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Study and Analysis of Austenitic Stainless steel of grade AISI 202

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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.

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.

LITERATUREREVIEW

This paper 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

MATERIALS AND METHODS

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.

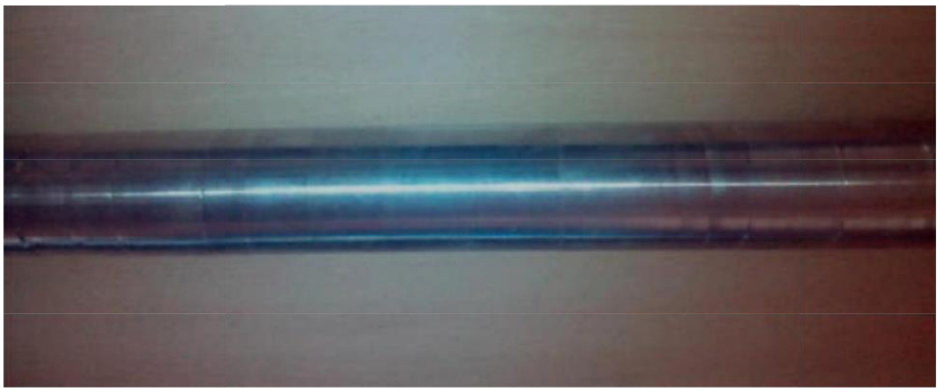


Fig 1: work piece

Insert Material

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

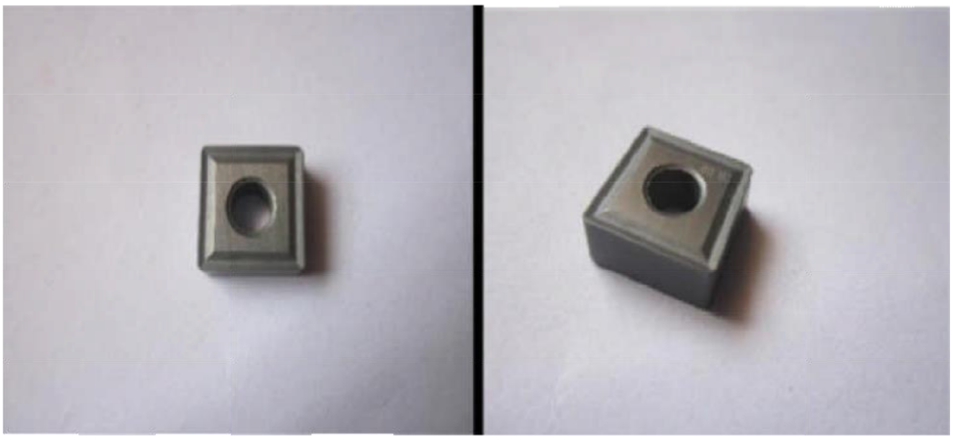


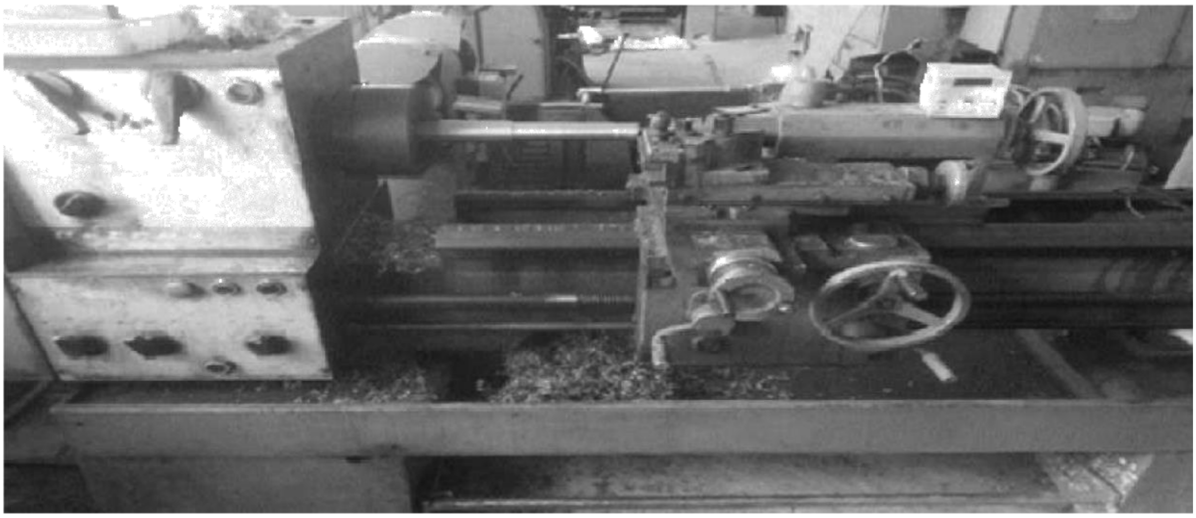
Fig 2: uncoated carbide Inserts

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:

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.



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 3: Taylor Hobson profilometer

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.

nd then from power

$$P = Fc * Vc$$

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

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.

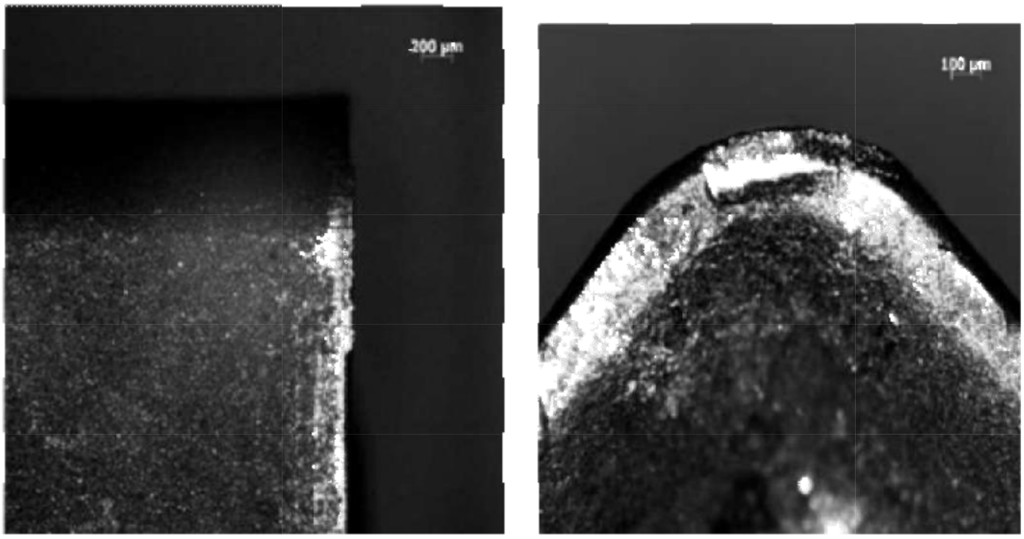


Fig 4: flank wear and crater wear

Process Parameters Table 2:

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

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.

Table3 Design Layout

Std Order	Run Order	Pt Type	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

the most significant parameter affecting surface roughness is nose radius.

RESULT AND DISCUSSION

Table 4: observations

Std Order	RunOrder	speed (m/min)	Feed (mm/rev)	DoC (mm)	Fc (N)	Ra (μm)	Wear (mm)
1	1	14	0.07	0.5	1272.1	0.84	0.293
2	2	40	0.13	0.5	621.51	1.78	0.386
3	3	40	0.07	1	733.58	1.84	0.566
4	4	14	0.13	1	1484.3	2.03	0.73
5	5	27	0.1	0.75	1188.7	1.65	0.609
6	6	27	0.1	0.75	1098.4	1.48	0.462
7	7	40	0.07	0.5	659.67	0.61	0.145

8	8	14	0.13	0.5	1234.1	2.06	0.485
9	9	14	0.07	1	1289.6	1.32	0.538
10	10	40	0.13	1	899.2	1.75	1.035
11	11	27	0.1	0.75	1132.4	1.39	0.816
12	12	27	0.1	0.75	1059.7	1.43	0.771
13	13	14	0.1	0.75	1372	1.33	1.068
14	14	40	0.1	0.75	643.83	0.98	0.919
15	15	27	0.07	0.75	1199.6	0.85	0.505
16	16	27	0.13	0.75	1334.2	1.89	0.921
17	17	27	0.1	0.5	1055.6	1.23	0.502
18	18	27	0.1	1	1249.4	1.47	0.981
19	19	27	0.1	0.75	1202.2	1.37	0.811
20	20	27	0.1	0.75	1188.6	1.52	0.787

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 5.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
Linear	3	1041130	1041130	347043	152.44	0
speed	1	957496	957496	957496	420.58	0
feed	1	17531	17531	17531	7.7	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
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	0.534
Pure Error	3	6812	6812	2271		
Total	19	1228287				

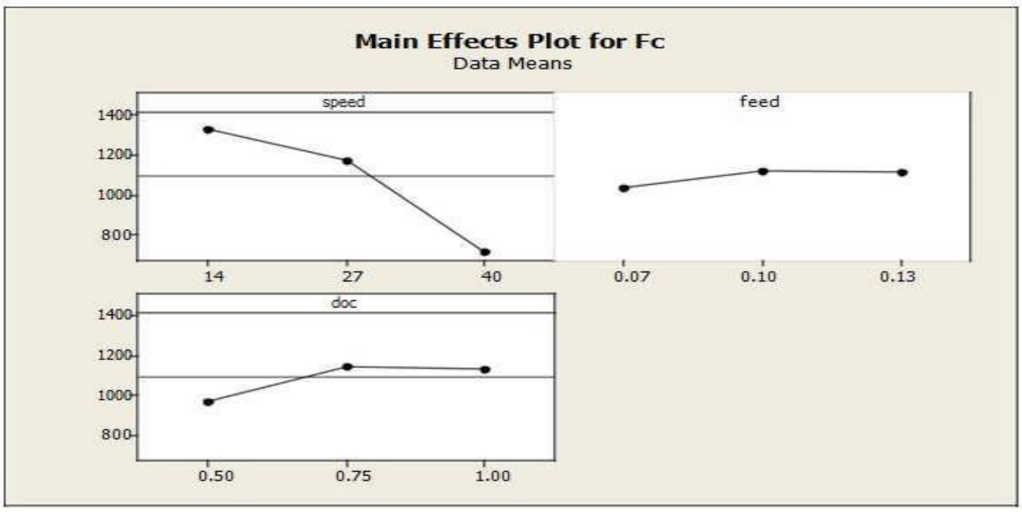


Fig 5. Main Effects Plot of Fc

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.

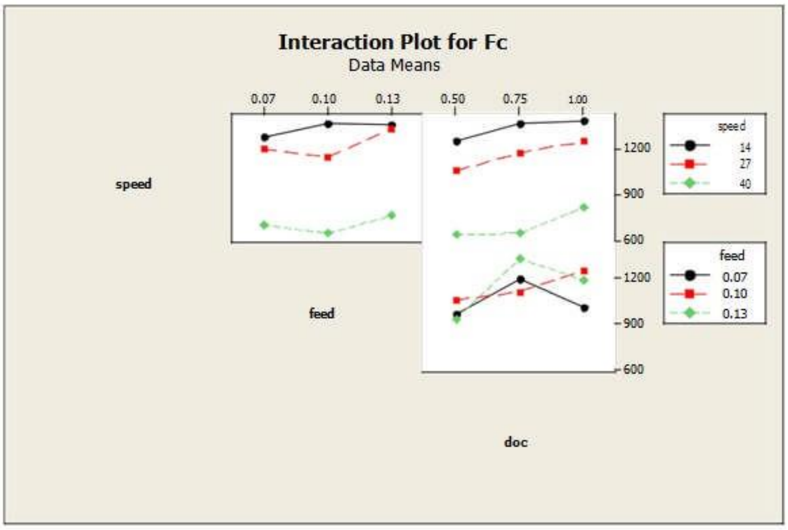


Fig6: Interaction plot for Fc

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
Linear	3	2.0359	2.0359	0.67863	37.83	0
speed	1	0.03844	0.03844	0.03844	2.14	0.181
feed	1	1.64025	1.64025	1.64025	91.44	0
doc	1	0.35721	0.35721	0.35721	19.91	0.002
Square	3	0.05683	0.05683	0.01894	1.06	0.42

speed*speed	1	0.01382	0.0473	0.0473	2.64	0.143
feed*feed	1	0.0326	0.01816	0.01816	1.01	0.344
doc*doc	1	0.0104	0.0104	0.0104	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	0.1435	0.1435	0.01794		
Lack-of-Fit	5	0.117	0.117	0.0234	2.65	0.226
Pure Error	3	0.0265	0.0265	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.

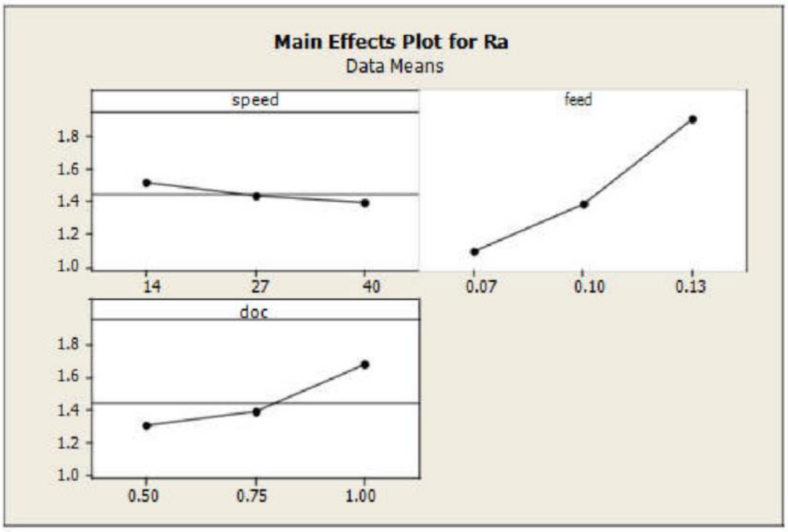


Fig 7: Main effect plots for Ra

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.

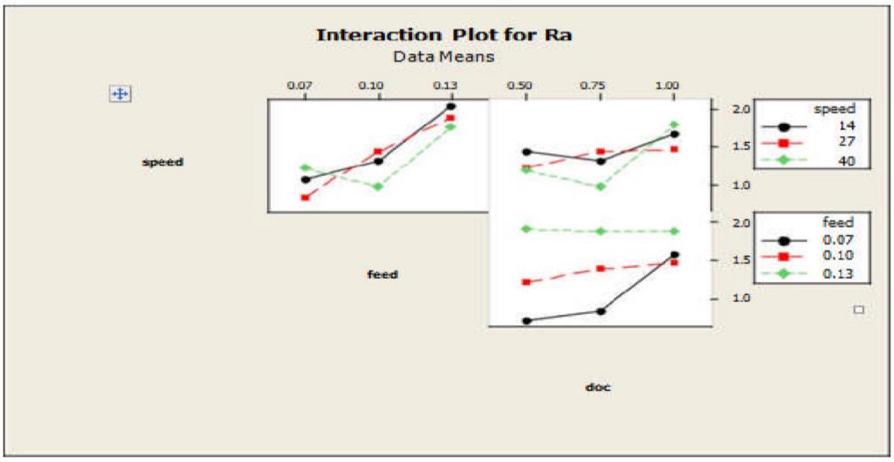


Fig 8: Interaction plots for Ra

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	0.21472	25.33	0
speed	1	0.0004	0.000397	0.000397	0.05	0.834
feed	1	0.22801	0.22801	0.22801	26.9	0.001
doc	1	0.41575	0.415752	0.415752	49.04	0
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	0.14
speed*feed	1	0.01328	0.013285	0.013285	1.57	0.246
speed*doc	1	0.04205	0.04205	0.04205	4.96	0.057
feed*doc	1	0.0065	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	0.0121	0.012105	0.004035		
Total	19	1.2451				

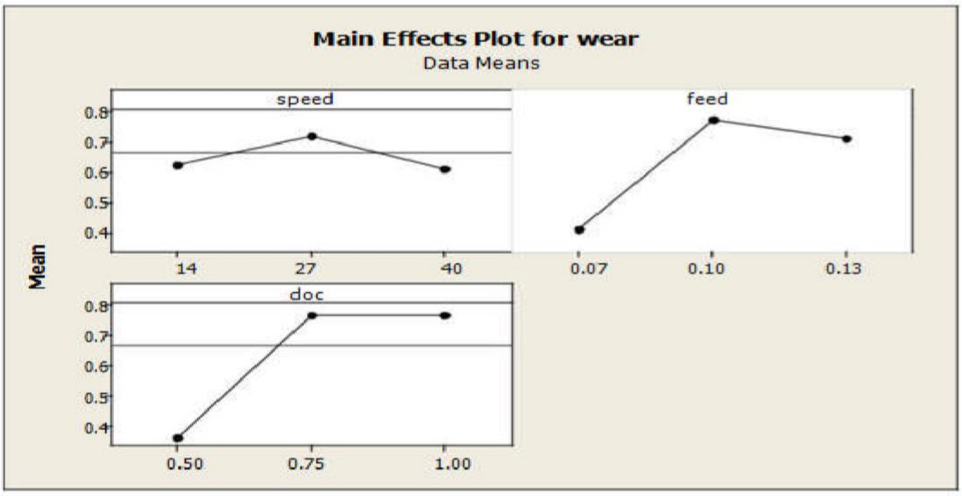


Fig 9: Main effect plot for Flank wear

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.

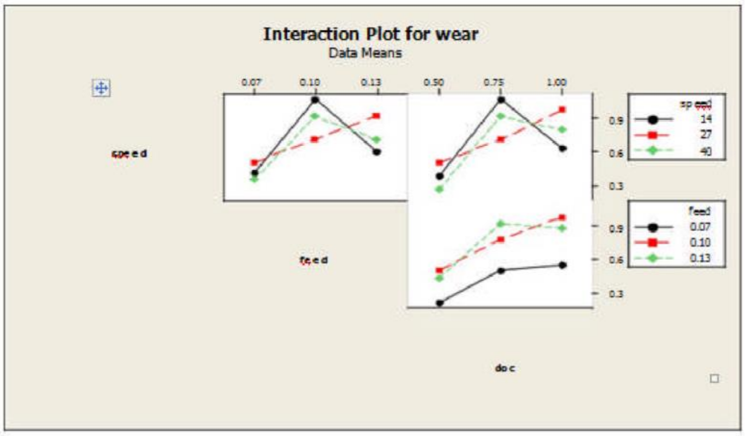


Fig10: interaction plot for Flank wear

Table 9 Estimated Regression Coefficient For Fc

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	1141.69	18.43	61.939	0
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
feed	41.87	15.09	2.775	0.024
doc	81.3	15.09	5.389	0.001
speed*speed	-167.6	29.12	-5.755	0
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

The regression equation for cutting force is:
S = 47.7137 , PRESS = 220848 R-Sq = 98.52%, R-Sq.(pred) = 82.02% R-Sq(adj) = 96.48 %

Table 10 Estimated regression coefficient for Ra

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	1.44712	0.05174	27.969	0
Block 1	0.14837	0.04508	3.291	0.011
Block 2	-0.0283	0.04508	-0.628	0.548
speed	-0.062	0.04235	-1.464	0.181
feed	0.405	0.04235	9.562	0
doc	0.189	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	1.98	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)

Table 11 Estimated regression coefficient for Tool wear

Term	**Coef**	**SE Coef**	**T**	**P**
Constant	0.719438	0.03557	20.227	0
Block 1	-0.124516	0.03099	-4.018	0.004
Block 2	-0.000516	0.03099	-0.017	0.987
speed	-0.0063	0.02912	-0.216	0.834
feed	0.151	0.02912	5.186	0.001
doc	0.2039	0.02912	7.003	0
speed*speed	0.133873	0.0562	2.382	0.044
feed*feed	-0.146627	0.0562	-2.609	0.031
doc*doc	-0.118127	0.0562	-2.102	0.069
speed*feed	0.04075	0.03255	1.252	0.246

speed*doc	0.0725	0.03255	2.227	0.057
feed*doc	0.0285	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 %

Contours and Surface Plots

Plots of cutting force

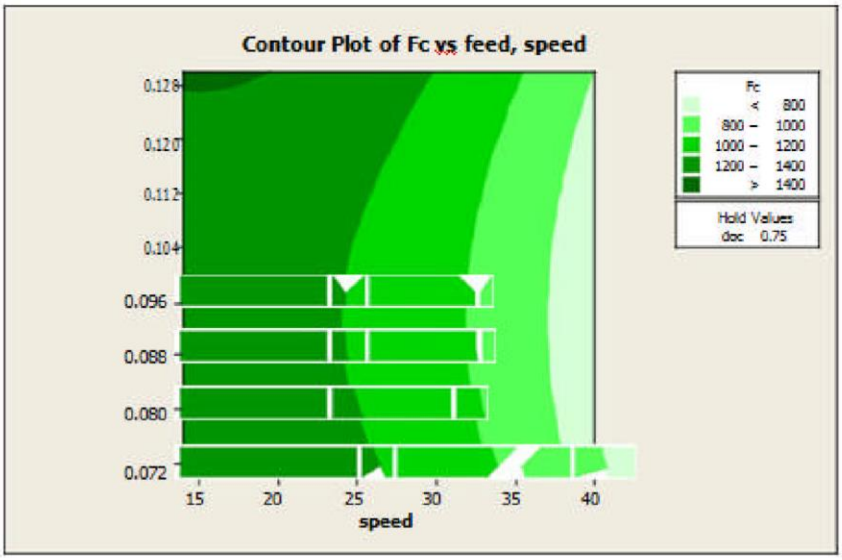


Fig11: contour plot Fc vs feed , speed

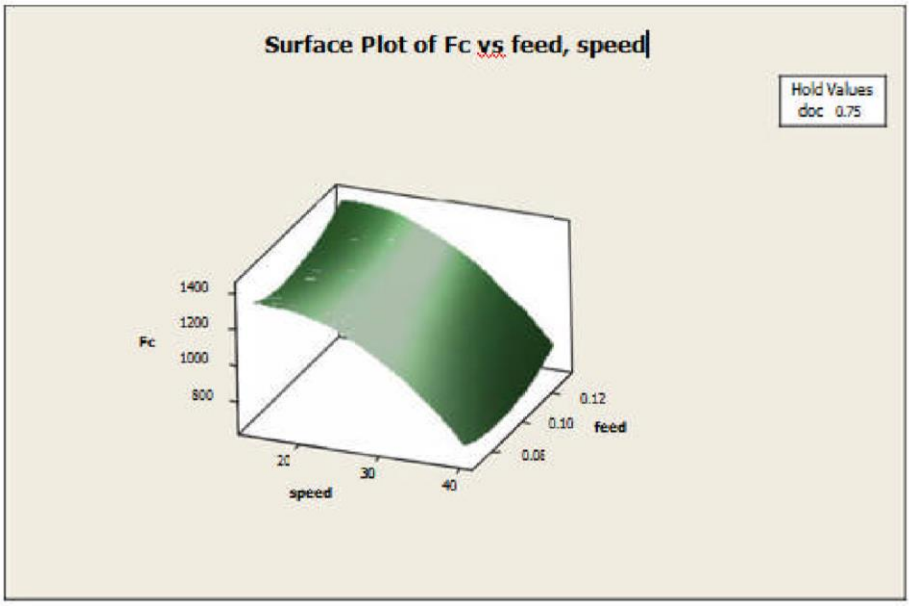


Fig 12: surface plot Fc vs feed, speed

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

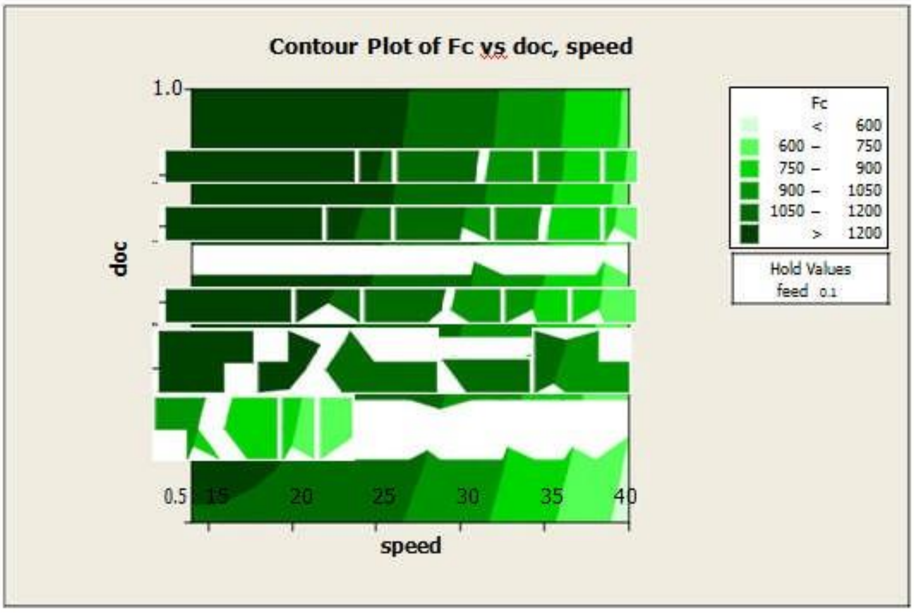


Fig 13: contour plot Fc vs Doc, speed

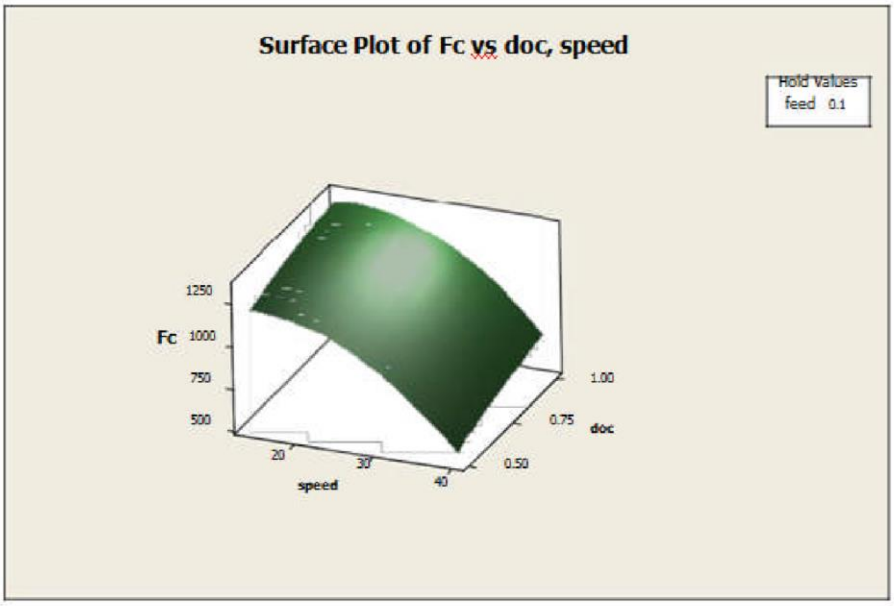


Fig14: Surface plot Fc vs doc, speed

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

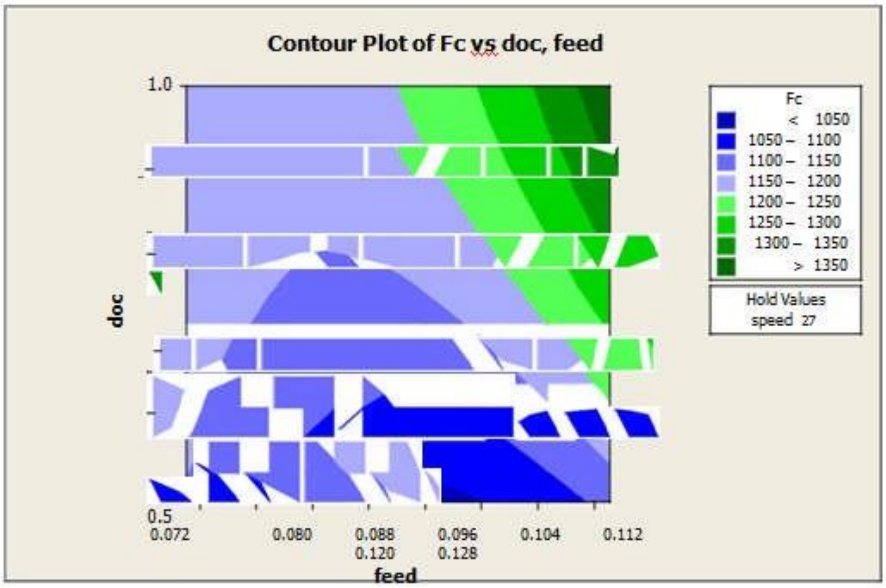


Fig 15: contour plot Fc vs doc, feed

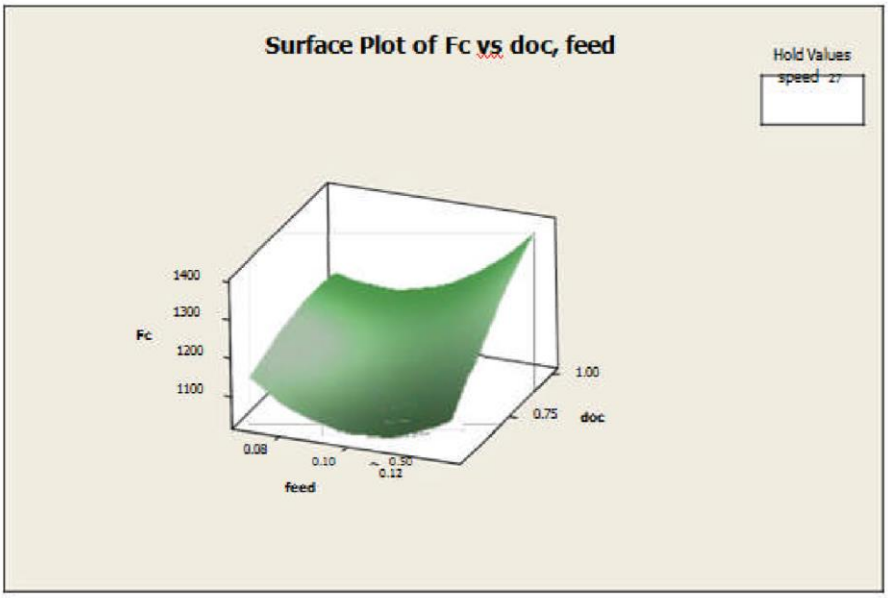


Fig 16: surface plot Fc vs doc, feed

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

Plots for Ra.

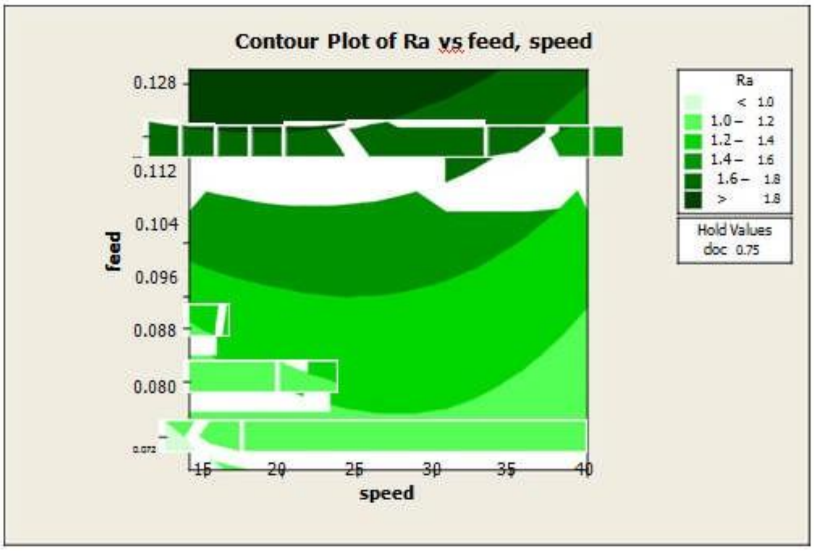


Fig 17: contour plot Ra vs feed, speed

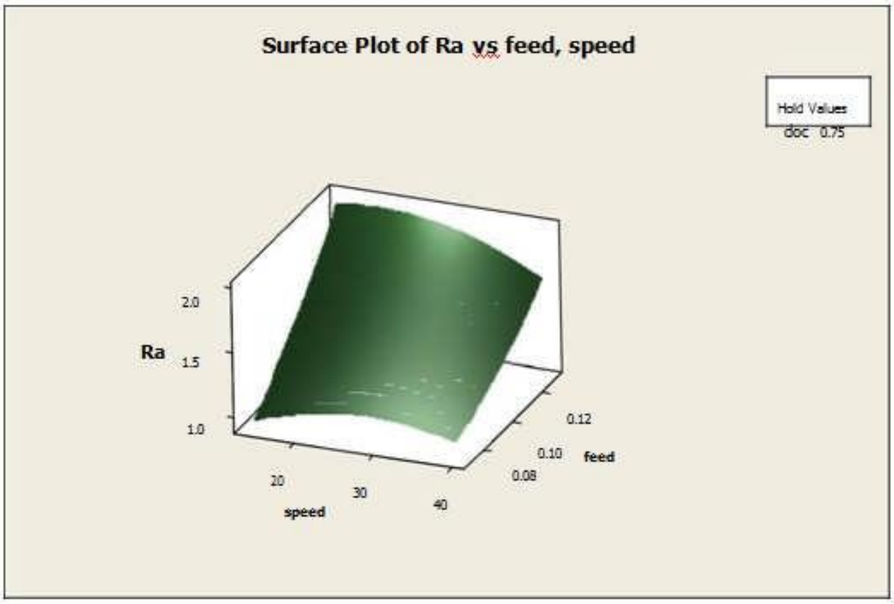


Fig 18: surface plot Ra vs feed, speed

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.

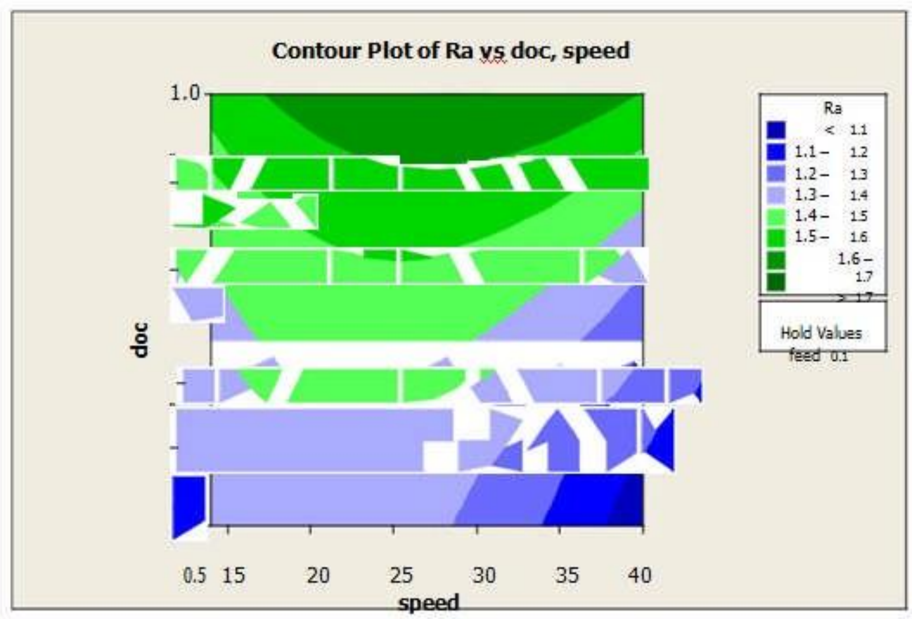


Fig 19: contour plot Ra vs doc, speed

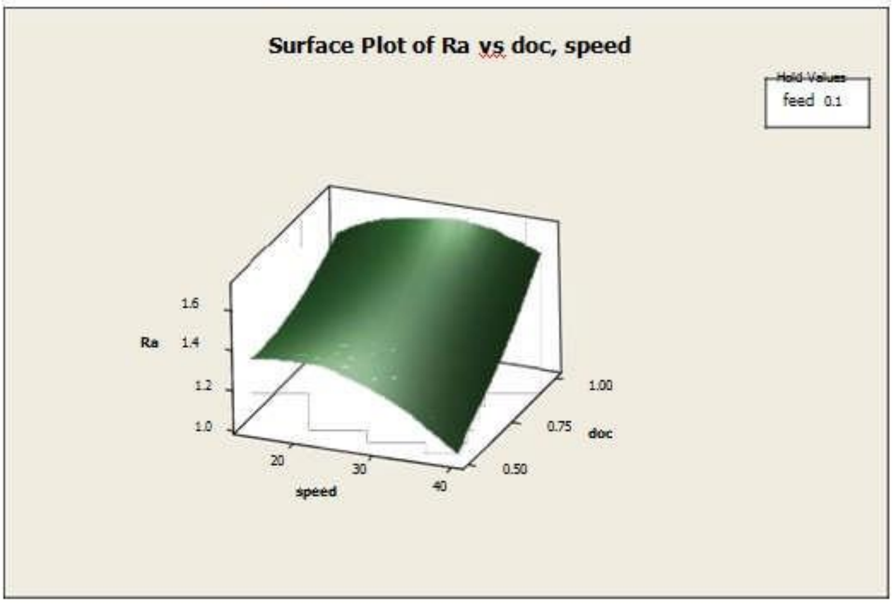


Fig 20: surface plot Ra vs doc, speed

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

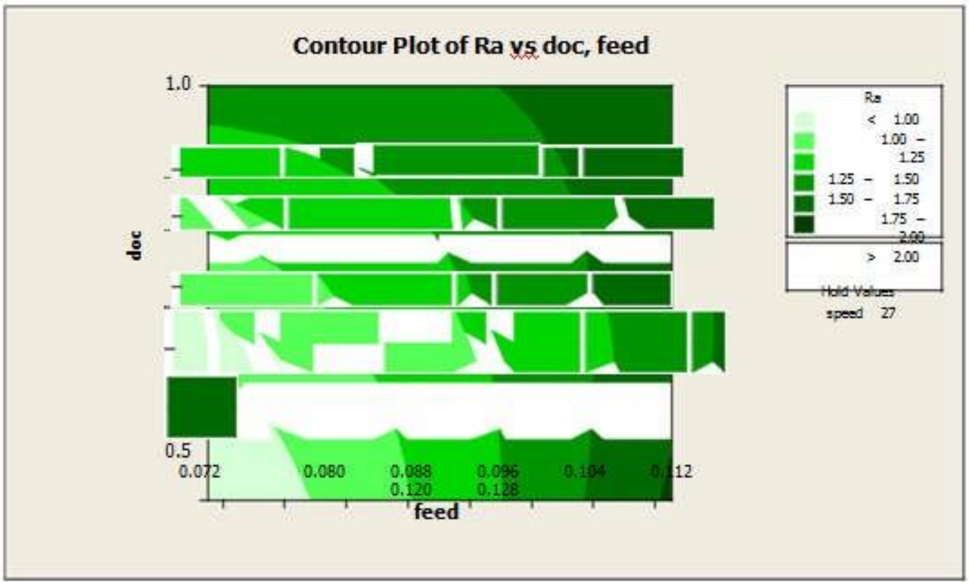


Fig 21: contour plot Ra vs doc , feed

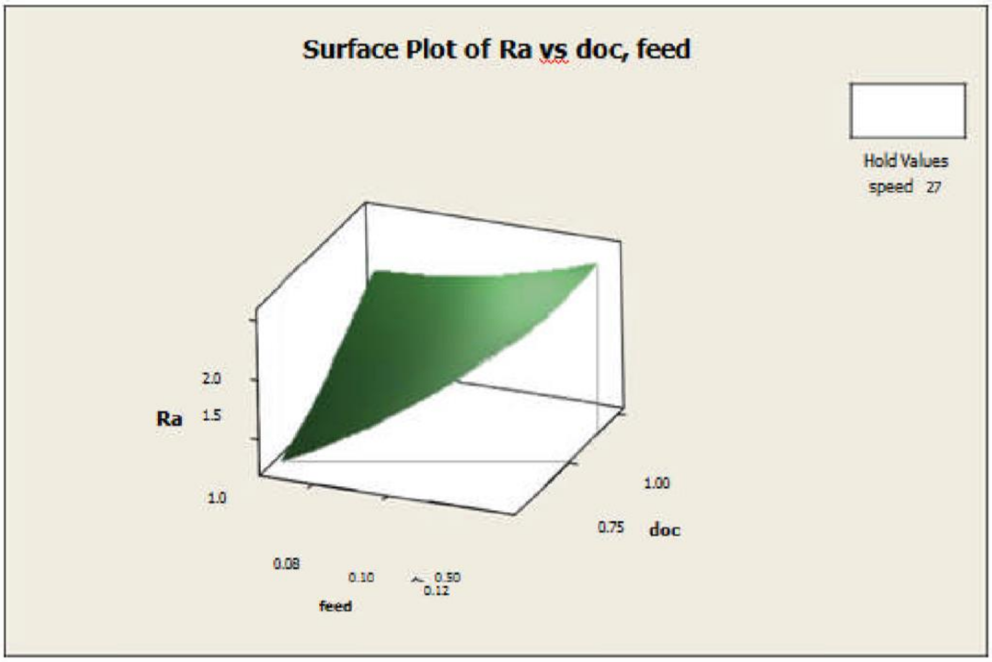


Fig 22: surface plot Ra vs doc, feed

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

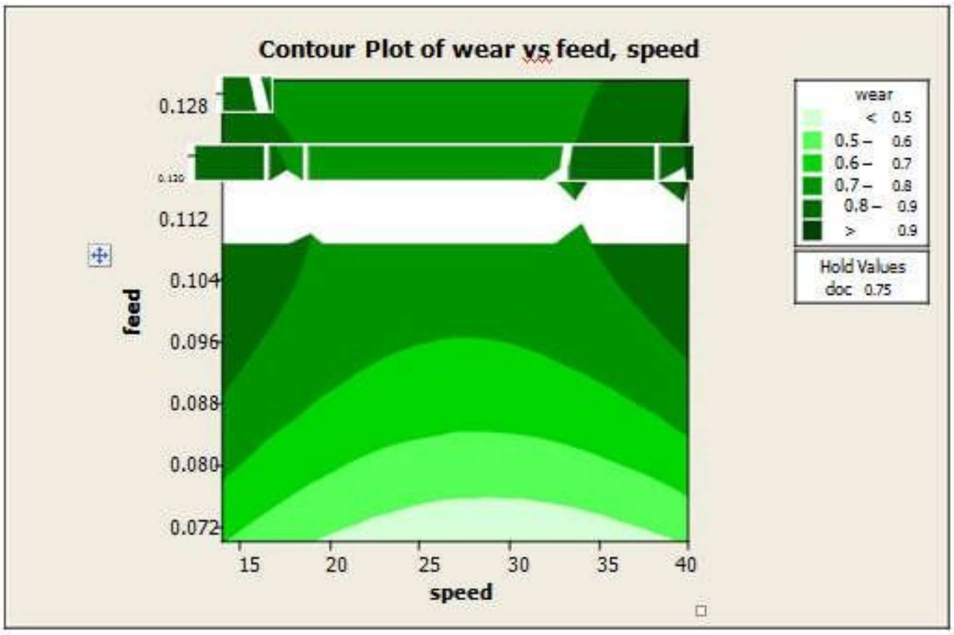


Fig 23: contour plot Wear vs feed, speed

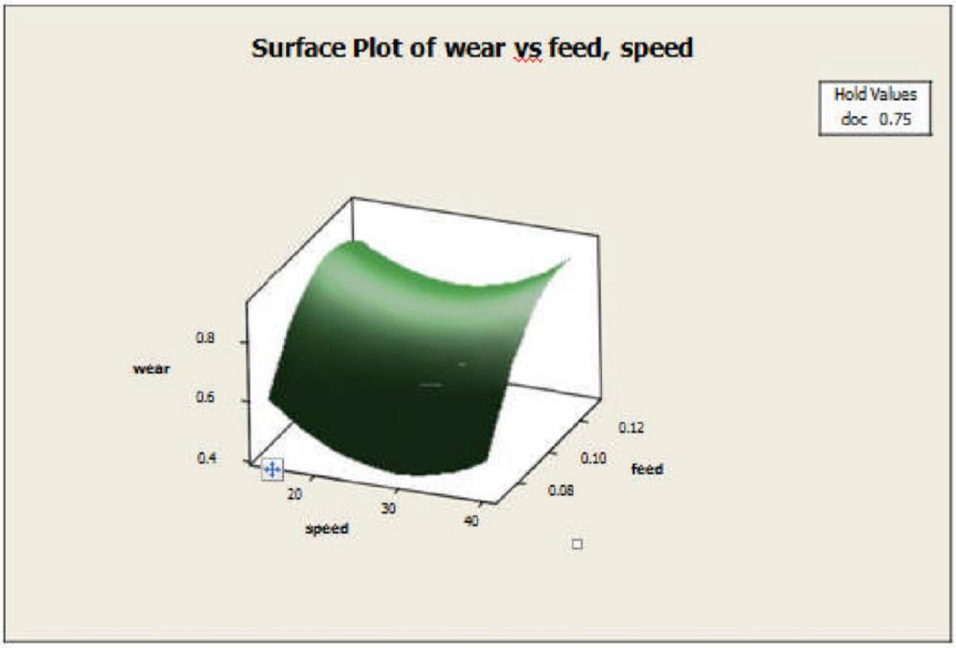


Fig 24: surface plot wear vs feed, speed Tool wear first decreases up to certain increase in speed and then increase with further increase in speed. Low feed is favorable for lower wear and it increases with feed.

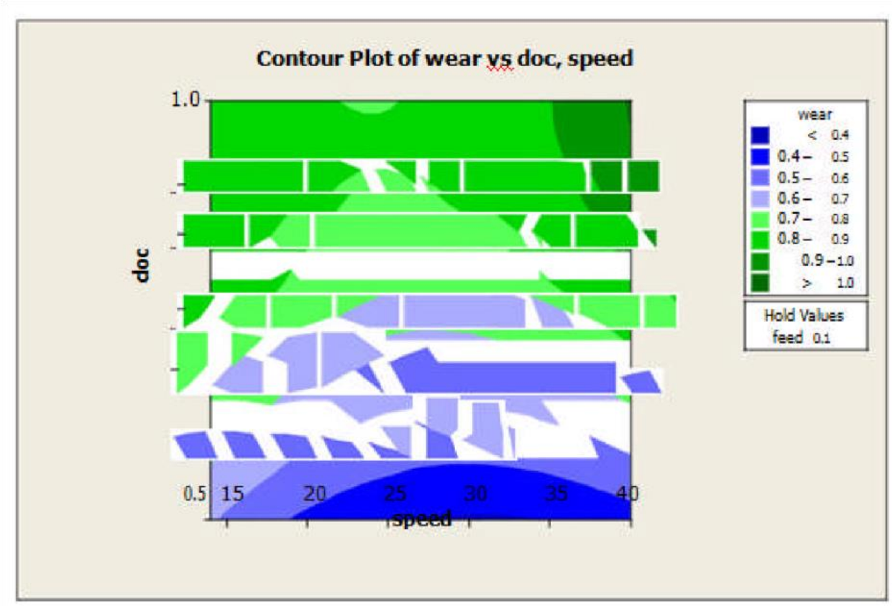


Fig 25: contour plot wear vs doc, speed

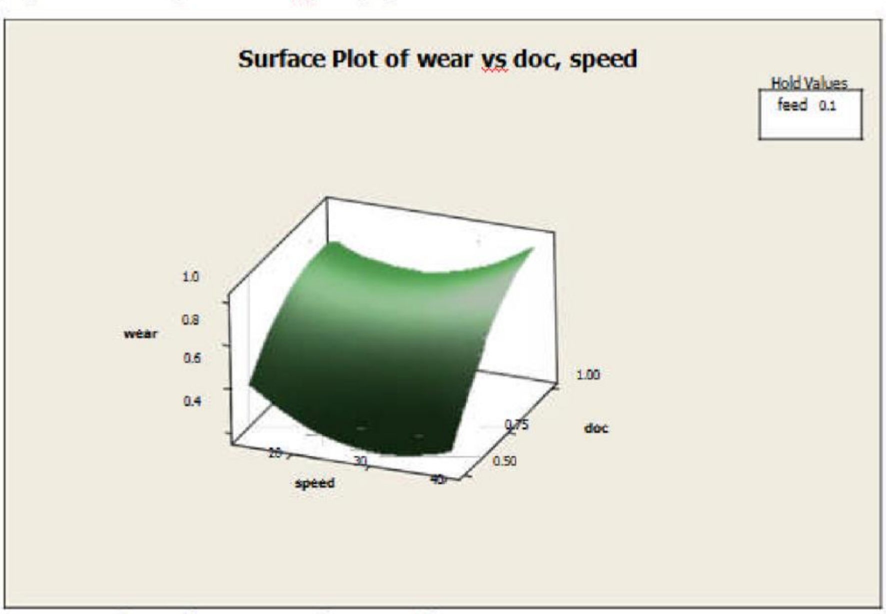


Fig 26: surface plot wear vs doc, speed

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.

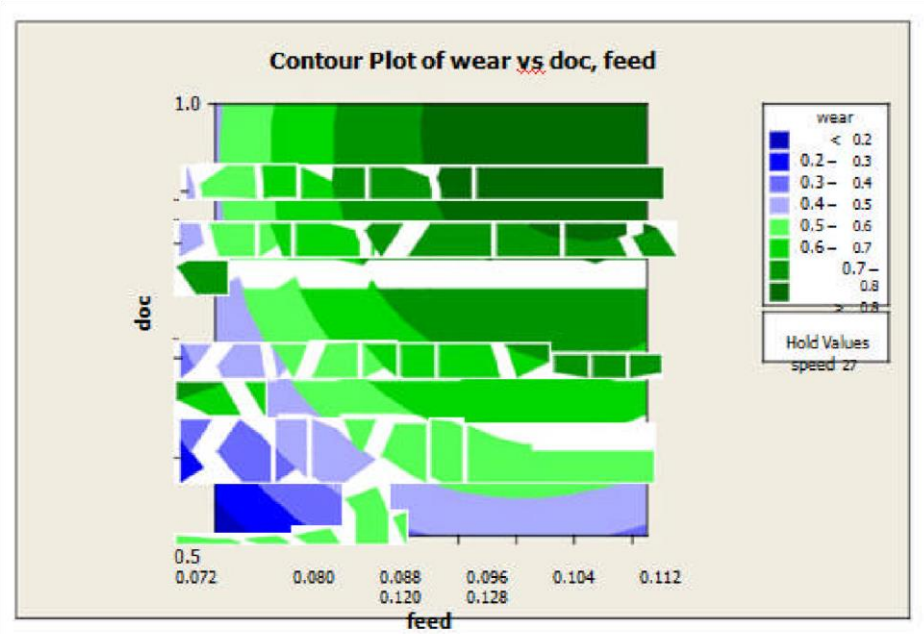


Fig 27: contour plot wear vs doc, feed

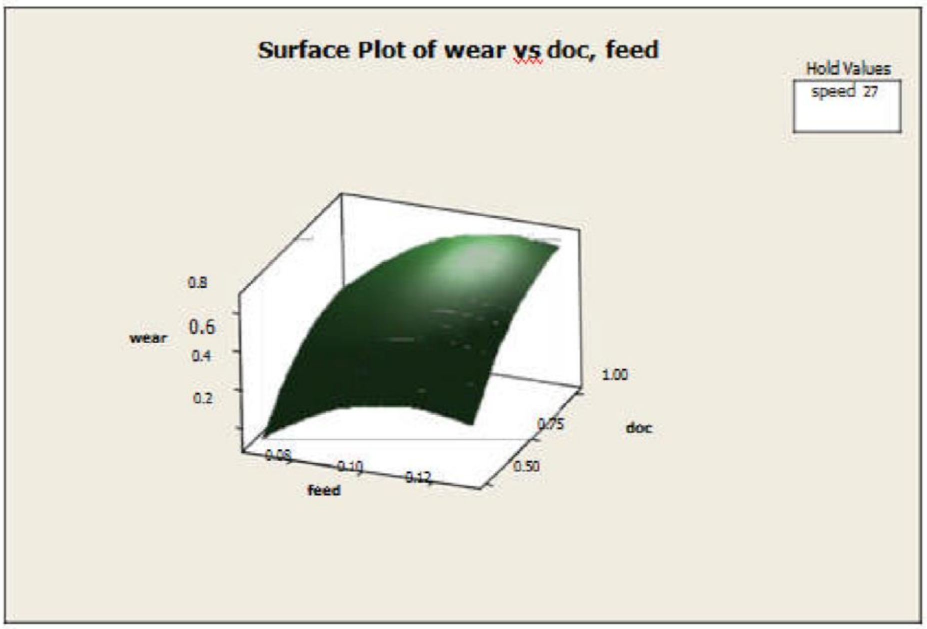


Fig 28: surface plot wear vs doc, feed

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.

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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