical model for using the main cutting parameters such as cutting speed, feed rate and depth of cut on Mild steel. Machining tests were carried out under different conditions with HSS cutting tool. The model predicting equations for cutting forces were developed. To calculate constants and coefficients of these models, the software Minitab characterized by analysis of variance (ANOVA), multiple linear regression and Full Factorial Methodology.

## 2. Material and Method

**Machine**: The experiment was carried out on the Royal Machine Tool Centre Lath which enables high precision machining and production of jobs. The main spindle runs on high precision roller taper bearings and is made from hardened and precision drawn nickel chromium steel. The lathe used for machining operations is are shown in Fig.2 and their specification listed in table1

Fig.2.Center Lath

Table-1 Specification of the Lathe machine

| | |
|---|---|
| Name | Royal Machine Tool Centre Lath |
| Manufacture by | Industrial Instruments Bangalore |
| Power of Motor | 7 KW, 5 HP |
| Centre height | 175mm |
| Accuracy | 0.1 |
| Swing over Bed | 350mm |
| Range of spindle speed | 120-300rpm |

**The Tool**: HSS tool with the alloying elements: manganese, chromium, tungsten, cobalt etc. has comparatively better resistance to heat and wear. Tool length of 75mm (approx.) was taken so as to minimize undesirable vibrations, which would influence cutting force and surface roughness. The lathe tool dynamometer was used for measuring cutting force and cutting process was continued until significant tool wear was observed 22-25 . The single point HSS tool specifications are as follows in table – 2

Table – 2 Tool Specifications

| | |
|---|---|
| Back Rake Angle | 12° |
| End Relief | 10° |
| End Cutting Edge Angle | 30° |
| Side Rake Angle | 12° |
| Nose Radius | 0.8 |
| Side Cutting Edge Angle | 15° |

.

**The workpiece:** The workpiece material used for the experiments is AISI 4340 mild steel of standard dimensions was used for machining with 45 mm diameter, 175 mm long show in fig. 3 and there chemical specification shown in table-3.

Fig.3 Work piece Mild steel bar

Table.3.The chemical composition of AISI 4340 steel in percentage by weight

| |
|---|
| C -0.382, Si-0.228, Mn-0.609, P-0.026,S-0.022, Cr-0.995, Ni-1.514, Mo-0.226 Fe -95.998 |

**Lathe Tool Dynamometer:** The instrument used for the measurement of cutting force was IEICOS multi-component force indicator. It comprises of three independent digital display calibrated to display force directly using three component tool dynamometer. This instrument comprises independent DC excitation supply for feeding strain gauge bridges, signal processing systems to process and compute respective force values for direct independent display. Instrument operates on 230V, 50Hz AC mains. To record the force readings, IEICOS multi-component force indicator software was used. The data was obtained through a USB cable connected to the Dynamometer and stored on a computer.

Dynamometer Specification

Manufactured by – Industrial Engineering Instruments ,Bangalore -560058

Calibrated partial range 500kgf

It is shown in fig 4 and there set up is shown in fig.5

Fig. 4 Lath Tool dynamometer

Forces were measured and recorded for the different cutting conditions. The three force components are, the main cutting force (Fz), thrust force (Fx) and radial force (Fy).

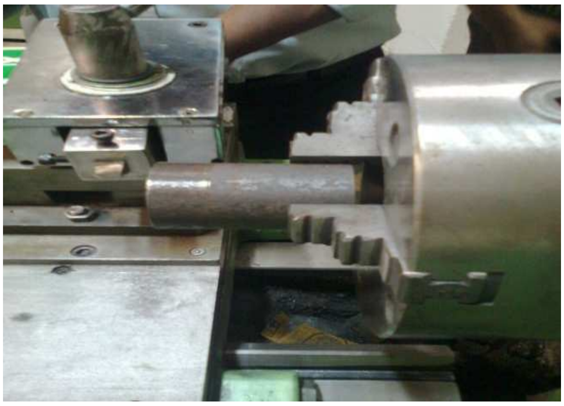


Fig.5 The experimental set up

**3. Measurement of MRR**

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, high surface finish, high production rate, Chip formation ,less tool wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. MRR of the machined chip is an important quality measure in metal cutting, and it is important to monitor and control during the machining operation. It's the ratio of weight of chip to the density of material in to removal time of material is find thesis below equation

MRR= weight of chip/( p × t)

Where p is density of material and ,t is removal time

**4. Cutting Conditions and Experimental Procedure:**

The present work deals with the turning of hard material such as AISI 4340 steel. It is an important engineering material employed in manufacturing of components in auto and aerospace industries. Since the present trend in the manufacturing industry is high speed dry machining, it was applied to evaluate the performance of coated tools in typical manufacturing processes Among the speed and feed rate combinations available on the Lathe, three levels of cutting parameters were selected. Full-Factorial design for three levels and three factors (3^3) yielded 27 experiments and two replicates were carried out. The standard order, run order, cutting parameters and responses were as shown in the Design of Experiments table It is given in table-5.The selection of parameters of interest was based on some experiment preliminary .The following process work: a) Cutting speed (A), b) Feed rate – (B), c) Depth of cut – (C), given in table.4

Table-4 Factors and their Levels

| **Factor** | **Level 1** | **Level 2** | **Level 3** |
|---|---|---|---|
| **A: Speed (rpm)** | 120 | 210 | 310 |
| **B: Feed (mm/rev)** | 0.1 | 0.2 | 0.3 |
| **C: Depth 0f Cut (mm)** | 0.1 | 0.3 | 0.5 |

Table – 5 Experimental results

| **Run** | **Block** | **V rpm** | **F Mm/rev** | **D mm** | **Fx N** | **Fy N** | **Fz N** | **MRR $mm^3$/min** |
|---|---|---|---|---|---|---|---|---|
| 1 | Block 1 | 210 | 0.2 | 0.5 | 91.13 | 74.44 | 188.89 | 6.42 |
| 2 | Block 1 | 120 | 0.3 | 0.5 | 66.22 | 61.26 | 184.16 | 6.25 |
| 3 | Block 1 | 210 | 0.3 | 0.3 | 103.59 | 167.59 | 209.08 | 6.94 |
| 4 | Block 1 | 310 | 0.1 | 0.3 | 106.76 | 72.73 | 160.14 | 5.25 |
| 5 | Block 1 | 210 | 0.2 | 0.3 | 126.3 | 76.23 | 160.8 | 6.28 |
| 6 | Block 1 | 210 | 0.3 | 0.1 | 38.14 | 97.36 | 123.62 | 6.74 |
| 7 | Block 1 | 210 | 0.1 | 0.1 | 31.79 | 49.26 | 66.03 | 5.37 |
| 8 | Block 1 | 120 | 0.2 | 0.1 | 90.89 | 196.93 | 153.73 | 6.55 |
| 9 | Block 1 | 310 | 0.3 | 0.1 | 75.02 | 57.8 | 199.63 | 6.87 |
| 10 | Block 1 | 210 | 0.2 | 0.1 | 54.99 | 96.4 | 107.61 | 6.09 |
| 11 | Block 1 | 120 | 0.1 | 0.5 | 172.45 | 146.51 | 187.5 | 5.96 |
| 12 | Block 1 | 120 | 0.1 | 0.3 | 92.6 | 117.8 | 121.38 | 5.88 |
| 13 | Block 1 | 310 | 0.1 | 0.1 | 42.54 | 133.65 | 87.13 | 5.05 |
| 14 | Block 1 | 310 | 0.1 | 0.5 | 109.69 | 135.45 | 140.91 | 5.31 |
| 15 | Block 1 | 310 | 0.3 | 0.1 | 47.91 | 45.74 | 155.12 | 6.61 |
| 16 | Block 1 | 120 | 0.2 | 0.5 | 51.82 | 61.92 | 254.35 | 6.74 |
| 17 | Block 1 | 120 | 0.1 | 0.1 | 35.7 | 51.8 | 80.28 | 5.76 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 18 | Block 1 | 310 | 0.2 | 0.3 | 40.58 | 44.01 | 124.97 | 6.09 |
| 19 | Block 1 | 120 | 0.3 | 0.3 | 116.53 | 106.42 | 211.6 | 7.72 |
| 20 | Block 1 | 120 | 0.3 | 0.1 | 77.46 | 134.53 | 164.2 | 7.59 |
| 21 | Block 1 | 210 | 0.1 | 0.3 | 42.54 | 106.72 | 90.98 | 5.7 |
| 22 | Block 1 | 210 | 0.1 | 0.5 | 51.57 | 68.56 | 105.16 | 5.77 |
| 23 | Block 1 | 120 | 0.2 | 0.3 | 96.5 | 254.69 | 219.41 | 6.67 |
| 24 | Block 1 | 310 | 0.2 | 0.5 | 59.14 | 54.5 | 140.43 | 6.16 |
| 25 | Block 1 | 310 | 0.2 | 0.1 | 58.9 | 46.34 | 122.52 | 5.9 |
| 26 | Block 1 | 210 | 0.3 | 0.5 | 84.78 | 60.67 | 213.32 | 7.13 |
| 27 | Block 1 | 310 | 0.3 | 0.3 | 51.08 | 59.78 | 151.97 | 6.74 |

## 5. Results and Discussion:

Table-5 presents experimental results of cutting force components (Fx, Fy and Fz) for various combinations of cutting regime parameters (cutting speed, feed rate and depth of cut) according to 3^3 full factorial design. The results indicate that the lower cutting forces were registered at the higher cutting speeds. This can be related to the temperature increase in cutting zone and leads to the drop of the workpiece yield strength and chip thickness. The results also show that cutting forces increase with increasing feed rate and depth of cut because chip thickness becomes significant what causes the growth of the volume of deformed metal.

**5.1 Analysis of Fx :-_**The results of analysis of variance (ANOVA) for axial force Fx are shown in table 6 This table also shows the degrees of freedom (df), F-values means ratio of variance and probability (P-VAL.) each factor and different interactions . A low P-value (≤0.05) indicates statistical significance for the source on the corresponding response (i.e., $\alpha = 0.05$, or 95% confidence level), this indicates that the obtained models are considered to be statistically significant, which is desirable; as it demonstrates that the terms in the model have a significant effect on the response. The other important coefficient, R-Squared, which is called coefficient of determination in the resulting ANOVA tables, is defined as the ratio of the explained variation to the total variation and is a measure of the fit degree. When R-Squared approaches to unity, it indicates a good correlation between the experimental and the predicted values.

The analysis of variance of first order model is shown in table 6 The "Model F-value" of 1.29 implies the model is not significant relative to the noise. There is a30.56 % chance that a "Model F-value" this large could occur due to noise.For the linear model, the p-value for lack of fit is 0.42 (>0.05) is not significant with the lack of fit and the f-statistic is 3.01 (>0.05).This implies that the model could fit and it is adequate Non-significant lack of fit is good we want the model to fit.This result shows that depth of cut has the most significant effect on the cutting force, followed by cutting speed and feed rate. A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model. To understand the hard turning process in terms of axial force Fx, mathematical model was developed using Classical sum of squares mathod. However, this model is built using only the main cutting variables (cutting speed, feed rate and depth of cut) and their significant interactions. Fx model is given by equation (1).

.Table-6 variance table of Fx

| | SS | DF | MS | F-V | P-V Prob>F |
|---|---|---|---|---|---|
| Model | 8297.66 | 6 | 1382.94 | 1.29 | 0.3056 |
| A-V | 2320.23 | 2 | 1160.12 | 1.08 | 0.3574 |
| B-F | 23.60 | 2 | 11.80 | 0.011 | 0.9890 |
| C-D | 5472.17 | 2 | 2736.08 | 2.56 | 0.1027 |
| Residual | 21411.38 | 20 | 1070.57 | | |
| Lack of Fit | 21043.91 | 19 | 1107.57 | 3.01 | 0.4286 |
| Pure Error | 367.48 | 1 | 367.48 | | |
| Cor Total | 29709.04 | 26 | | | |
| Std. Dev<br>R-Squared | 32.72<br>0.2793 | | | | |

Final Equation in Terms of Coded Factors:

$$Fx = +75.77 + 13.14 \times V[1] - 6.35 \times V[2] + 0.41 \times F[1] - 1.30 \times V[2] - 19.85 \times D[1] + 10.50 \times D[2] \quad (1)$$

**Effect graphs of the main cutting regime on Fx:**

Fig.6,7,8 gives the main factor plots for Fx. Axial force Fx appears to be a decreasing function of Vc. This figure also indicates that Fx is an almost linear increasing function of d. But the feed rate f has a little effect on Fx.

**Normal Probability Residuals plot-:** Normal probability plot of the studentized residuals to check for normality of residuals. Studentized residuals versus predicted values to check for constant error.shown in fig.9 .

**3d Surface plots of Fx:**

3d Surface plots of Fx vs. different combinations of cutting regime elements are shown in fig.10.These figures were obtained using Design Expert software according to their mathematical models

.

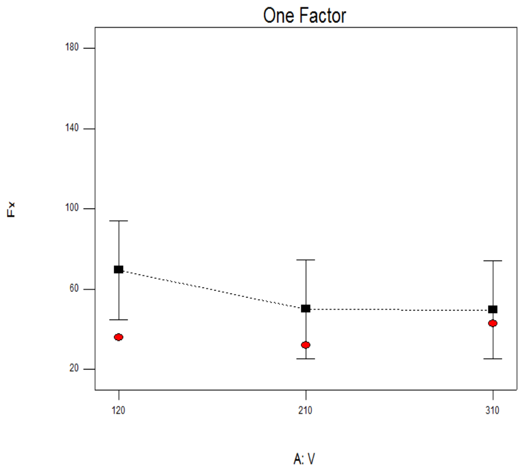



Fig.6Normal plot of Fx effect factor V

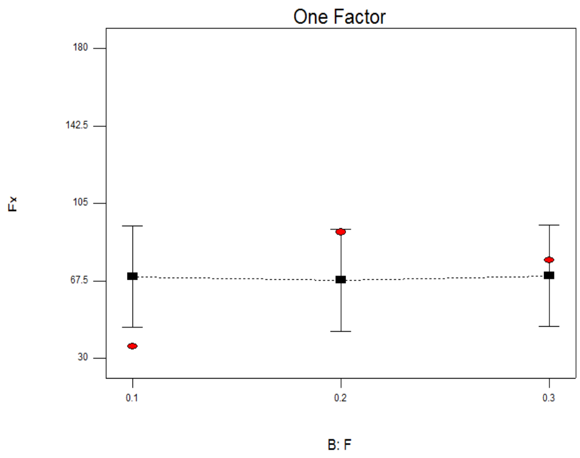



Fig.7Normal plot of Fx effect factor F

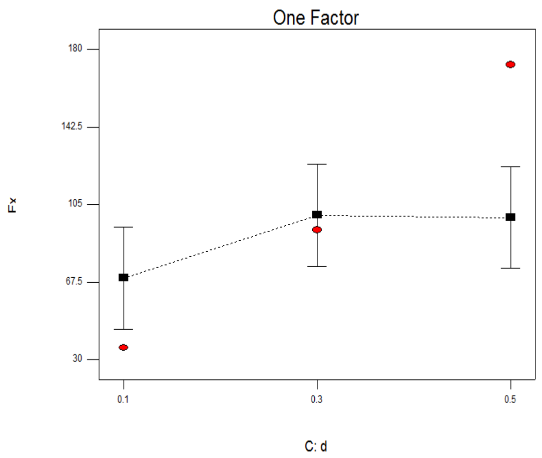



Fig.8Normal plot of Fx effect factor D

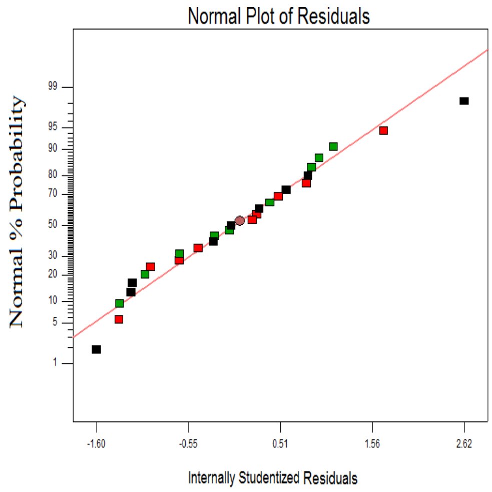



Fig.9 Plots of Residual of Fx

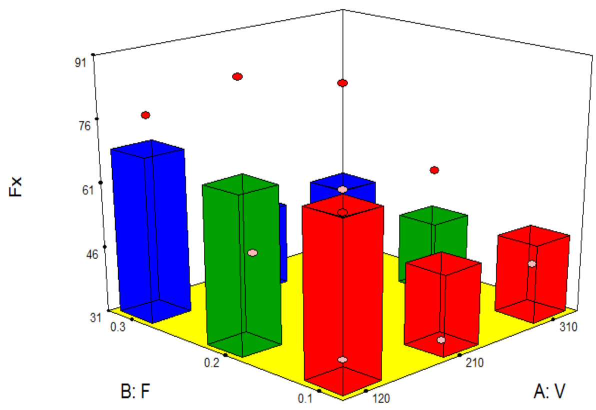



Fig.10 3D Solid plots of Fx

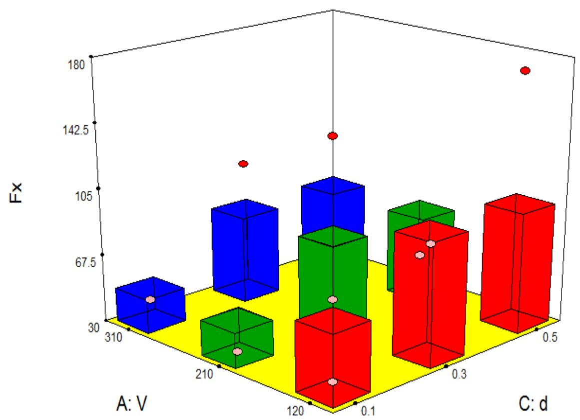



Fig.11 3D Solid plots Fx

### 5.2 Analysis of Fy

Table -7 Analysis of variance table for Fy

| Source | SS | df | MS | F Value | P-Value Prob>F |
|---|---|---|---|---|---|
| Model | 18965.87 | 6 | 3160.98 | 1.23 | 0.3319 |
| A-V | 14155.05 | 2 | 7077.53 | 2.76 | 0.0875 |
| B-F | 1049.48 | 2 | 524.74 | 0.20 | 0.8168 |
| C-D | 4603.68 | 2 | 2301.84 | 0.90 | 0.4236 |
| Residual | 51326.30 | 20 | 2566.32 | | |
| Lack of Fit | 51253.58 | 19 | 2697.56 | 37.09 | 0.1287 |
| Pure Error | 72.72 | 1 | 72.72 | | |
| Cor Total | 70292.17 | 26 | | | |

The analysis of variance of second order model is shown in table 7 The "Model F-value" of 1.23 implies the model is not significant relative to the noise. There is a33.19 % chance that a "Model F-value" this large could occur due to noise.For the linear model, the p-value for lack of fit is 0.129 (>0.05) is not significant with the lack of fit and the f-statistic is 37.09 (>0.05).This implies that the model could fit and it is adequate Non-significant lack of fit is good we want the model to fit.This result shows that cutting speed has the most significant effect on the cutting force, followed by feed rate and depth of cut .The second response model is more precise than first order model, because

the predicted result is much more accurate than the first response model.

To understand the hard turning process in terms of axial force Fy, mathematical model was developed using Classical sum of squares method. However, this model is built using only the main cutting variables (cutting speed, feed rate and depth of cut) and their significant interactions. Fx model is given by equation (2).

$$Fy = +94.95 + 30.82\times V[1] - 6.37 \times V[2] + 3.11 \times F[1] + 5.66\times F[2] - 0.64\times D[1] + 16.83\times D[2]$$

**Effect graphs of the main cutting regime on Fy**

Figure 13,14&15 shows the main factor plots for Fy. Radial force Fy appears to be a decreasing function of Vc. This figure also indicates that Fr is an almost increasing function of d. But feed rate f has a little effect on Fr.

**3D Surface plots of Fy**

Figures12 are Normal probability plot of the studentized residuals ,and 16&17 illustrate 3D surface plots of Fy. These figures were drawn according to their mathematical models and using Full factorial methodology.

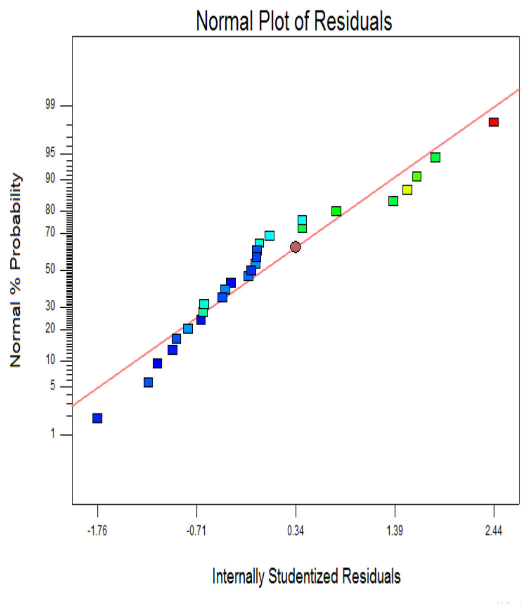



Fig.12 Plots of residual of Fy

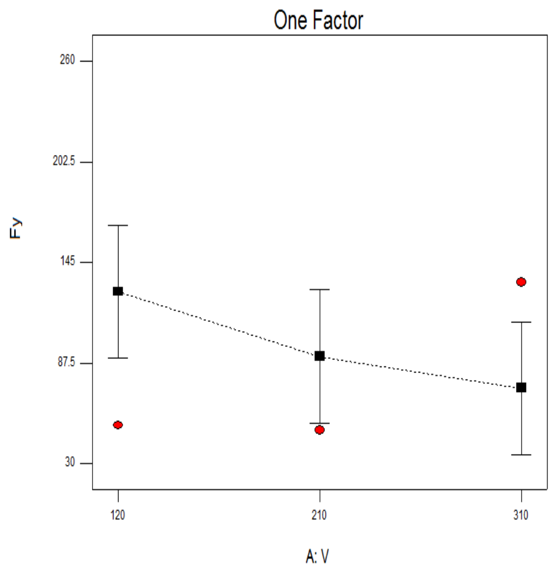
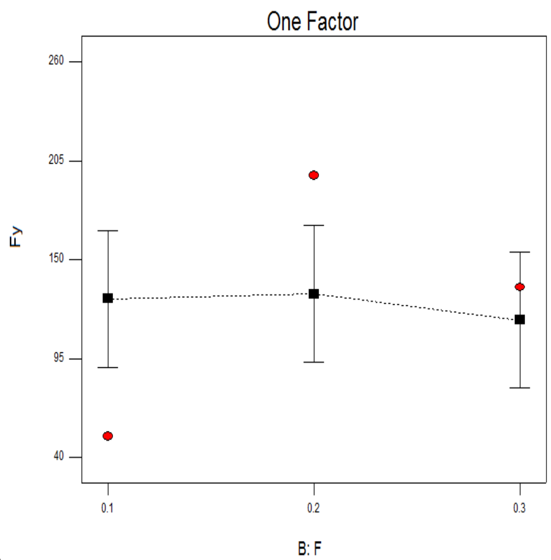



Fig.13 Normal plot of Fx effect factor V




\

Fig.14 Normal plot of Fx effect factor F

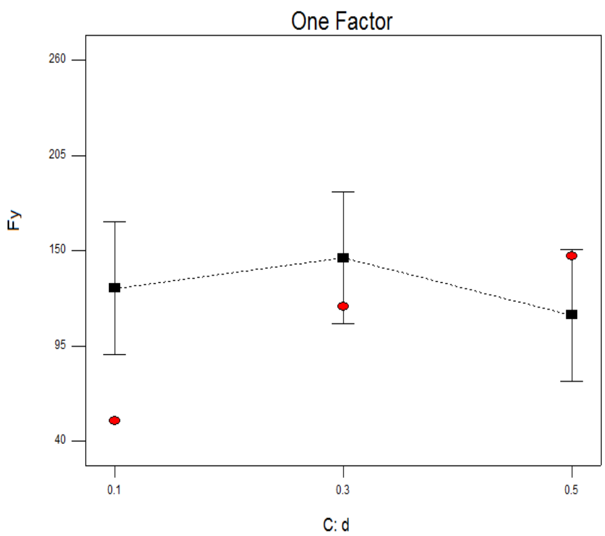



Fig.15 Normal plot of Fx effect factor D

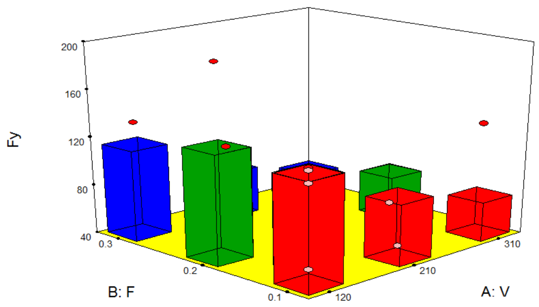



Fig.16. 3D solid plots of Fy

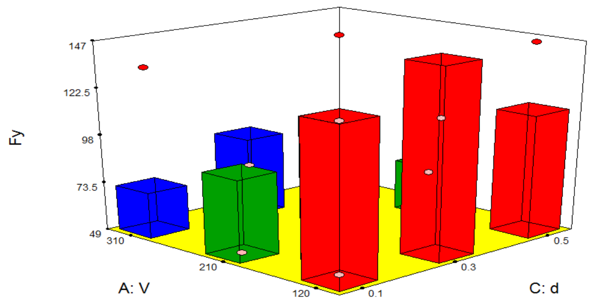



Fig.17. 3D solid plots of Fy

## Analysis of Fz

Table -8 Analysis of variance table for

| Source | SS | df | MS | F Value | P-Value Prob>F |
|---|---|---|---|---|---|
| Model | 41236.60 | 6 | 6872.75 | 7.31 | 0.0003 |
| A-V | 5865.48 | 2 | 2932.74 | 3.12 | 0.0661 |
| B-F | 22843.95 | 2 | 11421.97 | 12.15 | 0.0004 |
| C-D | 14598.92 | 2 | 7299.46 | 7.77 | 0.0032 |
| Residual | 18796.79 | 20 | 939.84 | | |
| Lack of Fit | 17806.22 | 19 | 937.17 | 0.95 | 0.6832 |
| Pure Error | 990.57 | 1 | 990.57 | | |
| Cor Total | 60033.29 | 26 | | | |
| Std. Dev. 30.66<br>R-Squared 68.69% | | | | | |

The analysis of variance of response Fz model is shown in table-8.The Model F-value of 7.31 implies the model is significant. There is only a 0.03% chance that a "Model F-Value" this large could occur due to noise.Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B, C are significant model terms.The "Lack of Fit F-value" of 0.95 implies the Lack of Fit is not significant relative to the pure error. There is a 68.32% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

This model can be used to navigate the design. It can be noted that the feed is the dominant factor affecting tangential cutting force Fz The second fac- tor influencing Fz is depth of cut For cutting speed, its effect is less significant Fz model is given by equation (3)

$$Fz = +154.86 + 20.32 \times V[1] - 14.25 \times V[2] - 39.36 \times F[1] + 8.77 \times F[2] - 31.33 \times D[1] + 6.29 \times D[2]]$$

**Effect graphs of the main cutting regime on Fz**

Figure19,20 & 21 highlights the main factor plots for Fz. Tangential cutting force Fz appears to be an almost decreasing function of Vc. This figure also indicates that Ft is an almost linear increasing function of f and d respectively.

**3D Surface plots for Fz**

Figures18 are Normal probability plot of the studentized residuals .Figures 22 and 23 show 3D surface plots for Fz. These figures were obtained by response surface methodology for different combinations of cutting regime elements according to their mathematical models.

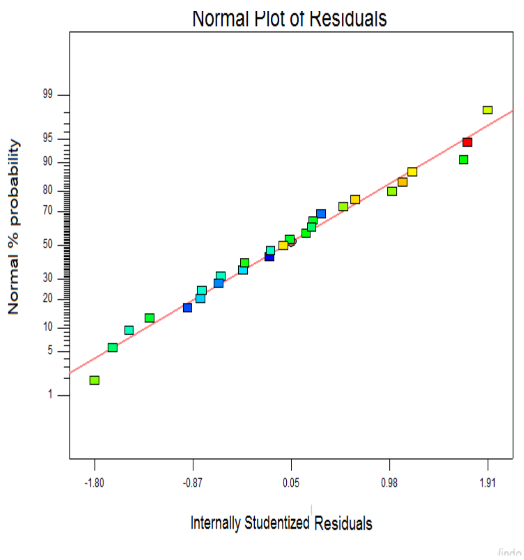



Fig.18.Normal Residual Plots of Fy

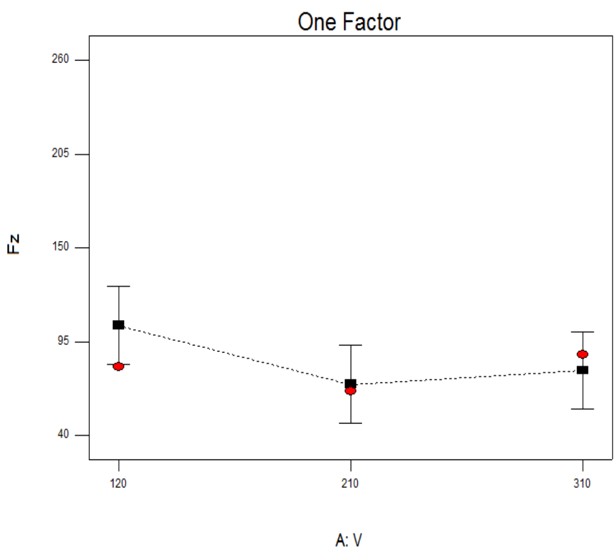



Fig.19 Normal plot of Fz effect factor V

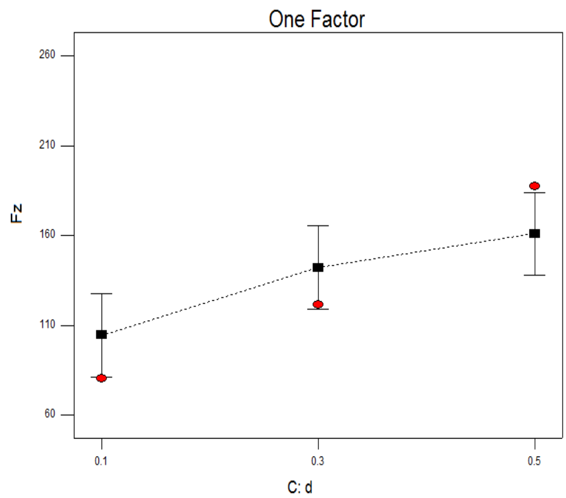



Fig.20 Normal plot of Fz effect factor D

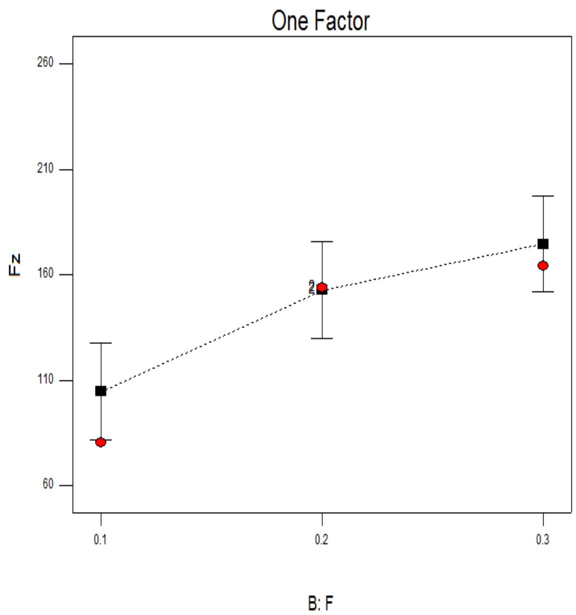



Fig.21 Normal plot of Fz effect factor F

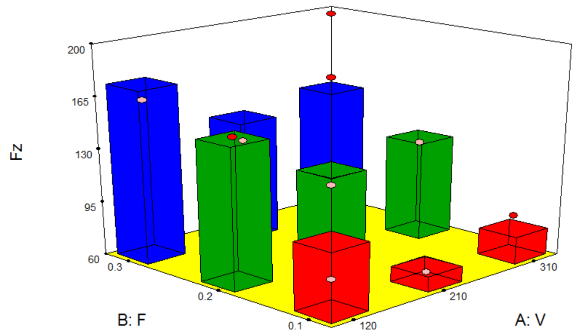



Fig.22. 3D solid plot of Fz

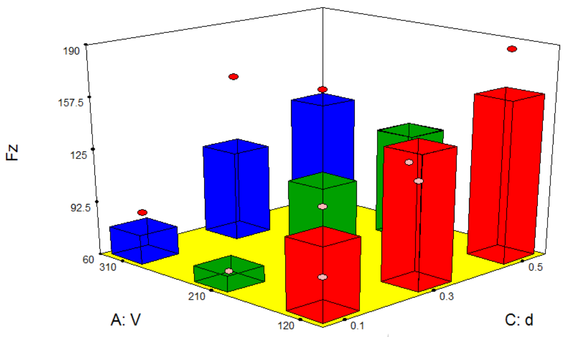



Fig.23. 3D solid plot of Fz

**Analysis of MRR**

Table -9 Analysis of variance table

| Source | SS | df | MS | F Value | P-Value Prob>F |
|---|---|---|---|---|---|
| Model | 10.34 | 6 | 1.72 | 20.88 | <0.0001 |
| A-V | 1.42 | 2 | 0.71 | 8.61 | 0.0020 |
| B-F | 8.73 | 2 | 4.36 | 52.91 | <0.0001 |
| C-D | 0.11 | 2 | 0.054 | 0.66 | 0.5293 |
| Residual | 1.65 | 20 | 0.083 | | |
| Lack of Fit | 1.62 | 19 | 0.85 | 2.52 | 0.4640 |
| Pure Error | 0.034 | 1 | 0.034 | | |
| Cor Total | 11.99 | 26 | | | |
| St. Dev. 0.29 | | R-Squared | | 86.24% | |

ANOVA results for MRR are indicated in table-9 .The Model F-value of 20.88 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant.In this case A, B are significant model terms. The "Lack of Fit F-value" of 2.52 implies the Lack of Fit is not significant relative to the pure error. There is a 46.40% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fitThe "Pred R-Squared" of 0.7398 is in reasonable agreement with the "Adj R-Squared" of 0.8211."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 14.461 indicates an adequate signal. This model can be used to navigate the design space. It can be noted that the feed is the dom inant factor affecting MRR. The second fac tor influencing MRR is cutting speed For deapth of cut, its effect is less significant.
MRR model is given by equation (3)

MRR =+6.28 +0.29×V[1]-0.010×V[2]-0.72×F[1]+0.041×F[2]-0.068
* C[1]+0.082 * C[4]

**Effect graphs of the MRR**

Fig. 24, 25, &26 highlights the main factor plots for MRR. MRR appears to be an almost linear decreasing function of Vc. This figure also indicates that MRR is an almost linear increasing function of f and d respectively.

**3D Surface plots for Ft**

Fig. 27 are Normal probability plot of the studentized residuals and, 28 & 29 show 3D surface plots for Fz. These figures were obtained by Full factoria methodology for different combinations of cutting regime elements according to their mathematical models.

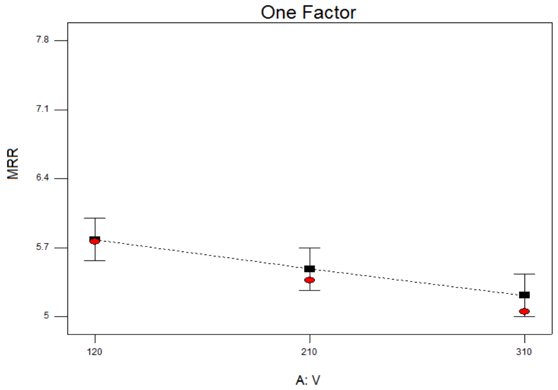



Fig.24 Normal plot of MRR effect factor V

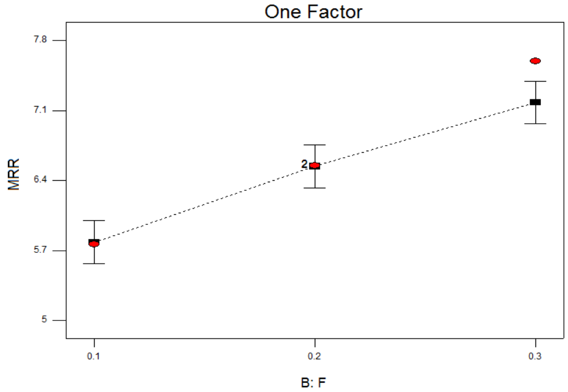



Fig.25 Normal plot of MRR effect factor F

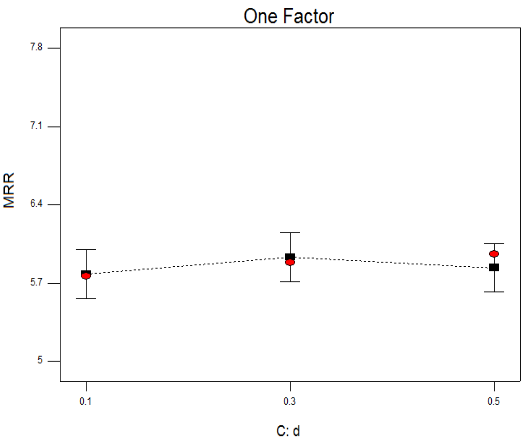



Fig.26 Normal plot of MRR effect factor D

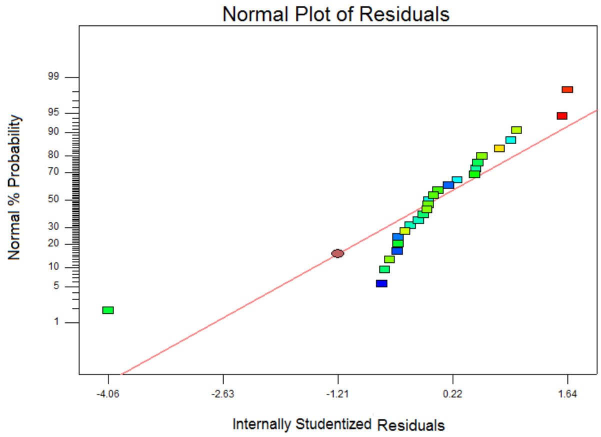



Fig.27 Plot of Residual of MRR

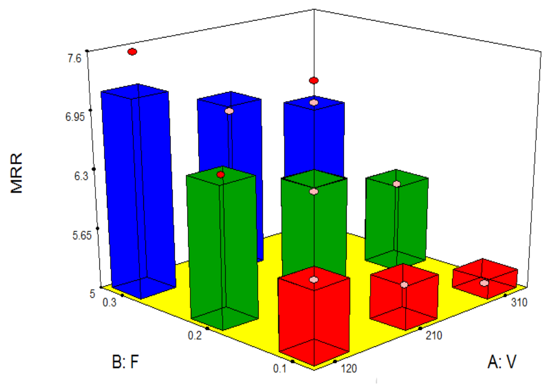



Fig.28 .3D solid plot of MRR

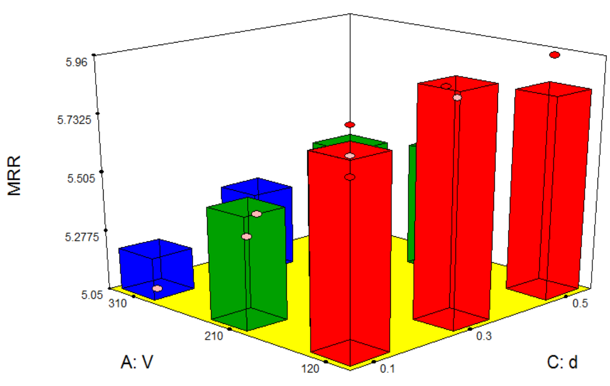



Fig.29 .3D solid plot of MRR

**6. Conclusion:**

Based on the experimental results, the following conclusions can be drawn:

1) Full Factorial Design method is found to be a successful technique to perform trend analysis of Cutting Force and MRR in metal cutting with respect to various combinations of design variables (metal cutting speed, feed rate, and depth of cut ).

2) 3rd Response model for Fz is more precise than first Response model for Fx and second Response model for Fy in predicting the power consumption and significant during machining

(i) The depth of cut influences cutting forces in a considerable way. Its contributions on Fx, Fy and fz are in F value 2.56, 0.90 and 7.77 respectively.

(ii) The second factor affecting cutting force is cutting speed . Its contributions on Fx, Fy and Fz are in F value is 1.08; 2.76 and 3.12%. For Feed rate, its effect is less important.

(iii) This study reveals that in dry hard turning of this steel and for all cutting conditions tested, the principal force is not always the radial force. the tangential cutting force becomes the major force followed by radial and axial forces.

(iv) Statistical models deduced defined the degree of influence of each cutting regime element on cutting force components. They can also be used for optimization of the hard cutting process.

(v) Thus, to get good machining system stability, we must use the highest level of cutting speed, 310 m/min, the lowest level of feed rate, 0.1 mm/rev and the lowest level of depth of cut, 0.1 mm.

**7.References:**

[1] Lalwani D.I., Mehta N.K., Jain P.K., Experimental Investigations of Cutting Parameters

[2] Influence on Cutting Forces and Surface Roughness in Finish Hard Turning of MDN250 Steel, Journal of Material Processing Technology , 206(1-3) , 167-179 (2007).

[3] Aruna M.Dhanalakshmi response surface methodology in finish turning INCONEL718, International Journal of Engineering Science and Technology , 2(9) , 4292-4297, (2010)

[4] Fnides B, Yallese M A, Aouici H 2008 Hard turning of hot work steel AISI H11: Evaluation of cutting pressures, resulting force and temperature. Mechanika. Kaunas: Technological, Nr. 3(77): 68–73

[5] Trent E M metal cutting 2nd edition Butterworth's & Co. London, UK, limited, ISBN 0-408- 34-38, (1984).

[6] Nagpal G.R. Machine Tool Engineering Khanna Publishers , New Delhi ,68-71 (1986).

[7] Kalpakjain S. Manufacturing Engineering and Tecnology, $th Eition.(2000).

[8] A.Devilleza,F.Schneider a, S. DOminiaka, D.Duzinskia,D.Larrouquereb, "Cutting Forces

and wear in dry maching of Inconel 718 with coated carbide tools" wear (2007).

[9] Bouacha K., Yallese M.A. Mabrouki T, Rigal J-F 2010 Statistical analysis of surface roughness and cutting forces using response surface methodology in hard turning of AISI 52100 bearing steel with CBN tool. Int. J. Refractory Metals and Hard Materials 28: 349–361.

[10]. Smith, G. T., "Advanced Machining: The Handbook of Cutting Technology", IFS Publications, 1989.

[11]. Soderberg, S. Sjostrand, M., Ljungberg, B., Advances in coating technology for metal cutting tools, Metal Powder Report 56 (2001) 24-30.

[12]Marandet B., Verquin B., Saint-Chely J., Anderson C. and Ryckeboer M., http://aluminium.matter.org.uk (last accessed on 24th June 2011), (2011) .

[13]Bradley C., Automated Surface Roughness Measurement, International Journal of Advanced Manufacturing Technology , 16(9) , 668-674 (2000).

[14]Kumar P., Singh N. and Goel P., A multi-objective framework for design of vacuum-sealed molding process, Robotics and Computer Integrated Manufacturing , 15(5) , 413-432 (1999)

[15]Xie L.J., Schmidt J., Schmidt C. and Biesinger F., 2D FEM estimate of tool wear in turning operation, Wear , 258(10) , 1479-1450 (2005)

[16]Oishi K., Built-up edge elimination in mirror cutting of hardened steel, International Journal of Machine Tools Manufacture , 39 , 885-903 (1995)

[17]Yang W. and Tarng Y., Design optimization of cutting parameters for turning operations, Journal of Material Processing Technology , 84(1-3) , 122-129 (1998)

[18]Davim P., Influence of cutting parameters of surface finish obtained by turning, M.Sc. Thesis, University of Porto, Porto, 10-128 (1990)

[19]Lu C., Ma N., Chen Z. and Costes J.P., Pre-evaluation on surface profile in turning process based on cutting parameters, International Journal of Advanced Manufacturing Technology, 49(5-8) , 447-458 (2010)

[20]Montgomery D.C., Design and Analysis of Experiments, 5th ed. John Wiley and Sons Inc., (2001)