EXPERIMENTAL INVESTIGATION OF TURNING OF AUSTENITIC STEEL

A Thesis submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY
In
MECHANICAL ENGINEERING
By
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Under the guidance of
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ROURKELA

CERTIFICATE

This is to certify that the thesis entitled "**Experimental investigation of turning of Austenitic Steel**", submitted by **Binaya Kumar Sahu** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Mechanical Engineering** during session 2014-2015 at National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance. The candidate has fulfilled all the prescribed requirements.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma. In my opinion, the thesis is of the standard required for the award of a bachelor of technology degree in Mechanical Engineering.

Place: Rourkela
Date:

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ABSTRACT

In this work, turning of Austenitic Stainless steel of grade AISI 202 using an uncoated carbide insert tool was done at specific input values of speed, feed and depth of cut. At first, we determine how the outputs like cutting force, surface roughness and the tool wear are related to the input parameters. At first the layout of the experiment was made using full factorial composite design. Then the experiment was conducted. First the cutting power is measured using the power meter and from the calculated power and cutting speed, the cutting force is determined. The surface roughness is measured using Talysurf profilometer by taking average of 3 readings in each region. Then the tool ware is measured by Toolmaker's optical microscope. We used Response surface method for the determination of the change of outputs with inputs plotting different graphs, contours and 3-D surface plots. We can easily determine the effects by visualizing the main effect plots and interaction plots also. Then using Analysis of variance (ANOVA), the most effective parameter for the output was determined. Then the mathematical model or the regression equation was made taking results from the regression coefficient table. From result, we can see that the most significant factor affecting the cutting force is cutting speed, feed for surface roughness and depth of cut for tool wear.

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Turning is a basic metal machining process in which a non rotary tool is used while the work-piece rotates. The term "turning" represents the generation of external surfaces by this cutting action, whereas this same cutting action when applied to internal surfaces is called "boring". Turning operation can be done manually in traditional lathe or using automated lathe like CNC. The conventional lathe operation requires continuous and frequent supervision of the operator, but automated lathe does not.

In turning process, we require certain minimum limit of performance, may it be related to quality, quantity, ease of production, cost etc. Selection of machining parameters has very much influence in the smooth and effective performance of the process. Mainly parameters like cutting speed, feed, and depth of cut have significance effect on surface roughness, cutting force, tool wear, tool life, material removal rate, power consumption and production rate etc.

Now a days, there is very much necessity of energy efficient processes due to scarcity of sources of fuel and environmental issues. Hence low power consumption is an important aspect of turning our cutting operation. As power consumption is directly related with cutting force, minimizing cutting force will decrease the power consumption. It also directly affects the tool work piece deflection.

Increasing demand of high precision and quality product has made surface roughness an important parameter in manufacturing. The surface characteristics have significant effect on properties like fatigue strength, corrosion resistance, creep life and also on surface friction, lubricant holding capacity, light reflection capacity, load bearing capacity. So, according to application the surface finish should be specified and accordingly process parameter should be chosen.

Tool wear is always attached with turning operation as there is continuous rubbing between tool and work piece. Production cost, tool life and quality of product are greatly influenced by the wear. Tool wear depends on the material property of tool as well as the cutting parameters.

1.2: OBJECTIVES OF PRESENT WORK

Cutting force, surface roughness and tool wear have very significance role in manufacturing processes. Hence, minimizing all these, will have positive impact on product quality and cost of production. We have taken cutting speed, feed and depth of cut as input parameters.

i) To determine the effect of input machining parameters on the cutting force

ii) To determine the effect of input on the surface roughness of machined work piece.

iii) To determine the effect of input parameters on the tool wear.

iv) To optimize machining parameter so as to minimize the cutting force, surface roughness and tool wear using Response surface methodology.

CHAPTER 2: LITERATURE REVIEW

This chapter covers review of various research papers containing various information and theory, different optimization techniques related to the turning operation.

Turning is a basic material removal process in which a single point cutting tool having hardness greater than the work piece is fixed on the tool post and is given feed to move along a rotating work piece to remove material. The work piece is given cutting motion whereas tool is given feed motion. The turning operation can be done in conventional lathe which needs frequent and continuous supervision of operator or using automated lathe.

Turning can be done in dry condition or wet condition using the cutting fluid. The dry cutting is environment friendly, chips can be easily collected and disposed in this case, but as there is constant interaction between tool and work piece, the heat generated at the tool tip is very high. So, it may lead to crater wear or thermal crack resulting poor performance of tool and poor quality of product. The use of cutting fluid actively reduces the temperature at the tool work piece interface by absorbing and carrying out large amount of heat generated. So, it has significant effect on reducing surface roughness and tool wear. Also, machining at increased speed can be easily done by the use of cutting fluid.

The type of cutting tool has also large impact on the machining process and the result. Due to the high hardness of work piece, the tool has to withstand a large amount force without mechanical breakage and deflection. There are uncoated carbide tool and also coated ones. Generally, coated carbide tools have high force withstand capacity with less tool wear.

D. Singh and P.V. Rao [1] had done study in this field taking bearing steel (AISI 52100) as specimen and mixed ceramic insert as the tool. They investigate the effect of cutting condition on surface roughness. They concluded that surface roughness is significantly affected by feed, nose radius and cutting velocity.

Yang and Tarng (1998) [2] did the designing and optimization of Surface quality. They applied Taguchi method and used the signal-to-noise (S/N) ratio and ANOVA for the significance and influence of cutting parameters.

Tugrul O zel et all [3] have studied about dependence of surface roughness and resultant forces on feed, cutting speed, cutting edge geometry and hardness of work piece. In this investigation ANOVA is applied taking four factors 2 level fractional factorial. In the experiment all the three components of forces and also surface roughness were measured. This experiment shows the influential factors on surface roughness are cutting edge geometry, feed, cutting speed and hardness of work piece.

Neseli et. al [4] studied taking input as nose radius, rake angle and approach angle and observed that the most significant parameter affecting surface roughness is nose radius.

Nanavati and Makadia[5] did the experiment and optimize the result using RSM method to show the significant factors. They took feed, cutting speed and tool nose radius as variables and found that surface roughness was most affected by the feed and then by the tool nose radius.

Bouacha [6] experimented and observed that feed has much influence on surface finish of material than the cutting speed.

Halim [7] observed that the tool wear is much affected by the depth of cut than other variables. Other input parameters have less significant effect on tool wear.

Dr. G. Hrinath Gowd et al experimented on 3 components of forces and Ra and made mathematical model for them. After experiment, using RSM it was found speed, feed and depth of cut significantly affect feed force, cutting force and thrust force and also surface roughness.

K. Adarsh kumar et all [8] used cemented carbide tools and determine the factor affecting surface quality of EN-8. He found effect of spindle speed, feed, and depth of cut to be influencing roughness. Then he determine the relation between all the input parameters and surface roughness.

Sikdar and Chen, (2002) worked on correlating cutting forces and the 3-d flank wear surfaces in turning operation. They concluded that flank wear area has direct influence on cutting forces. Cutting force increases with the increase in surface area of the wear.

Choudhury and Srinivas (2004)[9] showed that cutting speed and index of diffusion coefficient have much influence on tool wear. Then the next influential parameter is the depth of cut. He made a mathematical model to emphasize his point.

Kishore and Choudhury (2000) did research on the forces and the height of the flank wear. They calculate the proportion of the feed force and cutting force and correlate it with the heights of flank wear. He found that cutting speed is most influential for the flank wear whereas feed, doc have linear effect on it.

Y. Agrawalla[10] investigated the effect of cutting parameters i.e. speed, feed and doc on the surface roughness and the tool wear. Then he optimized the result using RSM method. His result shows that feed is most significant factor affecting surface roughness followed by doc, whereas doc is main factor affecting tool wear.

CHAPTER 3: THEORITICAL STUDY

3.1: Turning operation

Turning is a basic material removal process actively used in industries. In this process, a single point cutting tool having hardness greater than the work piece is fixed on the tool post and is given feed to move along a rotating work piece to remove material. The work piece is given cutting motion whereas tool is given feed motion. The turning operation can be done in conventional lathe which needs frequent and continuous supervision of operator or using automated lathe.

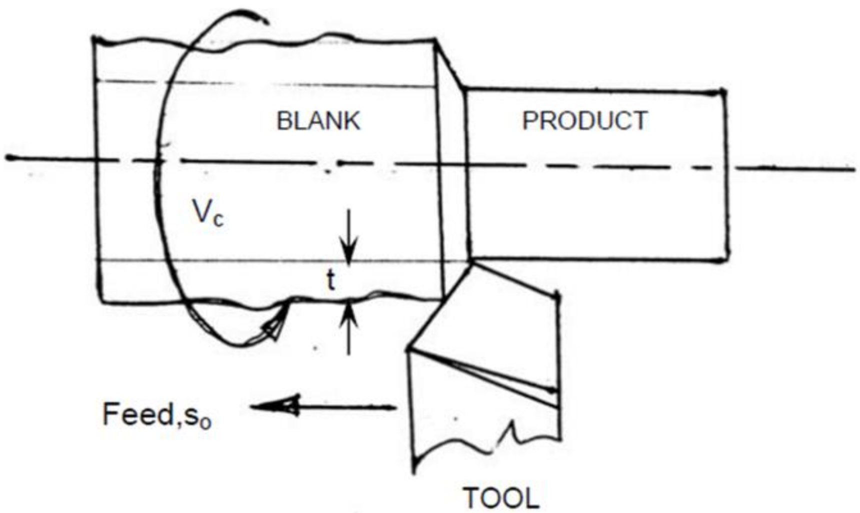


Fig 1: Turning operation [23]

3.2: Cutting tool: A single point cutting tool is used in turning process for material removal. The tool is fixed to the tool post and given feed motion (linear).

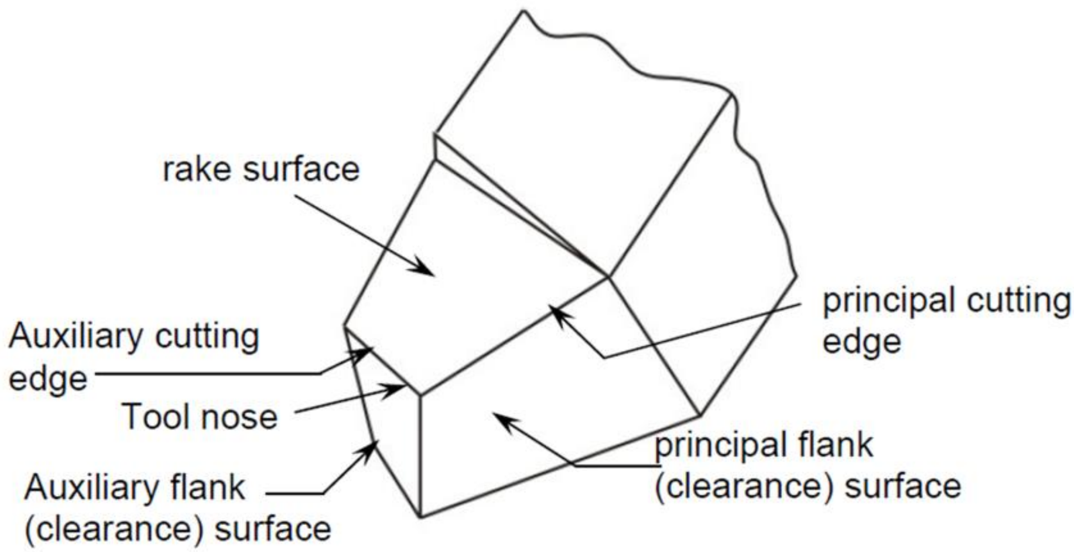


Fig 2: cutting tool nomenclature [22]

Cutting tool should be harder than work piece. It should possess enough toughness, hot hardness and wear resistance characteristics.

3.3 Cutting Tool Insert

The insert is attached/ clamped with a tool holder. Using insert is advantageous because when the cutting edge is worn after machining, instead of changing tool, we can simply rotate it to use the other fresh edge for machining. Rectangular inserts provide 8 cutting edge. The tool holder is further attached to the tool post.

Fig 3: some samples of inserts [20]

3.4: Parameters in turning

a) Cutting. Speed:

It is the tangential speed of the rotating piece. It can be defined as the rate at which surface of the work piece passes through the cutting tool. It is generally expressed in (m/ min).

$$Vc = \frac{\pi D N}{1000}$$

In the equation,

N= the spindle speed or rpm of the work piece

D = Dia. of the work piece (mm)

b) Feed:

The linear distance travelled by the tool for one revolution of the spindle or the work piece is referred as feed. It is expressed in mm/rev or sometimes in mm/min.

c) Depth of cut:

It is the distance between the cut and the uncut surface after a single run. It is the thickness of material that is removed from the specimen or reduction in thickness in single pass. If diameter of work piece before and after cut are D1 and D2, then doc is

$$d = \frac{D1 - D2}{2}$$

3.5 Cutting force

The cutting force calculation is an important parameter in designing cutting tool. The forces on the cutting tool can be resolved in to 3 components i.e. cutting force, feed force and thrust force. The cutting tool should have enough strength to withstand the forces during cutting operation.

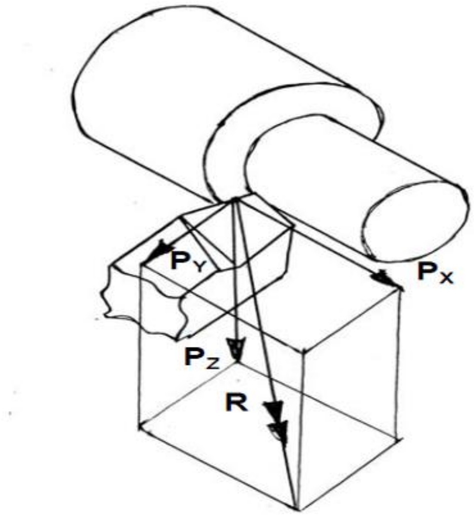


Fig 4: components of cutting force [21]

P_Z : is the tangential force or cutting force which is related to the power consumption
$P_{y:}$: is the radial or thrust force
P_X : is called the axial or feed force

3.6 Surface Roughness

Surface roughness or simply roughness is index of of the product quality or surface finish of a specimen. Surface roughness is a measurement of imperfection or irregularities or small scale variations in the height of a surface. The surface roughness is important to predict the longevity of object as the rough surface wear faster than the smooth one.

The arithmetic mean value (Ra) is the arithmetic mean of deviations of a series of points on the surface from the center line, or mean line . Surface roughness is expressed in microns (μm).

$$Ra = \frac{a + b + c + d + \cdots}{n}$$

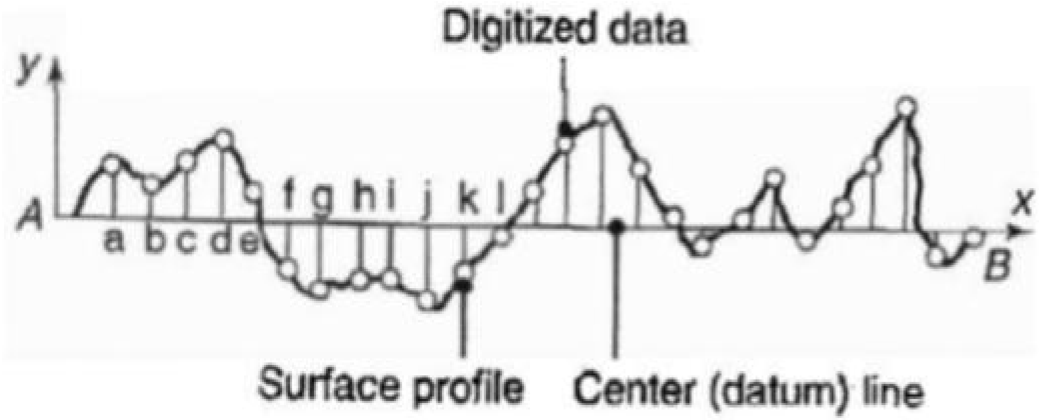


Fig 5: measurement of Surface Roughness using Equation [24]

3.7: Tool wear

In every conventional machining where there is interaction or friction between tool and work piece tool wear is present. Here, a continuous cutting force is acting on the work piece and the reaction force is imparted on the tool. The temperature at the tool/chip interface increases to a high amount because of heat released from friction and shear deformation. This elevated temperature at the tool rake face is the main cause of the wear. Tool wear in turning mainly divided into

(i) Crater wear

(ii) Flank wear

(iii) Notch wear

(iv) Thermal crack

Crater wear:

It is the erosion of the portion of tool which is in contact with the chip. The chemical interaction or diffusion is the main cause of such wear. After cutting, the chip flows across the rake surface and the friction between chip and work piece elevates the temperature. So the elevated temperature and chemical affinity between both makes the particles of rake to adhere with chip and scar is produced at the surface.

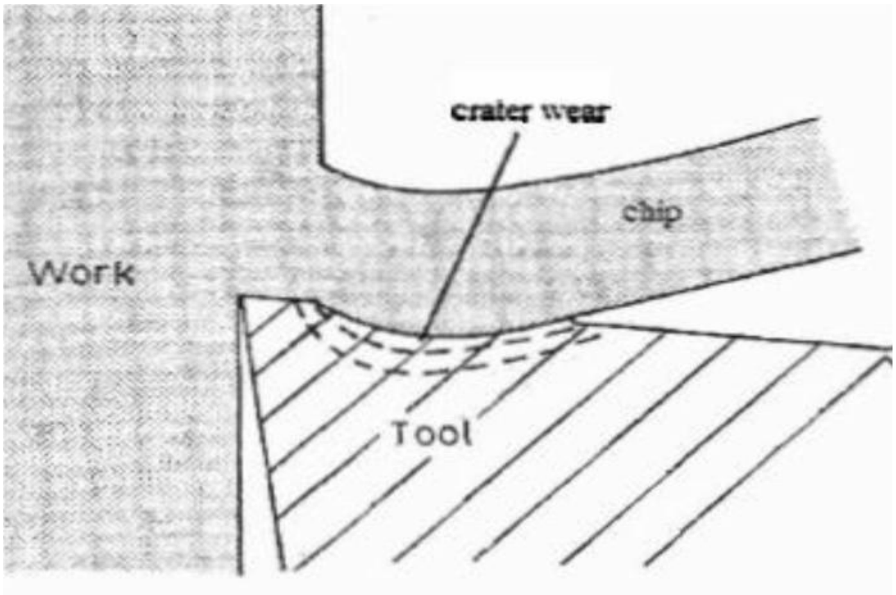


Fig 6 : crater wear [25]

Flank wear:

It is the erosion of the portion of the tool which is in contact with the finished part of the work piece. It is mainly caused by the abrasion due to hard constituents of the work piece. It occurs when the work piece is very hard and there is no chemical affinity between them.

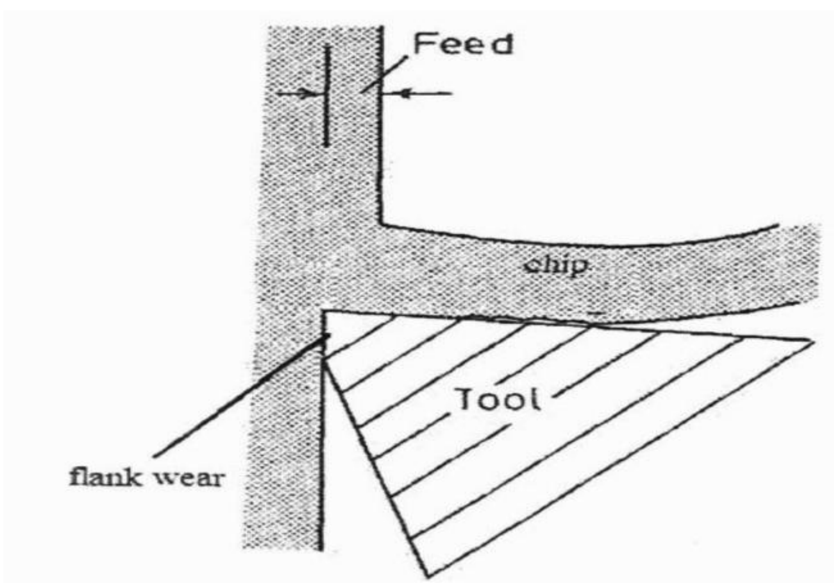


Fig 7: flank wear [25]

3.8 DESIGN OF EXPERIMENTS

The word: experiment, here, means, in a precise sense, a procedure of investigation to seek the effect of variation of the variables on the desired outputs of the experiment.

Statistically designed experiments are always more informative than the way conventional engineering experiments are conducted by varying one variable at a time. Most importantly, a statistical Design of Experiment (DOE) deals with several variables simultaneously and provides a complete insight into the combined effects of the factors on the response under investigation. As it is seen that the experiments usually involve a large number of variables, a well-planned statistically designed experiment requires a less number of experiments compared to a conventional experimental approach.

Response Surface Methodology (RSM)

Response Surface Method (RSM) is a collection of mathematical and statistical techniques for empirical model building. In this method, output is referred as responses and inputs as independent variables. Experiment consists of series of tests, called runs. The RSM method is useful to determine individual effect and pairwise effects of inputs on outputs.

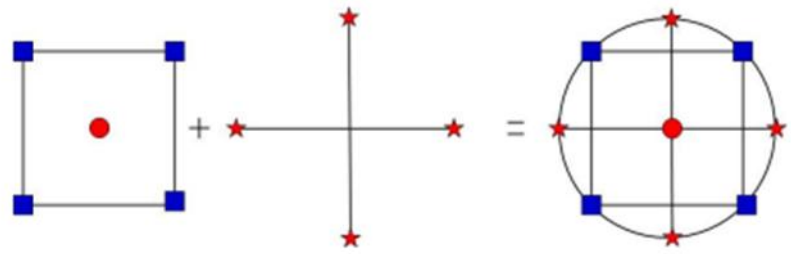
Two level full factorial design

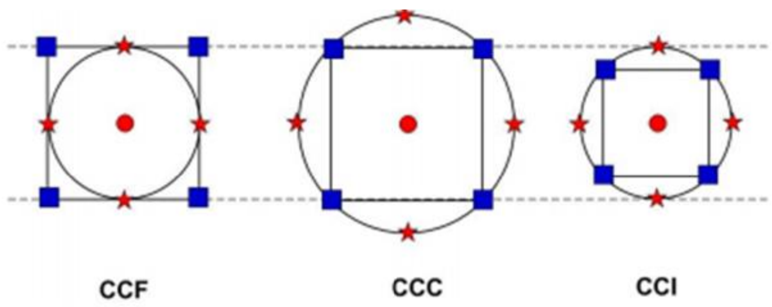
A full-factorial design of experiments can be used to develop linear relationship between input and output parameters by setting the input parameters at their lowest and highest levels. In a full-factorial experiment, complete information regarding main and interaction effects is obtained at a minimum number of experimental runs.

The effect of a factor in statistics is the change in response value, as the factor moves from a lower to a higher value. The main effect of a factor is calculated as the difference between the average response values, when the factor is set at maximum and minimum levels.

Central Composite Design

A central composite design is a design in which a groups of axial points are added that helps in estimating the curvature of response surface.





The blue points are the factorial points and reds are axial points. By superimposing both points, a CCD is developed. Followings are some types of CCD.

CCF= central composite face centered design

CCC= circumscribed central composite

CCI= central composite inscribed design

Chapter 4: MATERIALS AND METHODS

4.1 WORK-PIECE MATERIAL

Austenitic stainless steel of AISI 202 grade work piece of length 600mm and diameter 50mm is used for experiment. This steel is used in making plates, sheets and coils and finds extensive use in restaurant equipment, cooking utensils, automotive trims, architectural applications such as doors and windows in railways and cars. It has less Nickel content compared to AISI 300 series steel, hence it is less costly.

Table 1: chemical composition

Element	**Wt %**
Iron, Fe	68
Chromium	17-19
Nickel	4-6
Manganese	7.5-10
Silicon	1
Nitrogen	0.25
Carbon	0.15
Phosphorous	0.06
Sulphur	0.03

Table 2: mechanical properties

Property	Value
Tensile Strength	515 M Pa
Yield Strength	275 M Pa
Elastic Modulus	207 G Pa
Poisson's Ratio	0.27-0.30

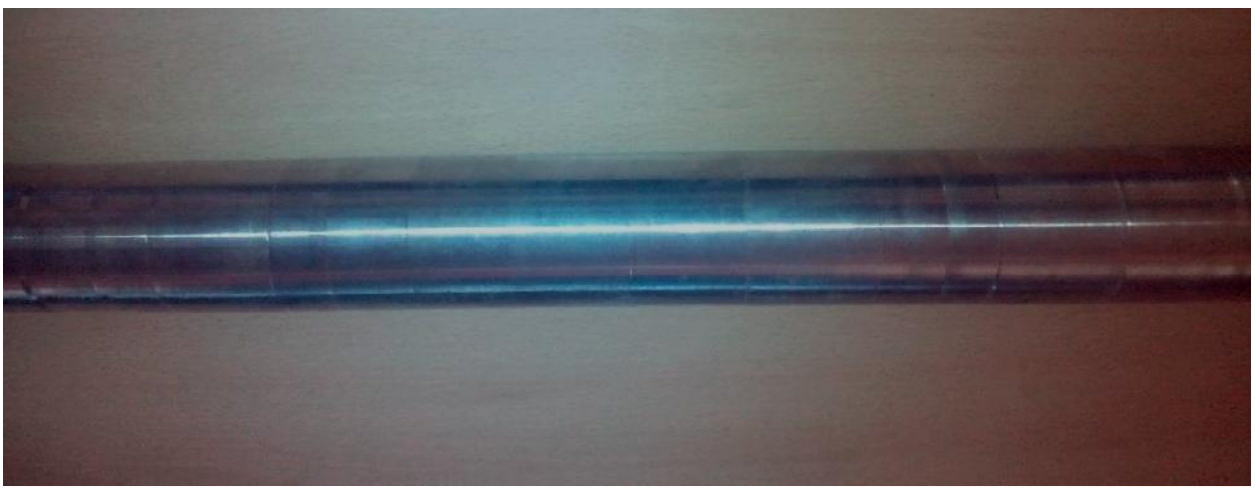


Fig 7: work piece

4.2 INSERT MATERIAL

The tool insert chosen was an uncoated carbide tool. It is SNMG 432 type of insert.

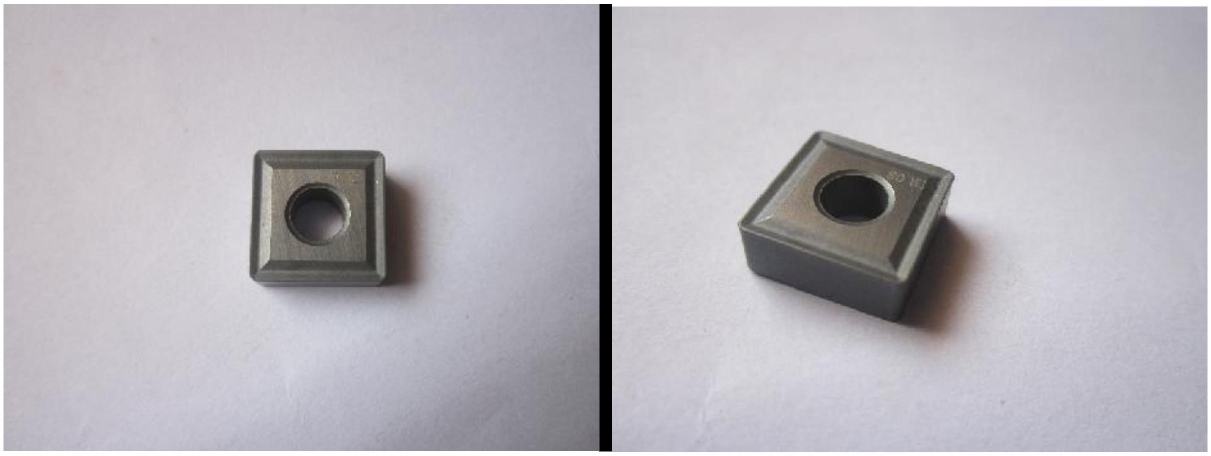


Fig 8: uncoated carbide Inserts

4.3 EXPERIMENTAL SETUP AND INITIAL PREPARATION

The experiment was conducted in center lathe in the work shop. The job was held rigidly by the 3 jaw chucks of the lathe. Centre drilling was done to hold the job rigidly in fixed position. The experiment was carried out in dry condition without using cutting fluid. Experimental set up is shown in the fig:

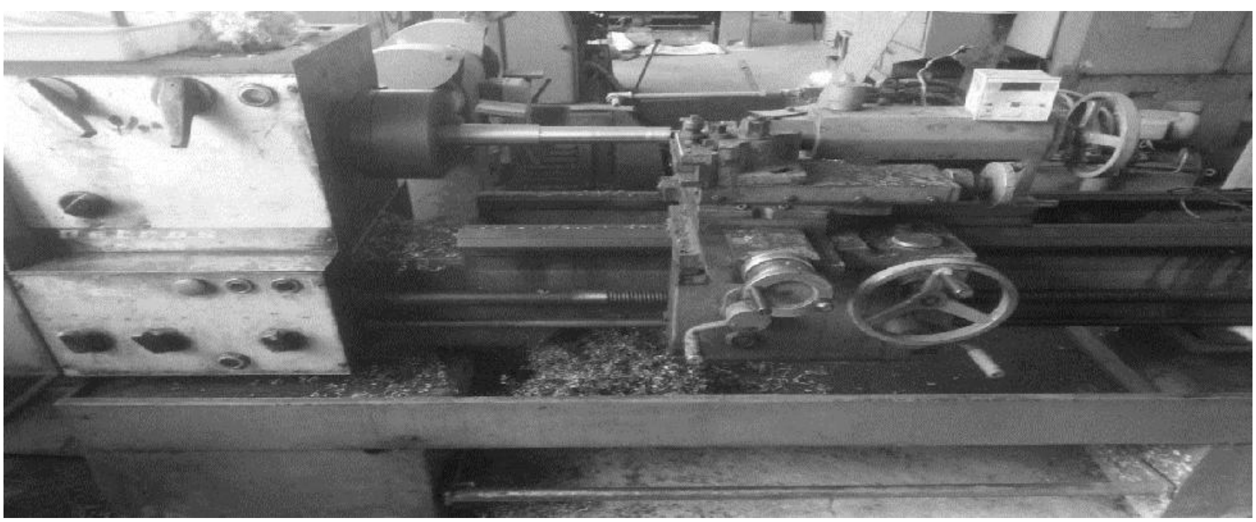


Fig 9: Experimental set up in Lathe machine

4.4. CUTTING CONDITION

Experiment was conducted in dry environment. So, no coolant or cutting fluid is used. By avoiding cutting fluid, we are able to reduce the cost.

4.5 MEASUREMENT OF SURFACE ROUGHNESS

Surface roughness was measured the help of a portable stylus-type Talysurf profilometer. For each region, three measurements were taken at different locations and the average was calculated.

Fig 10: Taylor Hobson profilometer

4.6 MEASUREMENT OF CUTTING FORCE

Cutting Force was calculated using power meter. First, power is calculate from voltage, current and power factor reading of power meter and then from power and cutting speed, cutting force was calculated.

$$P = Fc * Vc$$

Where, P= power, Fc= cutting force and Vc= cutting speed

4.7 MEASUREMENT OF TOOL WEAR

A new cutting edge was used for each run. The resulting tool wear was measured using a Tool makers optical Microscope.

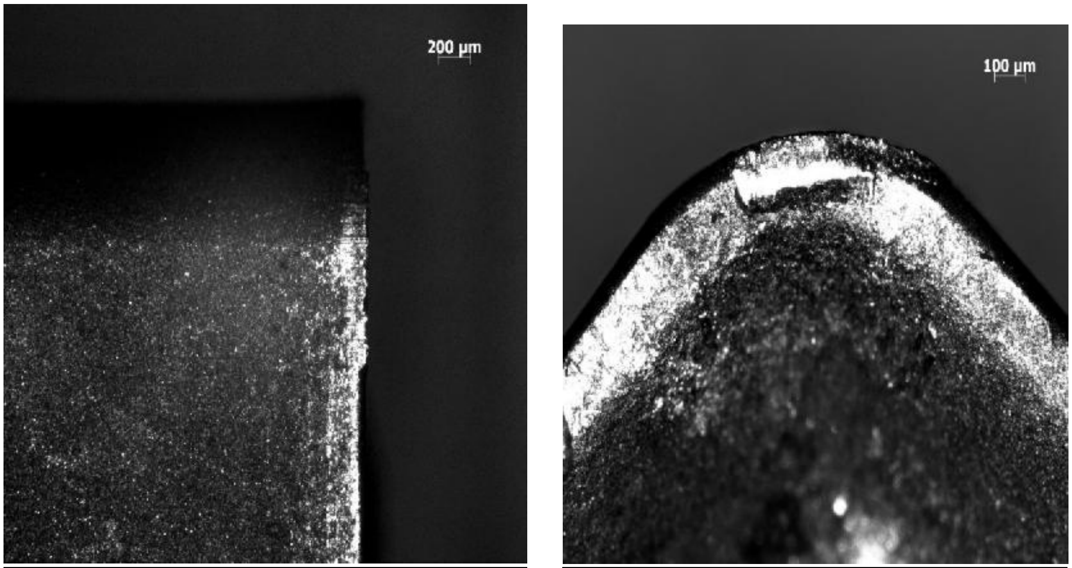


Fig 11: flank wear and crater wear

4.8 PROCESS PARAMETERS

Table 3:

Code	Parameter	Level (-1)	Level(+1)
A	Cutting speed (m/min)	14	40
B	Feed (mm/rev)	0.07	0.13
C	Depth of cut (mm)	0.5	1.0

4.9 LAYOUT OF EXPERIMENT FOR RSM METHOD

The experiment layout was obtained following the 2-level full-factorial Central Composite Design with 8 cube points, 6 axial points, 4 center points, and 2 center points in axial, resulting in a total of 20 runs.

DESIGN LAYOUT

Table 4

StdOrder	RunOrder	PtType	Blocks	Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)
1	1	1	1	14	0.07	0.50
2	2	1	1	40	0.13	0.50
3	3	1	1	40	0.07	1.00
4	4	1	1	14	0.13	1.00
5	5	0	1	27	0.10	0.75
6	6	0	1	27	0.10	0.75
7	7	1	2	40	0.07	0.50
8	8	1	2	14	0.13	0.50
9	9	1	2	14	0.07	1.00
10	10	1	2	40	0.13	1.00
11	11	0	2	27	0.10	0.75
12	12	0	2	27	0.10	0.75
13	13	-1	3	14	0.10	0.75
14	14	-1	3	40	0.10	0.75
15	15	-1	3	27	0.07	0.75
16	16	-1	3	27	0.13	0.75
17	17	-1	3	27	0.10	0.50
18	18	-1	3	27	0.10	1.00
19	19	0	3	27	0.10	0.75
20	20	0	3	27	0.10	0.75

CHAPTER 5: RESULT AND DISCUSSION

Table 5: observations

Std Order	RunOrder	speed (m/min)	Feed (mm/rev)	DoC (mm)	Fc (N)	Ra (µm)	Wear (mm)
1	1	14	0.07	0.50	1272.12	0.84	0.293
2	2	40	0.13	0.50	621.51	1.78	0.386
3	3	40	0.07	1.00	733.58	1.84	0.566
4	4	14	0.13	1.00	1484.29	2.03	0.730
5	5	27	0.10	0.75	1188.70	1.65	0.609
6	6	27	0.10	0.75	1098.40	1.48	0.462
7	7	40	0.07	0.50	659.67	0.61	0.145
8	8	14	0.13	0.50	1234.11	2.06	0.485
9	9	14	0.07	1.00	1289.60	1.32	0.538
10	10	40	0.13	1.00	899.20	1.75	1.035
11	11	27	0.10	0.75	1132.40	1.39	0.816
12	12	27	0.10	0.75	1059.70	1.43	0.771
13	13	14	0.10	0.75	1372.01	1.33	1.068
14	14	40	0.10	0.75	643.83	0.98	0.919
15	15	27	0.07	0.75	1199.59	0.85	0.505
16	16	27	0.13	0.75	1334.16	1.89	0.921
17	17	27	0.10	0.50	1055.60	1.23	0.502
18	18	27	0.10	1.00	1249.38	1.47	0.981
19	19	27	0.10	0.75	1202.20	1.37	0.811
20	20	27	0.10	0.75	1188.59	1.52	0.787

5.1 ANALYSIS OF RESULTS AND PLOTS

The experimental results were fed in to MINITAB ® 16 for further analysis.

ANOVA

ANOVA was used to study the effects of different cutting parameters i.e. speed, feed and depth of cut on the responses i.e. cutting force, surface roughness and tool wear.

Table 6.Anova for cutting force

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	2	48861	13844	6922	3.04	0.104
Regression	9	1161213	1161213	129024	56.67	0.000
Linear	3	1041130	1041130	347043	152.44	0.000
speed	1	957496	957496	957496	420.58	0.000
feed	1	17531	17531	17531	7.70	0.024
doc	1	66104	66104	66104	29.04	0.001
Square	3	95281	95281	31760	13.95	0.002
speed*speed	1	72673	75397	75397	33.12	0.000
feed*feed	1	21185	22402	22402	9.84	0.014
doc*doc	1	1423	1423	1423	0.63	0.452
Interaction	3	24803	24803	8268	3.63	0.064
speed*feed	1	107	107	107	0.05	0.834
speed*doc	1	881	881	881	0.39	0.551
feed*doc	1	23815	23815	23815	10.46	0.012
Residual Error	8	18213	18213	2277		
Lack-of-Fit	5	11400	11400	2280	1.00	0.534
Pure Error	3	6812	6812	2271		
Total	19	1228287				

From table 8, we observe that the P-value for speed, feed, depth of cut, speed * speed, feed*feed, feed * doc are less than significance value of 0.05. Hence, they have significant effect on response. The lack of fit should have P-value more than 0.05. Here, we have lack of fit have P-value 0.534, which is desirable. The most influential parameter is speed which has minimum value of P among all three parameter.

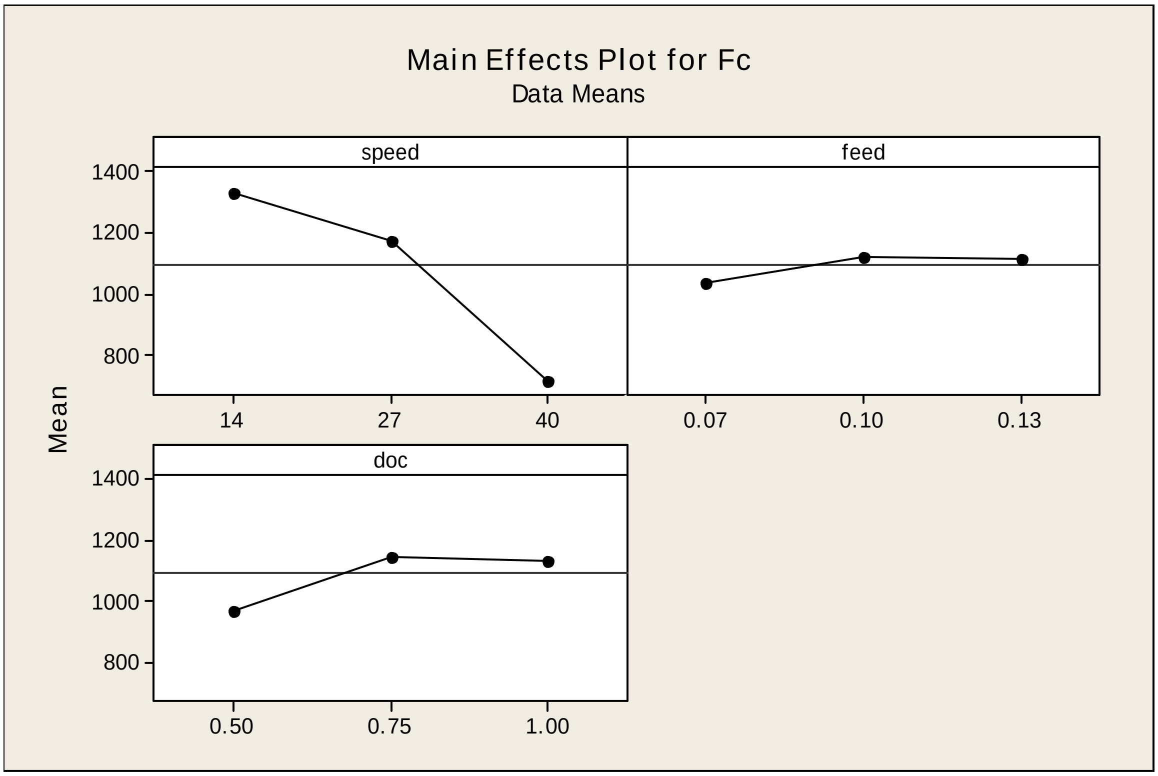


Fig 12 : Main effect plot of Fc

The main effect plot shows that the cutting force decreases continuously with increase in speed. With the increase in feed, cutting force increases up to certain value and then remains almost constant with further increase in feed. The same curve is seen in case of the variation of cutting force with depth of cut.

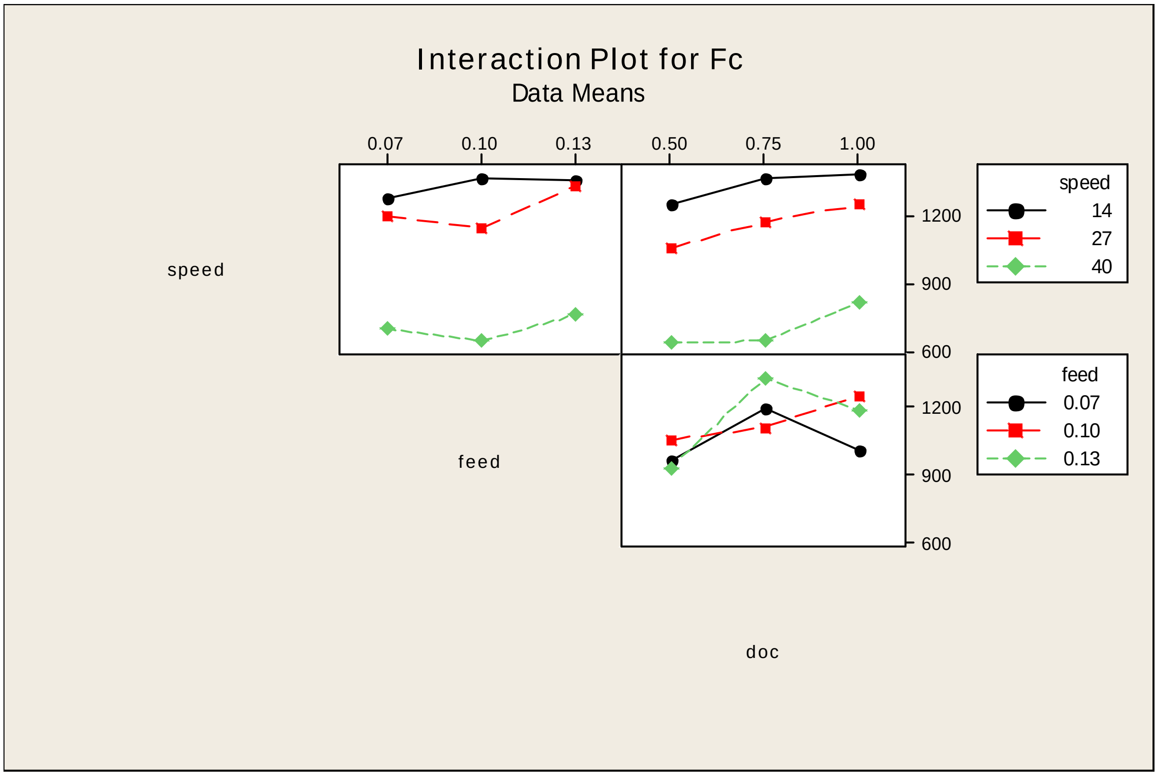


Fig13: Interaction plot for Fc

Table 6: ANOVA for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	2	0.25791	0.21394	0.10697	5.96	0.026
Regression	9	2.64496	2.64496	0.29388	16.38	0.000
Linear	3	2.03590	2.03590	0.67863	37.83	0.000
speed	1	0.03844	0.03844	0.03844	2.14	0.181
feed	1	1.64025	1.64025	1.64025	91.44	0.000
doc	1	0.35721	0.35721	0.35721	19.91	0.002
Square	3	0.05683	0.05683	0.01894	1.06	0.420
speed*speed	1	0.01382	0.04730	0.04730	2.64	0.143
feed*feed	1	0.03260	0.01816	0.01816	1.01	0.344
doc*doc	1	0.01040	0.01040	0.01040	0.58	0.468
Interaction	3	0.55224	0.55224	0.18408	10.26	0.004
speed*feed	1	0.09031	0.09031	0.09031	5.03	0.055
speed*doc	1	0.07031	0.07031	0.07031	3.92	0.083
feed*doc	1	0.39161	0.39161	0.39161	21.83	0.002
Residual Error	8	0.14350	0.14350	0.01794		
Lack-of-Fit	5	0.11700	0.11700	0.02340	2.65	0.226
Pure Error	3	0.02650	0.02650	0.00883		
Total	19	3.04638				

From table 6, we can see that feed, doc and feed * doc have P-value less than 0.05, hence they are significant. The lack of fit has P-value 0.226, which is desirable. Here, feed is most significant parameter having smallest P-value among all.

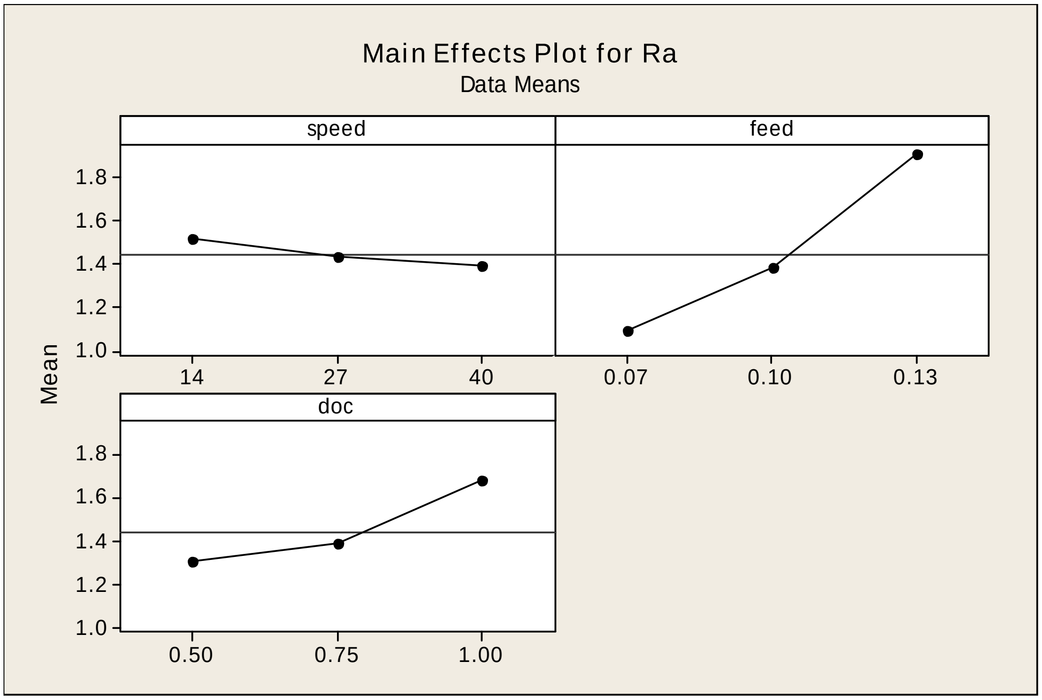


Fig 14: Main effect plots for Ra

From the main effects plot, we notice that with the increase in speed the surface roughness decreases though at a slower rate. The Ra value increases continuously with the increase in feed and depth of cut.

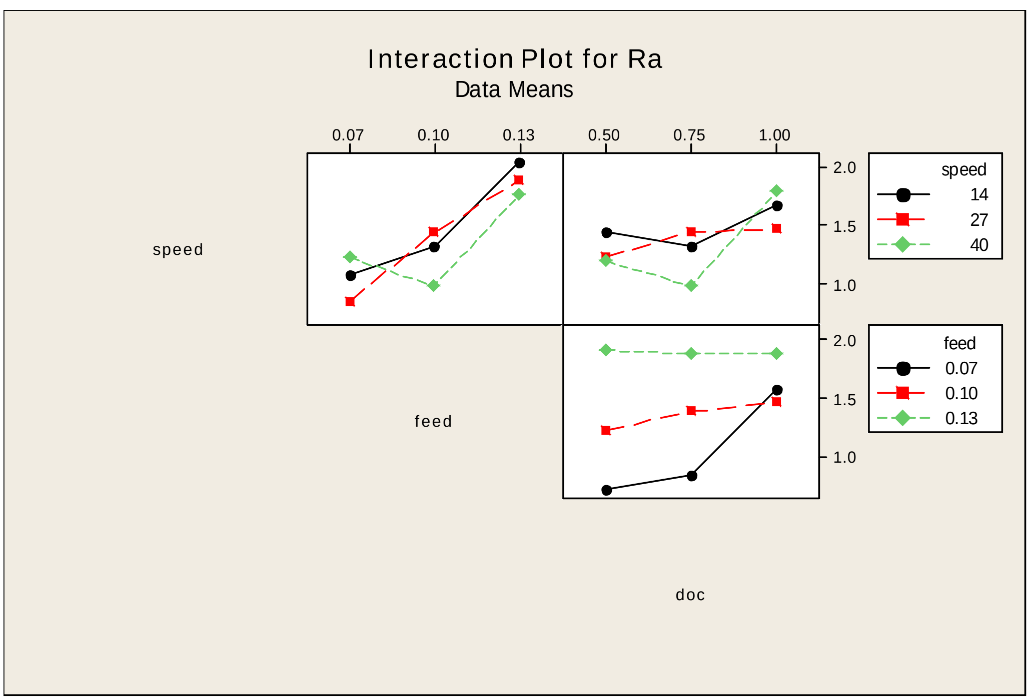


Fig 15: Interaction plots for Ra

Table 8: ANOVA for Tool wear

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	2	0.32743	0.176594	0.088297	10.42	0.006
Regression	9	0.84986	0.849858	0.094429	11.14	0.001
Linear	3	0.64416	0.644159	0.214720	25.33	0.000
speed	1	0.00040	0.000397	0.000397	0.05	0.834
feed	1	0.22801	0.228010	0.228010	26.90	0.001
doc	1	0.41575	0.415752	0.415752	49.04	0.000
Square	3	0.14387	0.143867	0.047956	5.66	0.022
speed*speed	1	0.00006	0.048106	0.048106	5.67	0.044
feed*feed	1	0.10635	0.057709	0.057709	6.81	0.031
doc*doc	1	0.03746	0.037456	0.037456	4.42	0.069
Interaction	3	0.06183	0.061833	0.020611	2.43	0.140
speed*feed	1	0.01328	0.013285	0.013285	1.57	0.246
speed*doc	1	0.04205	0.042050	0.042050	4.96	0.057
feed*doc	1	0.00650	0.006498	0.006498	0.77	0.407
Residual Error	8	0.06782	0.067816	0.008477		
Lack-of-Fit	5	0.05571	0.055711	0.011142	2.76	0.216
Pure Error	3	0.01210	0.012105	0.004035		
Total	19	1.24510				

From this table we can see that the speed, doc, speed*speed, feed*feed have P-value less than 0.05, so they have significant effect on flank wear. The lack of fit value is 0.216, which is more than 0.05, which shows that it is not significant as desirable. Depth of cut is most significant parameter having lowest P-value.

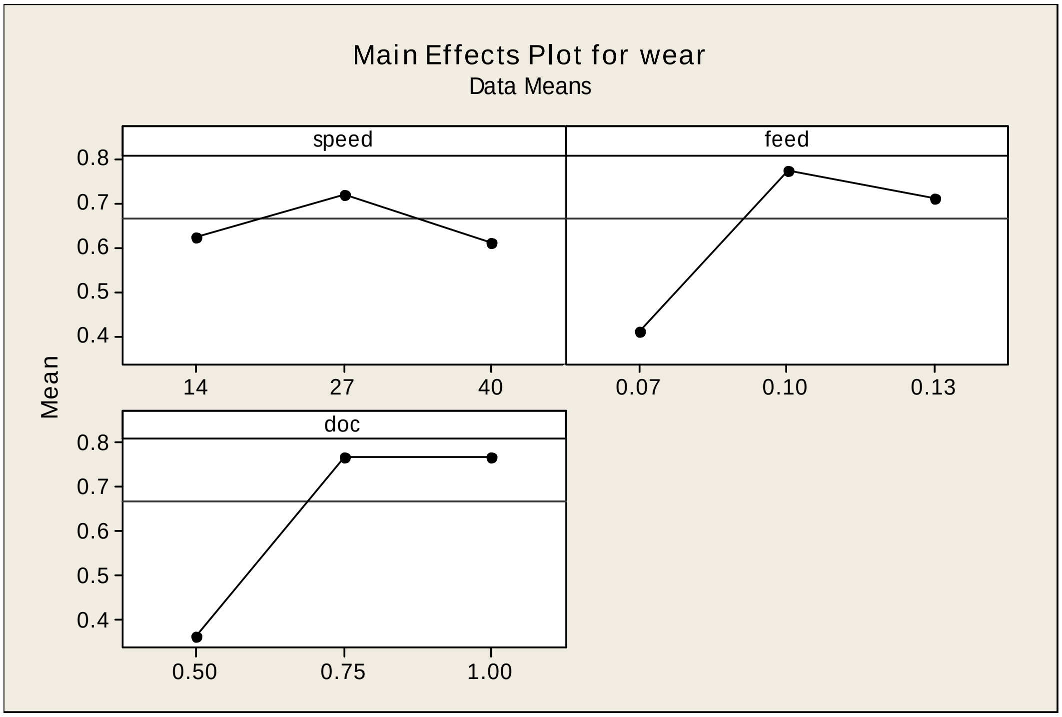


Fig 16: Main effect plot for Flank wear

Graphs show that the tool wear increases with cutting speed up to certain limit and then starts decreasing. Same effect can be seen in case of feed. Wear increases sharply at the starting and then starts decreasing. In case of depth of cut, the flank wear increases at staring and then remains almost constant.

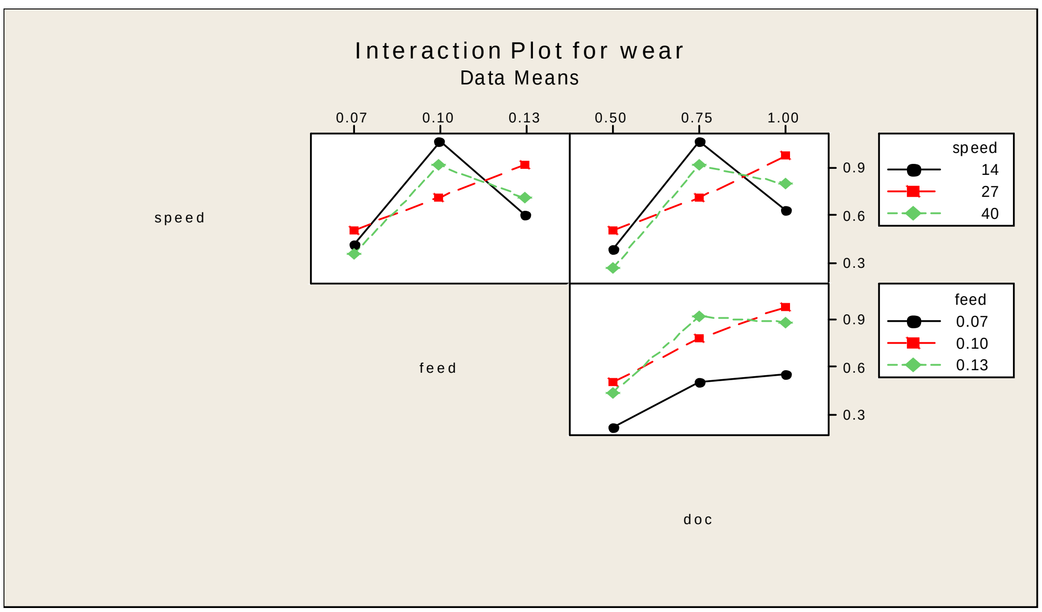


Fig17: interaction plot for Flank wear

Estimated regression coefficient for Fc

Table 9

Term	Coef	SE Coef	T	P
Constant	1141.69	18.43	61.939	0.000
Block 1	-9.07	16.06	-0.565	0.588
Block 2	-29.73	16.06	-1.851	0.101
speed	-309.43	15.09	-20.508	0.000
feed	41.87	15.09	2.775	0.024
doc	81.30	15.09	5.389	0.001
speed*speed	-167.60	29.12	-5.755	0.000
feed*feed	91.36	29.12	3.137	0.014
doc*doc	-23.03	29.12	-0.791	0.452
speed*feed	-3.65	16.87	-0.217	0.834
speed*doc	10.49	16.87	0.622	0.551
feed*doc	54.56	16.87	3.234	0.012

S = 47.7137 , PRESS = 220848
R-Sq = 98.52%, R-Sq.(pred) = 82.02% R-Sq(adj) = 96.48%

The regression equation for cutting force is:

Fc= 1141.69-309.43*speed+41.87*feed+81.30*doc-167.60*speed*speed+91.36*feed*feed-23.03*doc*doc-3.65*speed*feed+10.49*speed*doc+54.56*feed*doc

Estimated regression coefficient for Ra

Table 10

Term	Coef	SE Coef	T	P
Constant	1.44712	0.05174	27.969	0.000
Block 1	0.14837	0.04508	3.291	0.011
Block 2	-0.02830	0.04508	-0.628	0.548
speed	-0.06200	0.04235	-1.464	0.181
feed	0.40500	0.04235	9.562	0.000
doc	0.18900	0.04235	4.462	0.002
speed*speed	-0.13275	0.08175	-1.624	0.143
feed*feed	0.08225	0.08175	1.006	0.344
doc*doc	0.06225	0.08175	0.762	0.468
speed*feed	-0.10625	0.04735	-2.244	0.055
speed*doc	0.09375	0.04735	1.980	0.083
feed*doc	-0.22125	0.04735	-4.672	0.002

S = 0.133933 PRESS = 1.61312
R-Sq = 95.29% R-Sq(pred) = 47.05% R-Sq(adj) = 88.81%

Regression equation for surface roughness:

Ra = 1.4471-0.062*speed+0.405*feed+0.189*doc-0.13275*speed*speed+0.08225*feed*feed+0.06225*doc*doc-0.10625*speed*feed+0.09375*speed*doc-0.22125*feed*doc

Estimated regression coefficient for Tool wear

Table 11

Term	Coef	SE Coef	T	P
Constant	0.719438	0.03557	20.227	0.000
Block 1	-0.124516	0.03099	-4.018	0.004
Block 2	-0.000516	0.03099	-0.017	0.987
speed	-0.006300	0.02912	-0.216	0.834
feed	0.151000	0.02912	5.186	0.001
doc	0.203900	0.02912	7.003	0.000
speed*speed	0.133873	0.05620	2.382	0.044
feed*feed	-0.146627	0.05620	-2.609	0.031
doc*doc	-0.118127	0.05620	-2.102	0.069
speed*feed	0.040750	0.03255	1.252	0.246
speed*doc	0.072500	0.03255	2.227	0.057
feed*doc	0.028500	0.03255	0.876	0.407

S = 0.0920707 PRESS = 1.13773
R-Sq = 94.55%,R-Sq(pred) = 8.62%,R-Sq(adj) = 87.06%

The regression equation for tool wear:

Tool wear = 0.719438-.0063*speed+0.151*feed+

0.2039*doc+0.133873*speed*speed- 0.146627*feed*feed-

0.118127*doc*doc+0.04075*speed*feed+0.0725*speed*doc+0.0285*feed*doc

5.2:CONTOURS AND SURFACE PLOTS

Plots of cutting force

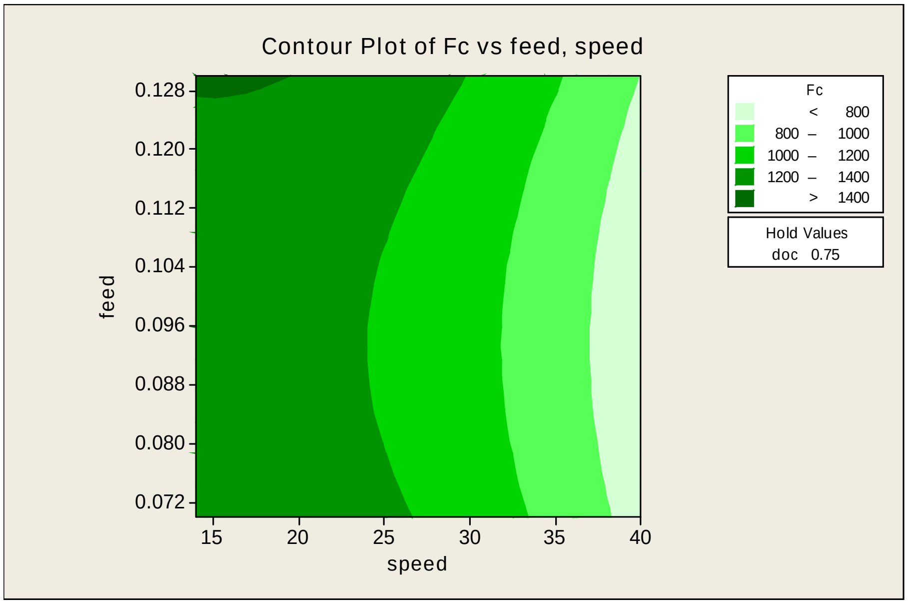


Fig18:contour plot Fc vs feed , speed

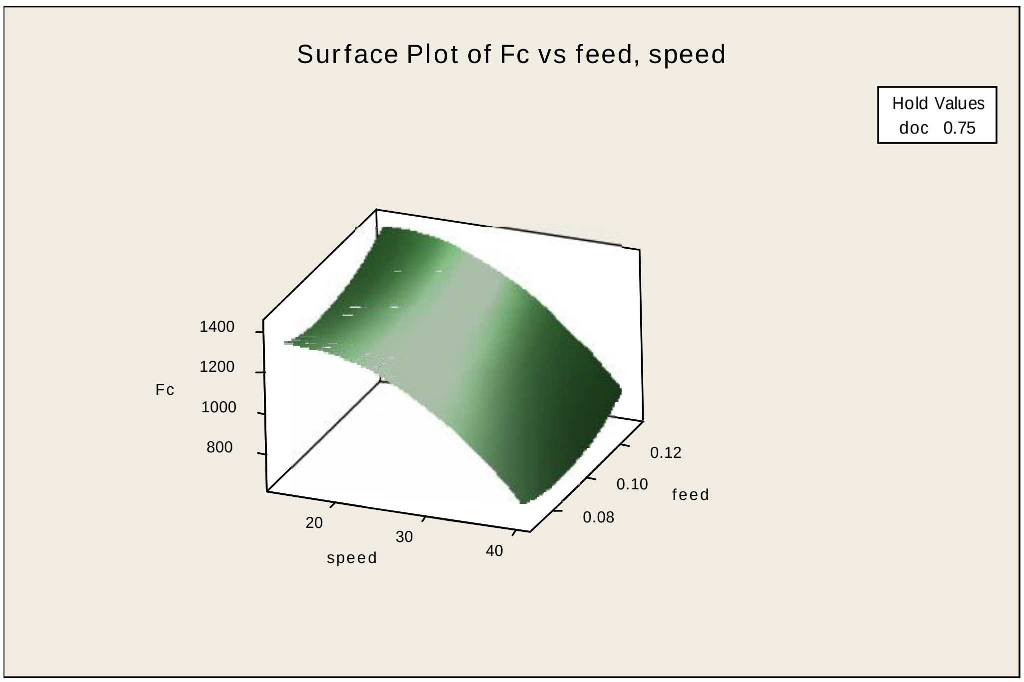


Fig 19: surface plot Fc vs feed, speed

From this plots we can conclude that high speed and low feed is favorable condition for less cutting force.

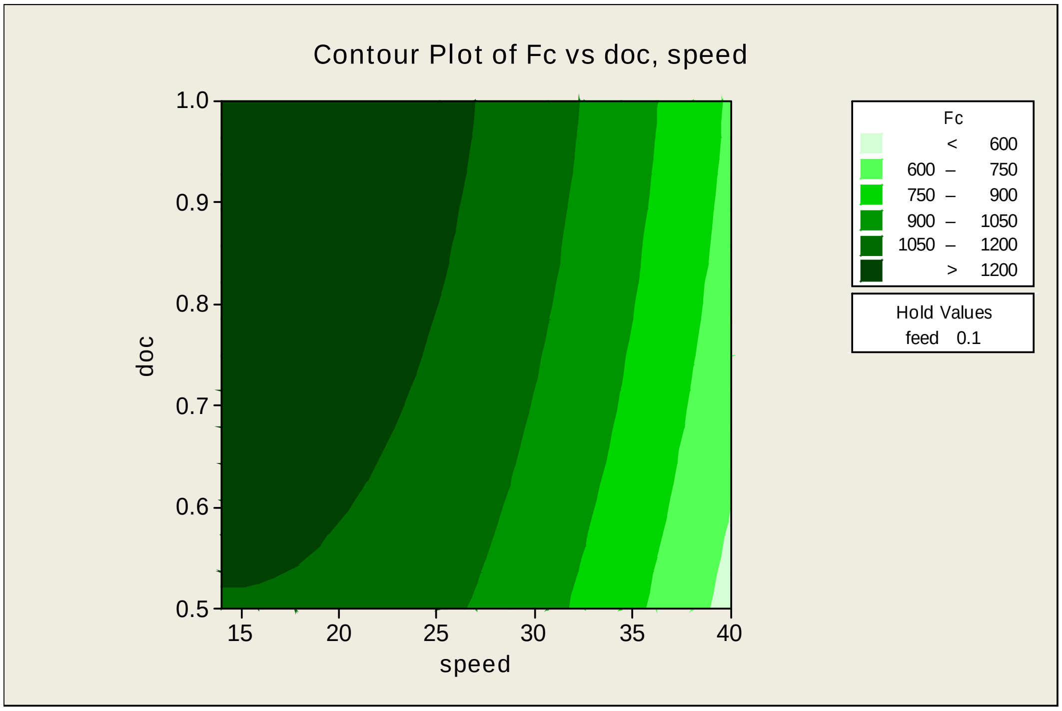


Fig 20: contour plot Fc vs Doc, speed

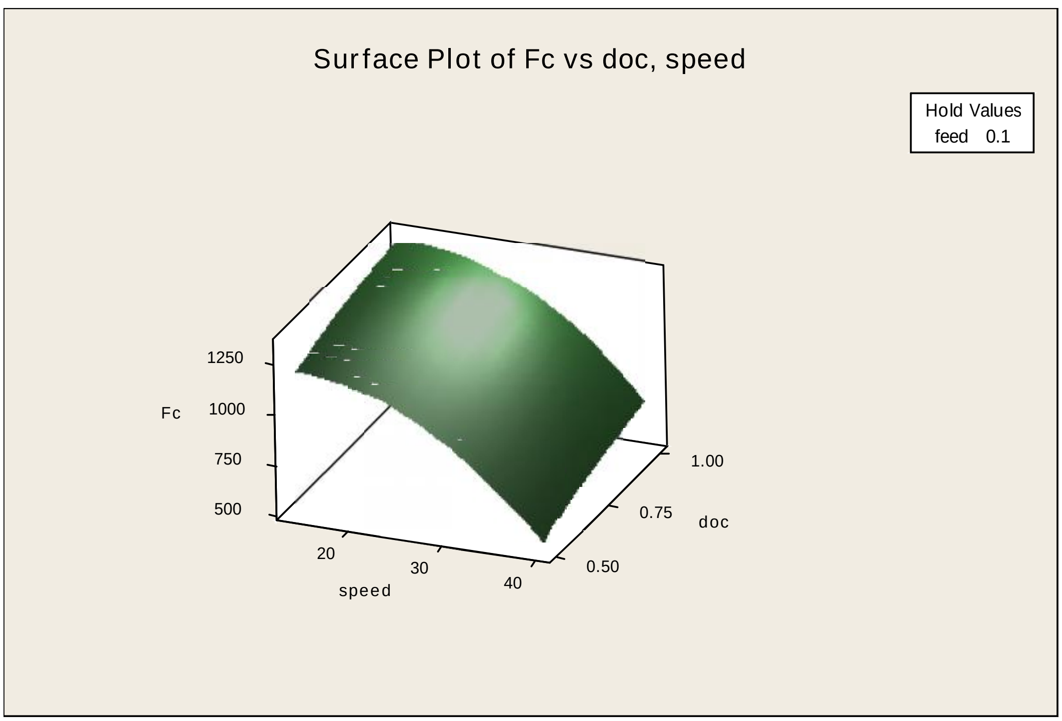


Fig21: Surface plot Fc vs doc, speed

From this plots we can conclude that high speed and low doc is favorable condition for less cutting force.

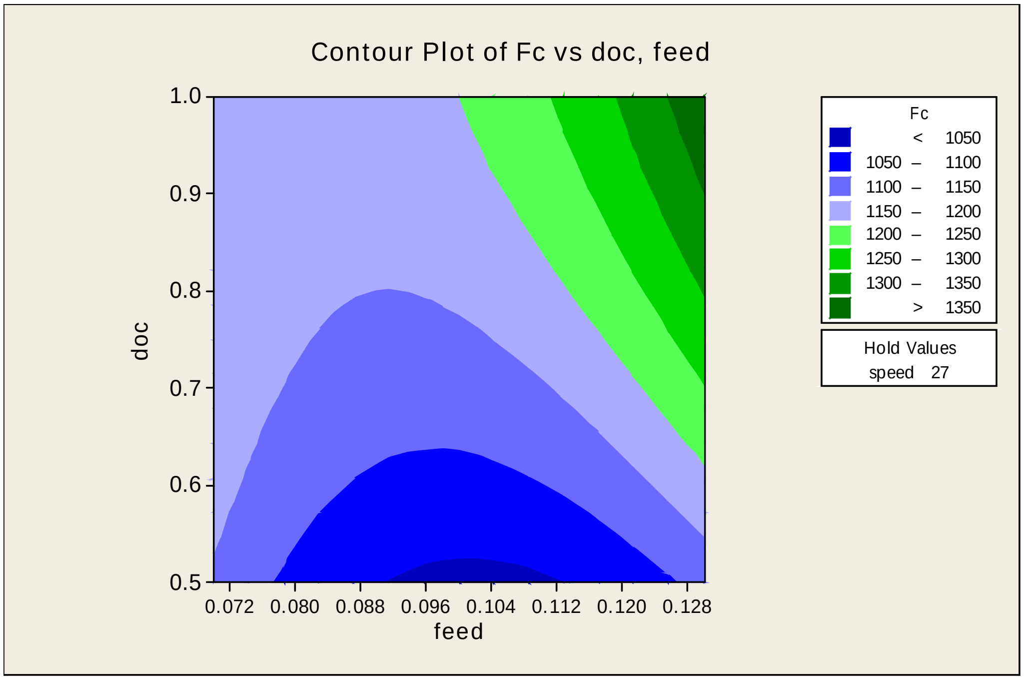


Fig 22: contour plot Fc vs doc, feed

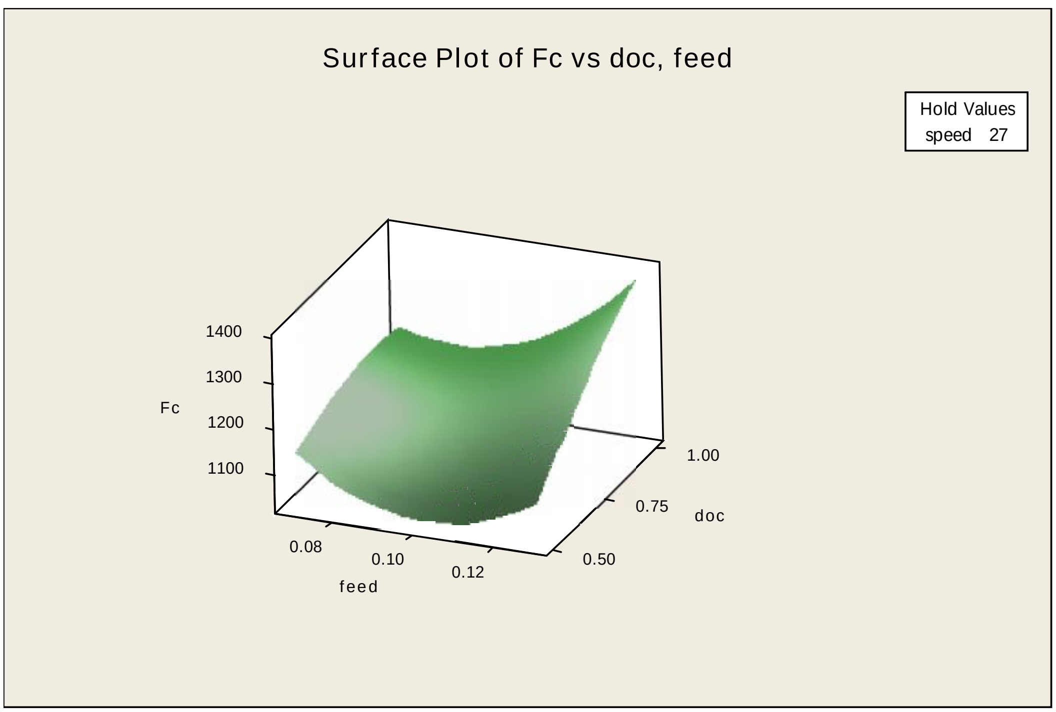


Fig 23: surface plot Fc vs doc, feed

From this plots we can conclude that cutting force is less for lower value of doc. With the increase in feed cutting force first decrease up to certain value and the continuously increase with further increase in feed.

Plots for Ra

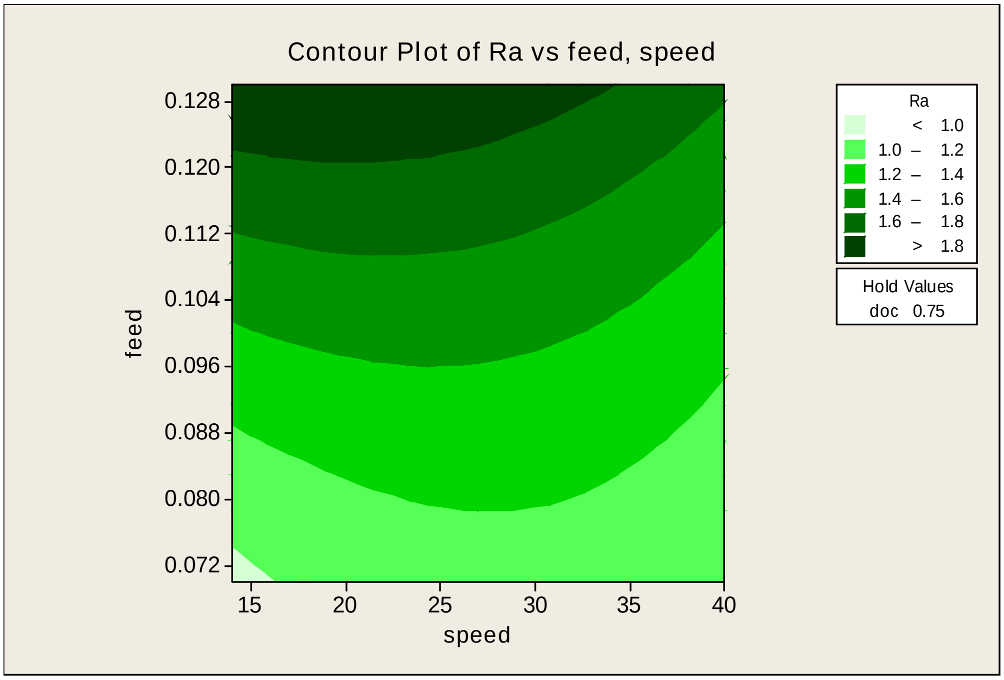


Fig 24: contour plot Ra vs feed, speed

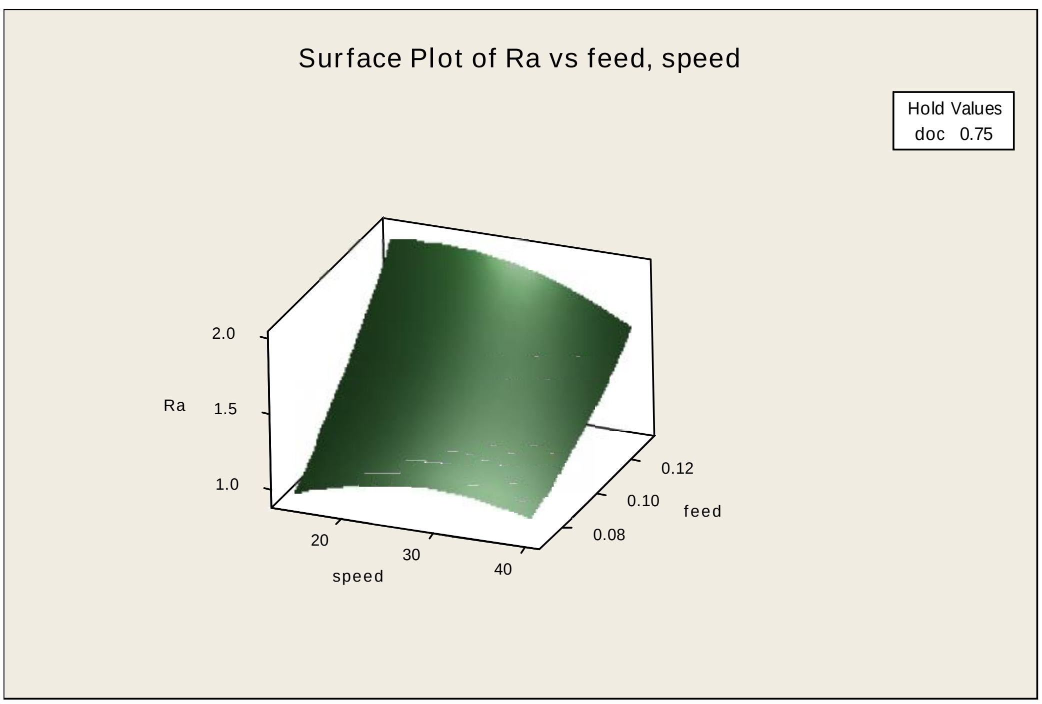


Fig 25: surface plot Ra vs feed, speed

Low feed is favorable for low surface roughness and it continuously increase with increase in feed. Ra is less dependent on speed however high speed is favorable.

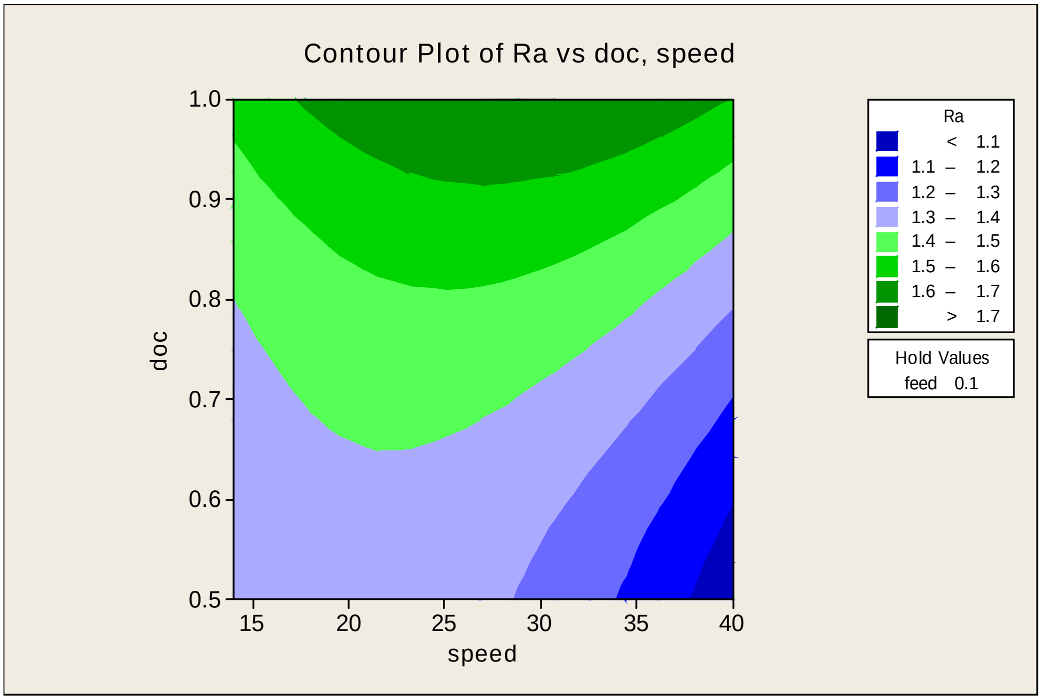


Fig26: contour plot Ra vs doc, speed

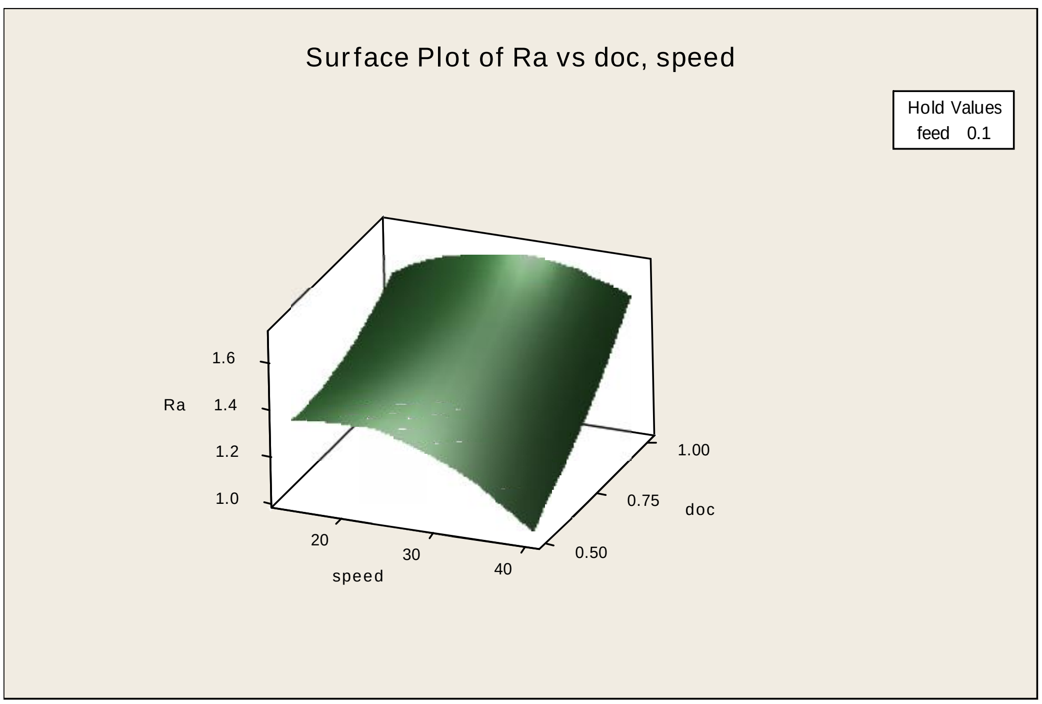


Fig 27: surface plot Ra vs doc, speed

From plots, Low doc and high speed is favorable for low surface roughness.

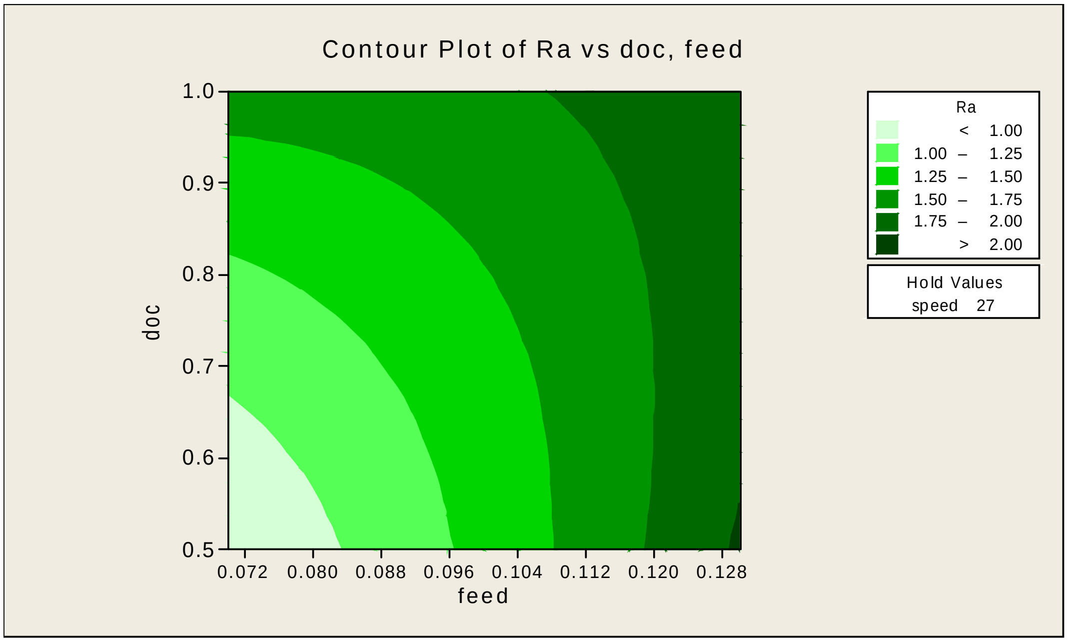


Fig 28: contour plot Ra vs doc , feed

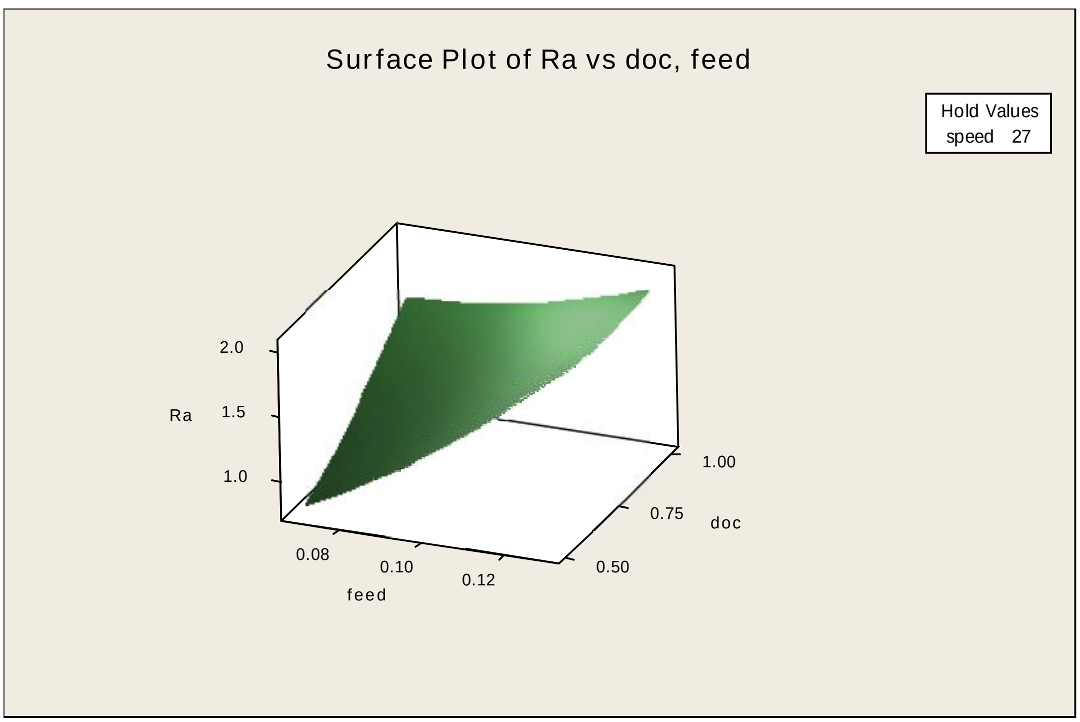


Fig 29: surface plot Ra vs doc, feed

From plots, Low doc and low feed is favorable for low surface roughness.

Plots for tool wear

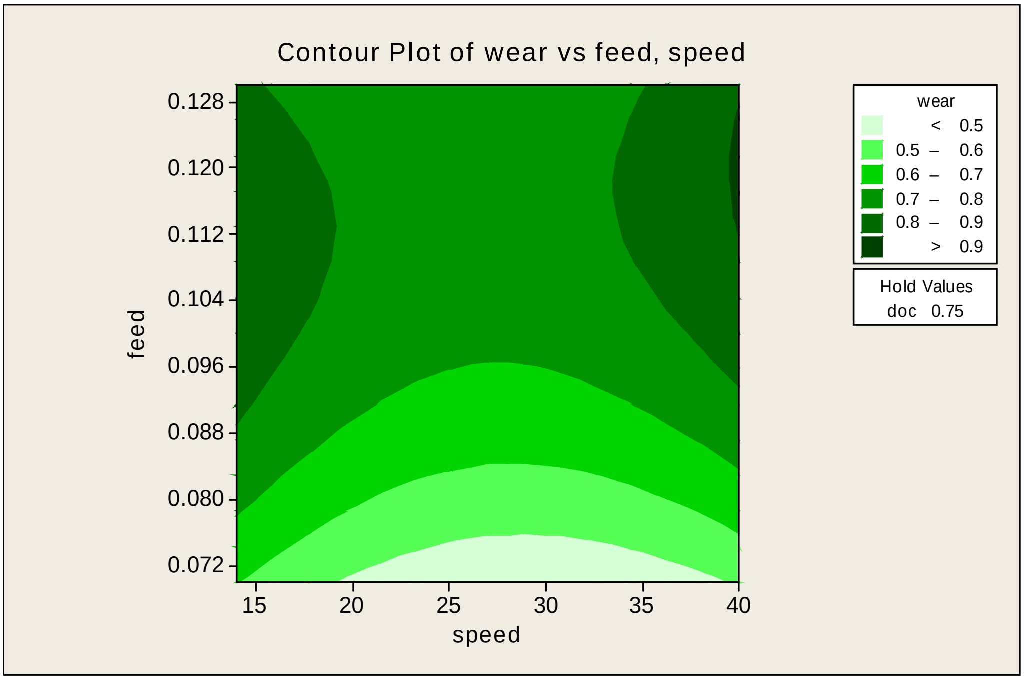


Fig 30: contour plot Wear vs feed, speed

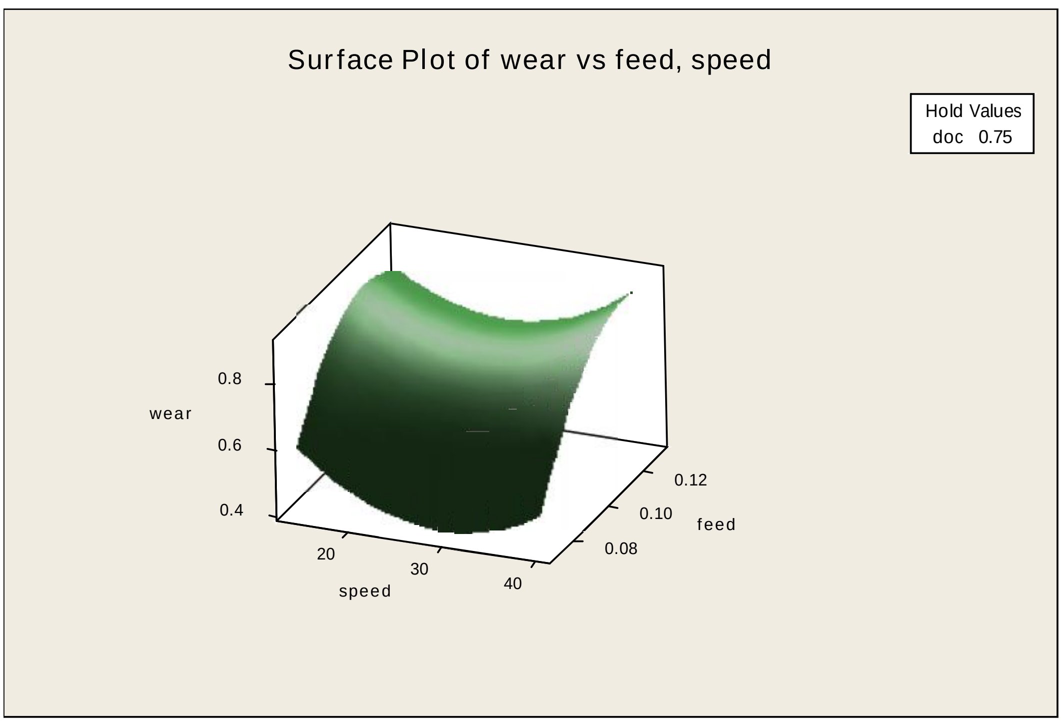


Fig 31: surface plot wear vs feed, speed

Tool wear first decreases up to certain increase in speed and then increase with further increase in speed. Low feed is favorable for lower wear and it increases with feed.

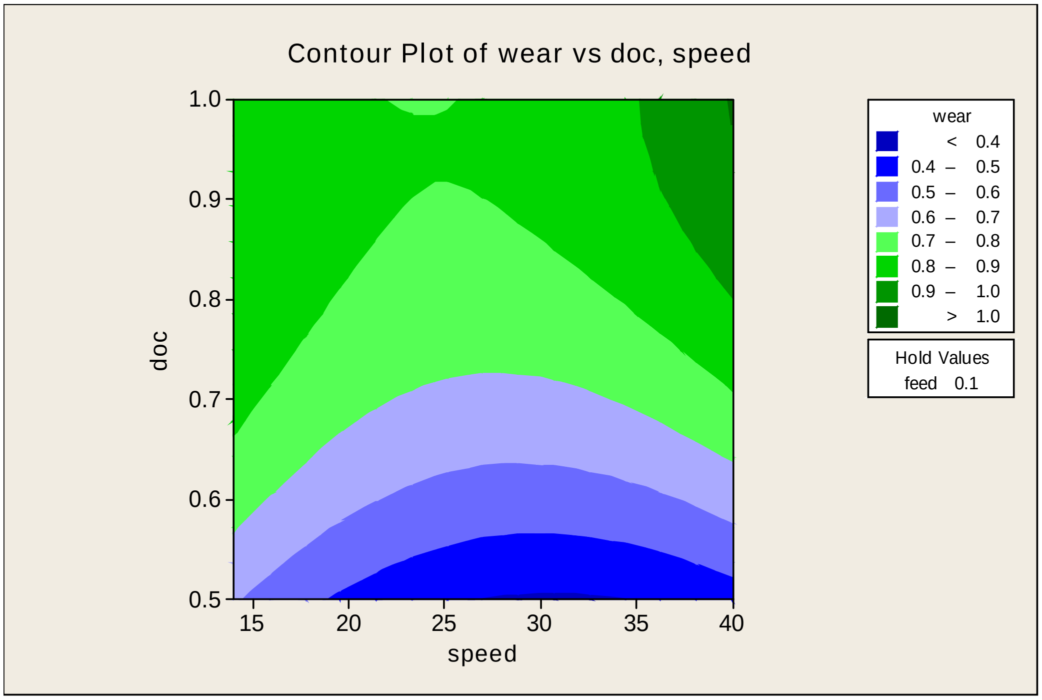


Fig 32: contour plot wear vs doc, speed

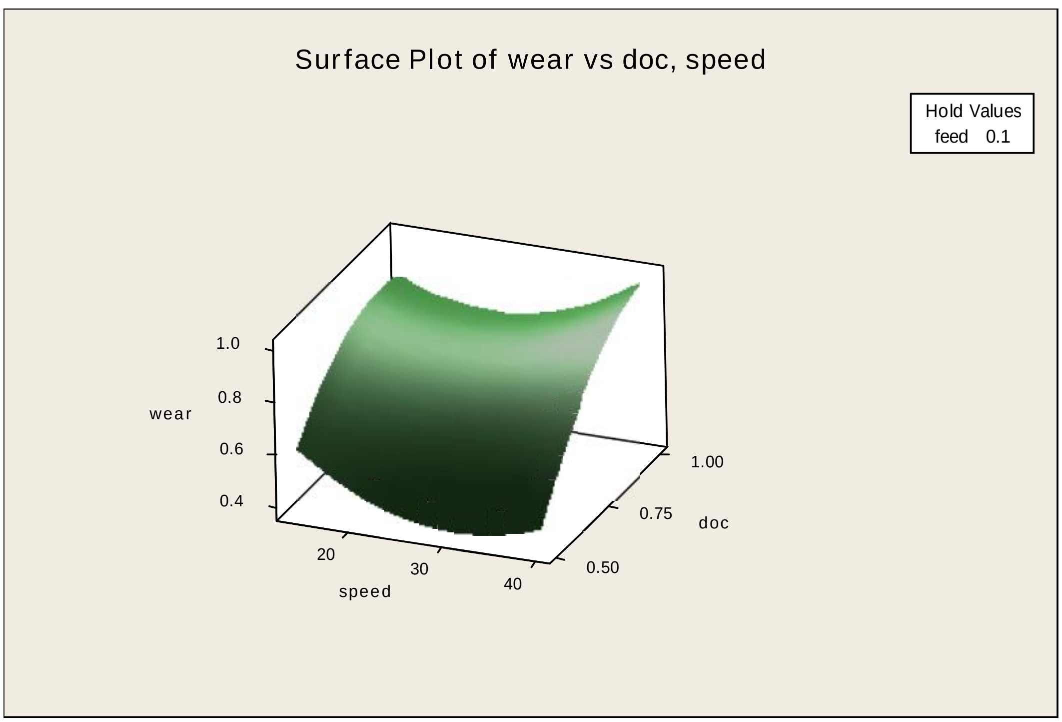


Fig 33: surface plot wear vs doc, speed

Tool wear first decreases up to certain increase in speed and then increase with further increase in speed. Low doc is favorable for lower wear and it increases with the increase in doc.

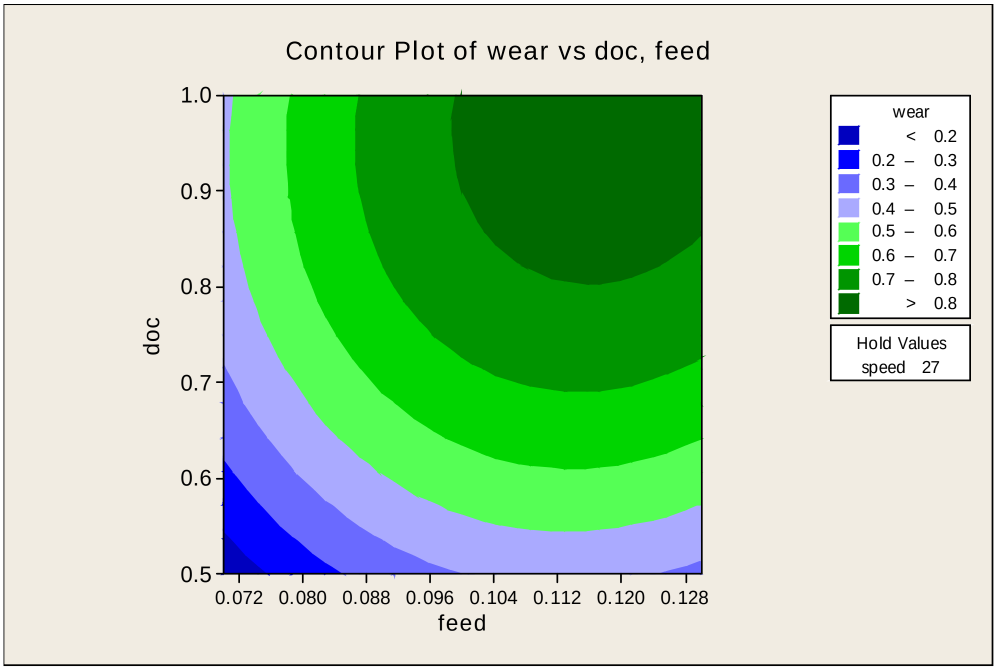


Fig 34: contour plot wear vs doc, feed

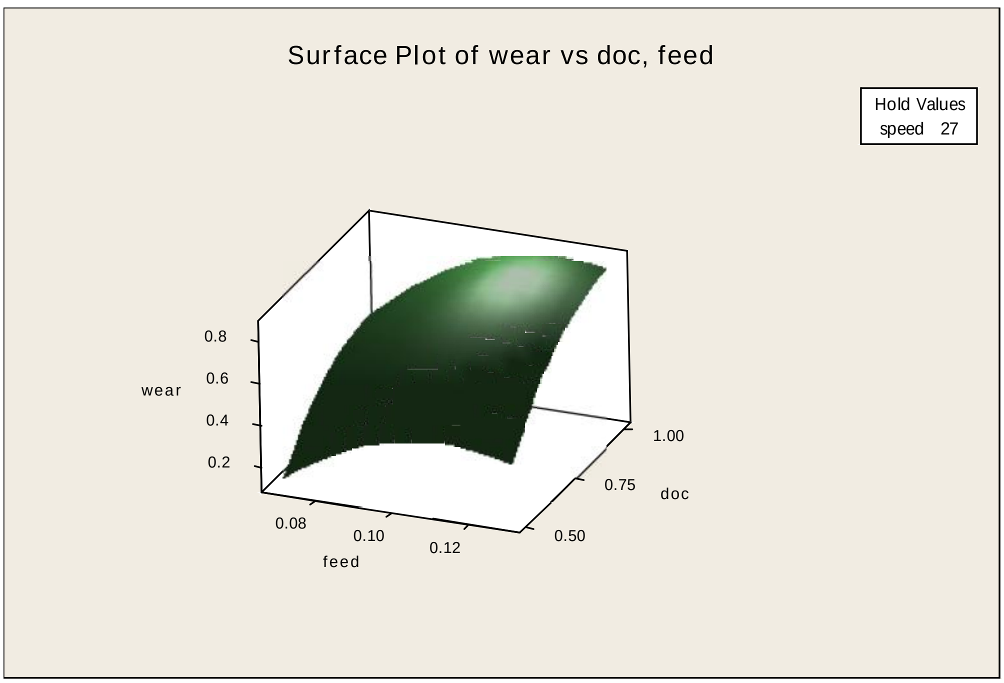


Fig35: surface plot wear vs doc, feed

Low feed and low doc is favorable for lower wear. With the increase in feed and doc the tool wear increases.

5.3 OPTIMUM SETTINGS

The optimum setting was found to be

Speed=40m/min, feed=0.706 mm/rev and doc=0.50mm

Optimum setting is shown in the plot:

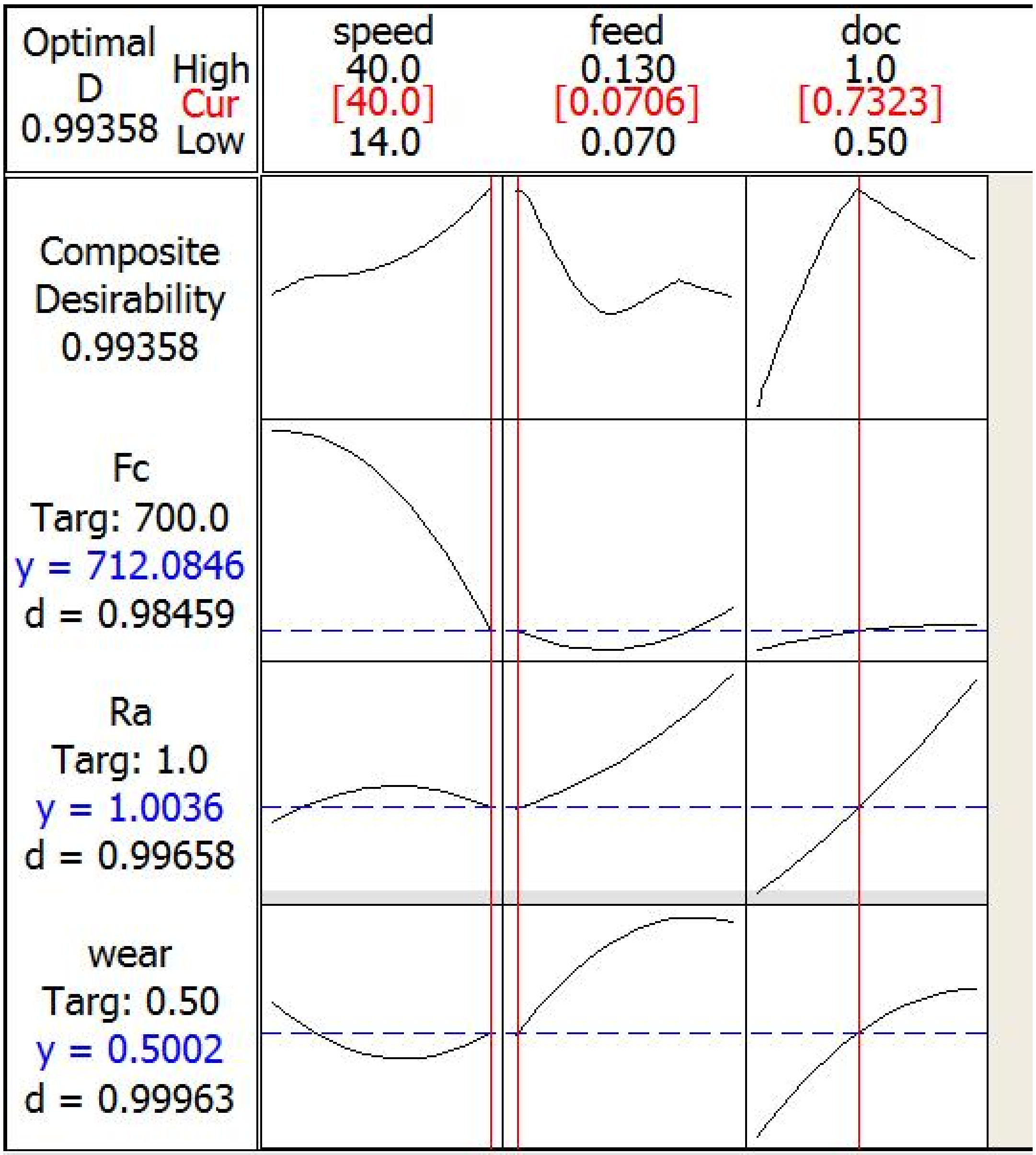


Fig 36: optimum setting

CHAPTER 6: CONCLUSION

6.1 CONCLUSIONS

The experimented was conducted successfully with the supervision of the lab assistant and taking the results as input to the RSM, the effect of cutting parameters on the cutting force, surface roughness and tool wear was observed. ANOVA was carried out to determine most influential parameter on certain output. From result, we can see that speed is the most significant factor affecting the cutting force, feed has most significant effect on surface roughness and depth of cut is most influential for tool wear. By optimizing, the optimum values are found to be Speed=40m/min, feed=0.706 mm/rev and doc=0.50mm.

6.2 SCOPE FOR FUTURE STUDY

We have conducted the experiment in dry condition using uncoated carbide tool.
So, the experiment can be done in wet condition using cutting fluid for better results. In future, applying cutting fluid and taking same work piece –tool combination, the cutting force, surface roughness and tool wear can be analyzed.

We have conducted experiment in low speed condition, so by increasing speed the experiment can be done in the future.

Also, MRR, chip reduction coefficient can be added to the output and analyzed taking same combination of tool and work piece and same parameter.

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