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Evalution of Surface Finish on Machining Of Mild Steel Using High Speed Steel Tool in Lathe with Normal Coolant (Or) Nano Material Added Coolant

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Abstract: *Surface finish is one of the prime requirements of industrial machining. The purpose of this project is focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning. This paper presents an experimental study to investigate the effects of cutting parameters like spindle speed, feed, depth of cut and nano material added type of coolant on surface finish on EN-8 by HSS M2 tool. The objective was to establish correlation between cutting speed, feed rate, depth of cut and type of coolant to optimize the turning conditions based on surface roughness. The study was conducted through RSM method with the help of Design Expert 8.0 software. We have used Servo cut of Indian oil or cool edge SL of Castrol used with water in a ratio of 1:20 as per manufacturer specification. The experiment conducted with 3 different speed, feed and DOC with out nano material ordinary coolant and with one nano material (TiO_2) included coolant for L27 method.*
Key Words: *Turning, Surface Roughness, Regression Surface Methodology(RSM), Sum Of Squares (SOS), Degree Of Freedom (DOF), surface roughness.*

I. Introduction

Surface roughness has received serious attention for many years. It has formulated an important design feature in many situations such as parts subject to fatigue loads, precision fits, fastener holes, and aesthetic requirements. In addition to tolerances, surface roughness imposes one of the most critical constraints for the selection of machines and cutting parameters in process planning. Surface finish is the method of measuring the quality of a product and is an important parameter in machining process. It is one of the prime requirements of customers for machined parts. Productivity is also necessary to fulfill the customers demand. For this purpose quality of a product and productivity should be high. In addition to the surface finish quality is also an important characteristic in turning operation and high MRR is always desirable. Even in the occurrence of chatter or vibrations of the machine tool, defects in the structure of the work material, wear of tool, or irregularities of chip formation contribute to the surface damage in practice during machining.

1.1 Turning : Turning is a process, in which materials machined with the single point cutting tools which held stationary and work piece rotates. A large number of operations are required to produce the finished product, if some of the operations can be combined, or rough turning, heat treatment, and then grinding process. Surface roughness plays an important role as it influences the fatigue strength, wear rate, coefficient of friction, and corrosion resistance of the machined components. In actual practice, there are many factors which affect the surface roughness, i.e., tool variables, work piece hardness and cutting conditions. Theoretical turning, surface finish has been found to be influenced by a number of factors such as feed rate, cutting speed, tool nose radius and tool geometry, cutting time, work piece hardness, stability of the machine tool and the work piece set up. Surface roughness increases with increasing the feed rate but decreased with increasing the cutting speed and the depth of cut, respectively. The experiments were carried out using different feed rates (0.05, 0.10, 0.15 mm/rev) and different cutting speeds (220, 360, 560rpm) and different depth of cuts (0.25, 0.50, 0.75 mm) with (or) with out nano material (TiO_2) added fluid coolant. The turning operation is done on PSG A124 lathe (Fig 1).

Fig 1

Fig 2

1.2. Measurement of Surface Roughness There are many ways to define surface roughness depending on its applications like Ra, Ry, Rz, but roughness average Ra is widely used in industry for the mechanical components for indication of surface roughness, also known as arithmetic aver-age (AA) or centre line average (CLA) is the area between surface profile and centre line hence in this study Ra is used for indication of surface roughness $Ra = 1/L \times (Y(x))$ Whereas L is the sample length, Y(x) is the profile along the direction x. Surface roughness plays an important role in product quality. Developing an empirical model for the prediction of surface roughness in turning. The model considers the following working parameters feed, depth of cut, spindle speed, and nano material added coolant effect. Measured the surface roughness by Mitutoyo SJ310 (Fig 2).

II. Experimental Work

The experiment was conducted using one work piece material namely EN-8 with High Speed Steel tool and normal machine coolant. The tests were carried for a length of 100mm and Ø28mm in a PSG A124 lathe. The cutting parameters are shown in the Table 1. Three levels of cutting speed, three levels of feed and three levels of depth of cut were used and are shown in the Table 1. The different alloying elements present in a work piece and cutting tool are shown in the table 2 & 3.

Cutting Parameters	Level 1	Level 2	Level 3
Speed (rpm) (A)	220	360	560
Feed (mm) (B)	0.05	0.10	0.15
Depth Of Cut (mm) (C)	0.25	0.5	0.75

Table 1

2.1 HSS M2 Tool

Shaping of M2 tool steels can be carried out using grinding methods. However, they have poor grinding capability and hence they are regarded as "medium" machinability tool steel under annealed conditions. The machinability of these steels is only 50% of that of the easily machinable W group or water hardening tool steels. Tool life HSS M2 is high-speed steel in tungsten–molybdenum series. The carbides in it are small and evenly distributed. It has high wear resistance. After heat treatment, its hardness is the same as T1, but its bending strength can reach 4700 M Pa, and its toughness and thermo plasticity are higher than T1 by 50%. It is usually used to manufacture a variety of tools, such as drill bits, taps and reamers. Its decarburization sensitivity is a little bit height.

Grade	C	Cr	Mo	W	V
M2	0.95	4.2	5.0	6.0	2.0

Table 2

2.2 Work Piece EN 8

Mild steel EN8 size of D28mm × 100mm rods. Mild steel is the most common form of steel because it's price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low-carbon steel contains approximately 0.05–0.3% carbon. Mild steel has a relatively low tensile strength. Surface hardness can be increased through carburizing. It is often used when large quantities of steel are needed.

Cr	Mn	Si	P	S
0.4	0.8	0.3	0.05	0.5

Table 3.

III. Results And Discussion With Out Nano Fluid (Normal Coolant)

Sl no	Speed (mm)	Feed (mm)	DOC (mm)	MRR (mm3/ sec)	Ra (µm)	Rq(µm)	Rz(µm)
1	220	0.05	0.25	3.63	6.662	7.890	29.045
2	220	0.05	0.50	7.34	5.330	6.368	25.452
3	220	0.05	0.75	11.12	6.547	7.858	31.040
4	220	0.10	0.25	7.26	4.856	6.141	23.180
5	220	0.10	0.50	14.68	5.655	6.852	26.950
6	220	0.10	0.75	22.25	5.141	6.423	24.379
7	220	0.15	0.25	10.91	5.342	6.642	25.520
8	220	0.15	0.50	22.03	6.902	8.447	34.781
9	220	0.15	0.75	33.37	5.865	7.405	28.871
10	360	0.05	0.25	5.95	4.241	5.137	22.041
11	360	0.05	0.50	12.01	5.624	6.647	25.068
12	360	0.05	0.75	18.20	5.131	6.314	28.121
13	360	0.10	0.25	11.90	6.437	7.747	33.523
14	360	0.10	0.50	24.02	5.821	7.414	32.937
15	360	0.10	0.75	36.41	5.932	7.607	33.452
16	360	0.15	0.25	17.85	5.769	7.340	32.540
17	360	0.15	0.50	36.05	5.315	6.241	25.182
18	360	0.15	0.75	54.61	4.450	5.415	23.947
19	560	0.05	0.25	9.26	4.815	6.017	22.912
20	560	0.05	0.50	18.68	5.234	6.214	23.851
21	560	0.05	0.75	28.31	2.538	3.170	15.537
22	560	0.10	0.25	18.51	4.831	5.771	23.051
23	560	0.10	0.50	37.37	5.420	6.702	28.907
24	560	0.10	0.75	56.63	5.314	6.301	25.326
25	560	0.15	0.25	27.77	4.875	6.241	23.314
26	560	0.15	0.50	56.08	4.307	5.221	22.992
27	560	0.15	0.75	84.95	5.485	6.919	29.557

Table 4.

3.1.1 Results And Discussion

Response 1 Ra ANOVA for Response Surface Quadratic Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	5.36	3	1.79	2.78	0.0640 not
A - Speed	5.15	1	5.15	8.01	0.0095
B - Feed	0.16	1	0.16	0.25	0.6229
C - DOC	0.048	1	0.048	0.075	0.7865
Residual	14.78	23	0.64		
Cor Total	20.13	26			

Table 5 Ra Calculation Table

Final equation of actual factors

Ra = 6.45004 - 0.003129 Speed + 1.8833 Feed - 0.20711 DOC

Response 2 Ry ANOVA for Response Surface 2FI Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	8.44	3	2.81	3.01	0.0511 not
A - Speed	7.52	1	7.52	8.03	0.0094
B - Feed	0.85	1	0.85	0.90	0.3514
C - DOC	0.075	1	0.075	0.080	0.7795
Residual	21.54	23	0.94		
Cor Total	29.99	26			

Table 6 Ry Calculation Table

Final equation of actual factors **Ry = 7.68 - 0.00378 Speed + 4.339 Feed - 0.2585 DOC**

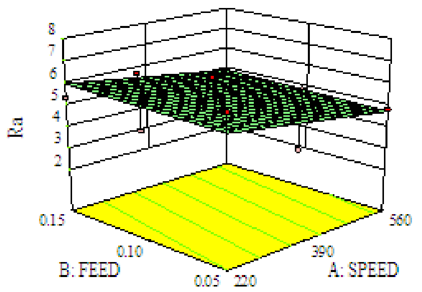
Response 3 Rz ANOVA for Response Surface Linear Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	112.23	3	37.41	2.12	0.1250 not
A - Speed	72.42	1	72.42	4.11	0.0544
B - Feed	39.58	1	39.58	2.25	0.1476
C - DOC	0.23	1	0.23	0.013	0.9093
Residual	405.28	23	17.62		
Cor Total	517.51	26			

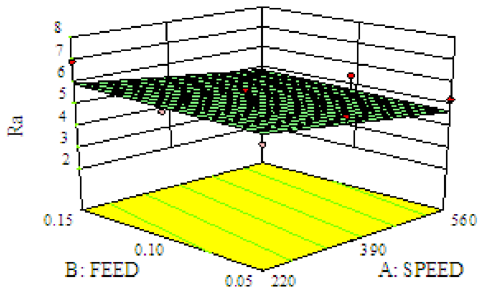
Table 7 Rz Calculation Table

Final equation of actual factors **Rz = 27.875 - 0.01173 Speed + 29.65 Feed + 0.45578 DOC**

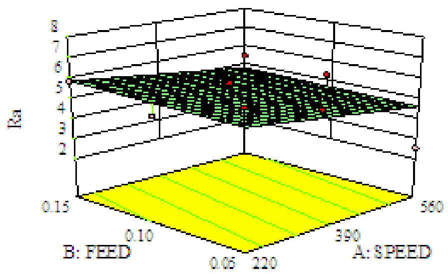
In the next page graph between Speed and Feed for various feed rates and the difference between theoretical derived formula value and actual surface finish achieved is shown.



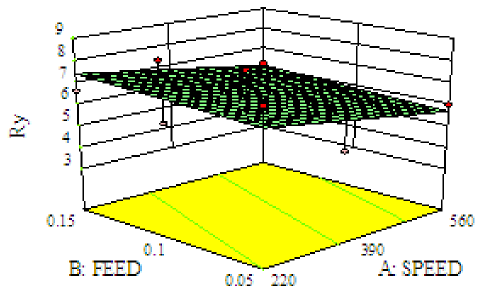
Graph 1: Ra for Speed with Feed of DOC 0.25



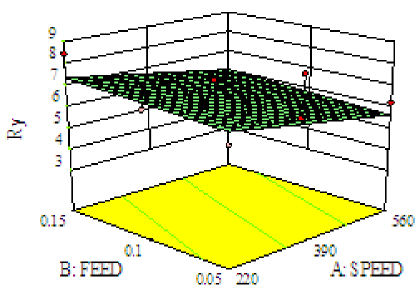
Graph 2: Ra for Speed with Feed of DOC 0.50



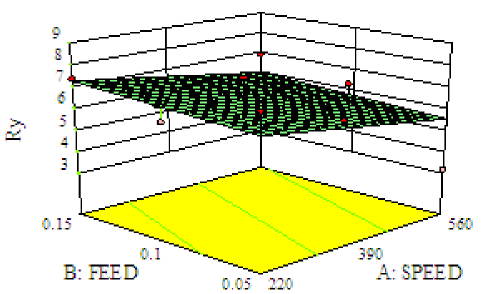
Graph 3:Ra for Speed with Feed of DOC 0.75



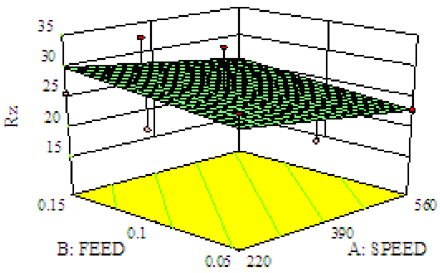
Graph 4:Ry for Speed with Feed of DOC 0.25



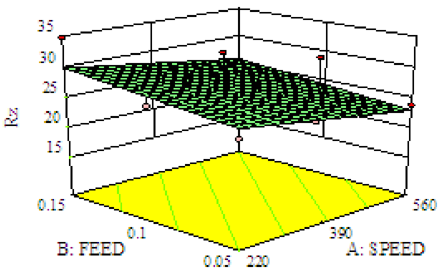
Graph 5:Ry for Speed with Feed of DOC 0.50



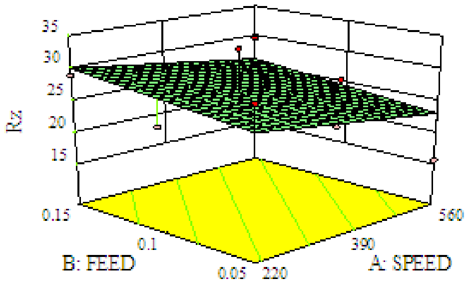
Graph 6:Ry for Speed with Feed of DOC 0.75



Graph 7:Rz for Speed with Feed of DOC 0.25



Graph 8:Rz for Speed with Feed of DOC 0.50



Graph 9:Rz for Speed with Feed of DOC 0.75

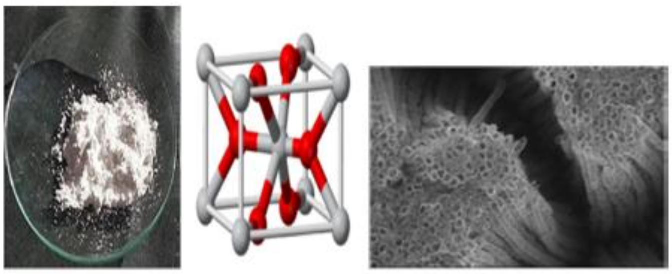


Figure 3. TiO_2 Powder and nano tube construction

3.2.1 Preparation of TiO_2 nano material added fluid

The TiO_2Nanoparticle is mixed with the conventional cutting fluid. The conventional cutting fluid is a mixture of soluble oil and water in the proportion of the TiO_2 is mixed in the concentration of 0.1% with the cutting fluid. The nano cutting fluid is prepared for 3 litres. The mass of the TiO_2 nanoparticle required for the preparation of nano fluid is calculated as follows

Density of TiO_2= 4230 kg/m³, One litre $=\frac{1}{1000}m^3$, $\frac{Mass}{Volume}$=Density, Mass = Density × Volume, For 1 litre the mass of TiO_2 required is Mass = 4230 $\times \frac{1}{1000}$ = 4.23 kg , At 0.1% concentration Mass = 4.23 $\times \frac{0.1}{100} \times 1000$ = 4.23 gm, for 3 litres the mass of TiO_2 is Mass = 4.23 × 3 = 12.69 gm

The mass of the TiO_2 required for the preparation of the nanofluid is 12.69 gm. This Nano particle is mixed with the cutting fluid using "Ultrasonic Vibrator" in the Nano science laboratory. Then the Nano cutting fluid is used as the coolant the machining operation.

Sl no	Speed (mm)	Feed (mm)	DOC (mm)	MRR (mm3/ sec)	Ra (µm)	Rq(µm)	Rz(µm)
1	360	0.05	0.25	5.95	3.2255	3.568	21.2845
2	360	0.10	0.25	11.90	4.021	4.4575	16.7535
3	560	0.10	0.75	56.63	4.1245	4.3245	17.488
4	560	0.05	0.50	18.68	2.1075	2.647	13.314
5	360	0.10	0.50	24.02	4.261	4.471	17.2145

6	560	0.05	0.75	28.31	2.358	3.0255	14.2845
7	560	0.10	0.50	37.37	3.9935	4.426	16.9265
8	360	0.15	0.75	54.61	4.856	4.924	18.8425
9	220	0.15	0.50	22.03	5.0125	5.654	22.8865
10	560	0.05	0.25	9.26	2.2465	2.4285	12.6825
11	360	0.15	0.50	36.05	4.769	5.1245	21.624
12	560	0.15	0.75	84.95	4.594	4.8645	18.6142
13	220	0.05	0.50	7.34	4.234	4.562	18.8785
14	220	0.15	0.25	10.91	4.8665	5.1265	22.6475
15	360	0.05	0.75	18.20	3.4565	5.8545	24.8755
16	360	0.05	0.50	12.01	3.566	3.8945	17.426
17	220	0.10	0.50	14.68	4.9645	5.214	21.642
18	220	0.05	0.25	3.63	3.8465	3.9025	15.6465
19	560	0.15	0.25	27.77	4.234	4.336	16.2855
20	220	0.15	0.75	33.37	5.345	5.9855	23.1245
21	220	0.10	0.25	7.26	4.6845	4.0245	16.0245
22	220	0.10	0.75	22.25	5.126	5.3045	22.467
23	220	0.05	0.75	11.12	4.6545	5.102	21.423
24	360	0.10	0.75	36.41	4.3895	4.946	19.147
25	360	0.15	0.25	17.85	4.3465	4.762	18.3425
26	560	0.10	0.25	18.51	3.6325	3.942	16.984
27	560	0.15	0.50	56.08	4.364	4.7365	18.4241

Table 8 Experimental Readings

3.2.2 RESULTS AND DISCUSSION

Response 1 Ra ANOVA for Response Surface Quadratic Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	18.74	9	2.08	86.82	<0.0001
A - Speed	6.82	1	6.82	284.28	<0.0001
B - Feed	9.41	1	9.41	392.34	<0.0001
C - DOC	0.77	1	1.37	57.24	<0.0001
AB	1.37	1	1.37	57.24	<0.0001
AC	0.045	1	0.045	1.87	0.1897
BC	3.23×10^{-3}	1	3.23×10^{-3}	0.13	0.7180
A^2	0.12	1	0.12	5.02	0.0387
B^2	0.74	1	0.74	30.76	<0.0001
C^2	5.340×10^{-6}	1	5.340×10^{-6}	0.22	0.6431
Residual	0.41	17	0.024		
Cor Total	19.15	26			

Table 9 Ra Calculation Table

Finalequationofactualfactors**Ra=4.36881(0.010831×Speed)+(26.45443×Feed)+(1.73395×DOC)+(0.039594×Speed×Feed)– (1.42968×10^{-3}×Speed×DOC) + (1.3133×Feed×DOC) + (5.08473×10^{-6}×Speed^2)-(140.2667×Feed^2)–(0.47733×DOC^2)**

Response 2 Ry ANOVA for Response Surface 2FI Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	17.04	6	2.84	16.89	<0.0001
A - Speed	5.95	1	5.95	35.38	<0.0001
B - Feed	6.44	1	6.44	38.25	0.0003
C - DOC	3.21	1	3.21	19.07	0.0491
AB	0.74	1	0.74	4.39	0.2004
AC	0.29	1	0.29	1.75	0.0898
BC	0.53	1	0.53	3.18	
Residual	3.36	20	0.17		
Cor Total	20.41	26			

Table 10 Ry Calculation Table

Final equation of actual factors **Ry=3.30956-(4.43364×10^{-3}×Speed) + (9.11066×Feed)+ (4.81313×DOC) + (0.029035×Speed×Feed) –(3.66963×10^{-3}×Speed×DOC) –(16.89×Feed×DOC)**

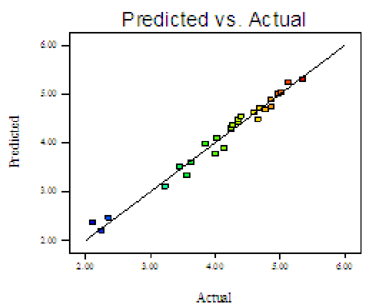
Response 3 Rz ANOVA for Response Surface Linear Model Analysis of variance table [Partial sum of squares - Type III]

Source	SOS	DOF	Mean Square	Fo Value	P- Value Prob>F
Model Significant	147.81	3	48.27	10.19	0.0002
A - Speed	92.38	1	92.38	19.11	0.0002
B - Feed	24.44	1	24.44	5.06	0.0344
C - DOC	30.98	1	30.98	6.41	0.0186
Residual	111.17	23	4.83		
Cor Total	258.98	26			

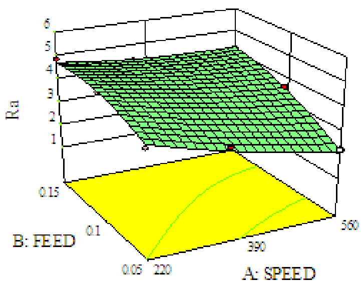
Table 11 Rz Calculation Table

Final equation of actual factors **Rz = 18.79626- (0.013257×Speed) + (23.30667×Feed) + (5.24789×DOC)**

In the next page graph between Speed and Feed for various feed rates and the difference between theoretical derived formula value and actual surface finish achieved is shown.

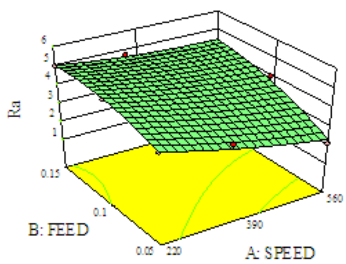


Graph 10: Ra actual and predicted

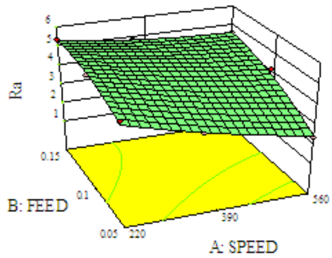


Graph 11: Ra for Speed with Feed of DOC 0.25

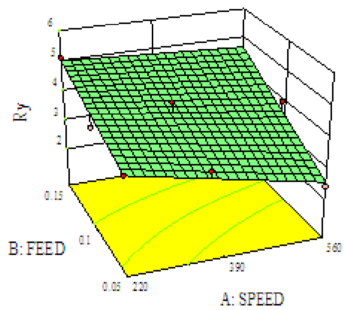
Feed of DOC 0.25



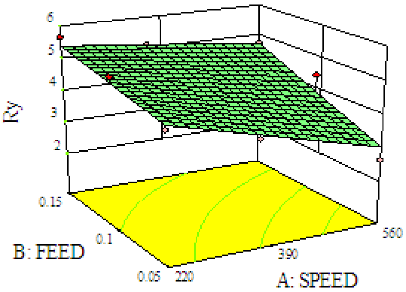
Graph 12: Ra Speed with Feed of DOC 0.50



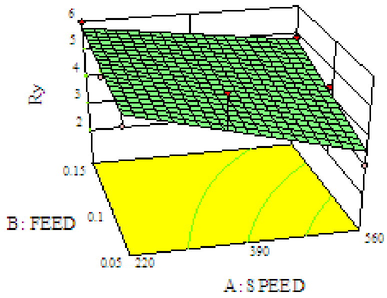
Graph 13: Ra Speed with Feed of DOC 0.75



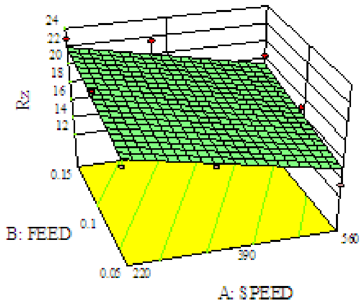
Graph 14: Ry for Speed with Feed of DOC 0.25



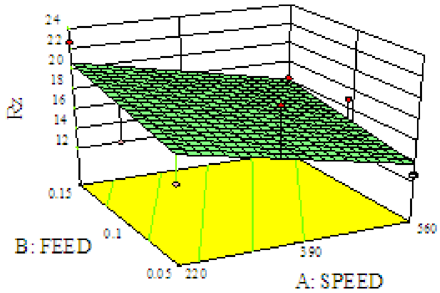
Graph 15 : Ry Speed with Feed of DOC 0.50



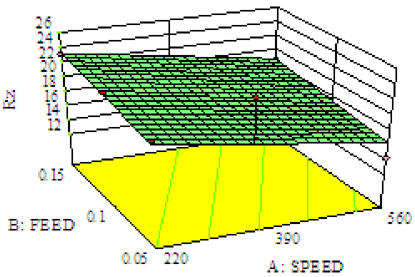
Graph 16: Ry Speed with Feed of DOC 0.75



Graph 17: Rz Speed with Feed of DOC 0.25

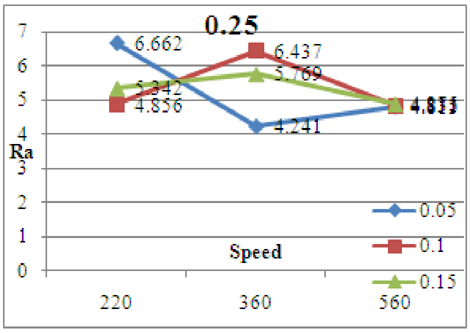


Graph 18: Rz Speed with Feed of DOC 0.50

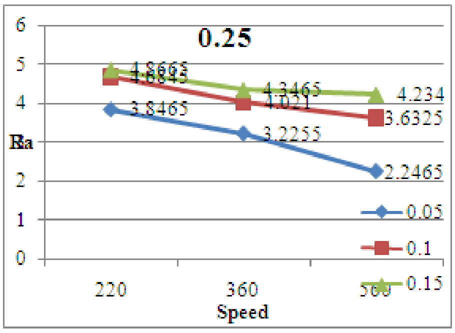


Graph 19: Rz Speed with Feed of DOC 0.75

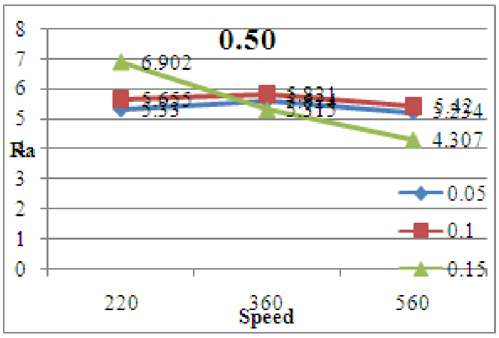
3.3comparison Graph Between With And With Out Nano Material Added Coolant



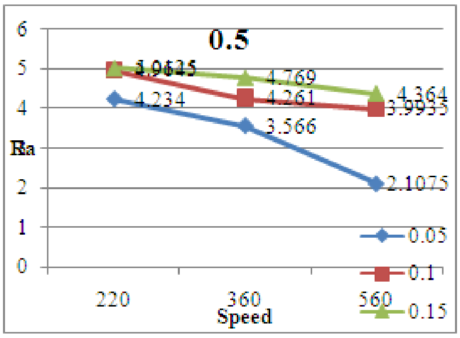
Graph: 20 Normal coolants



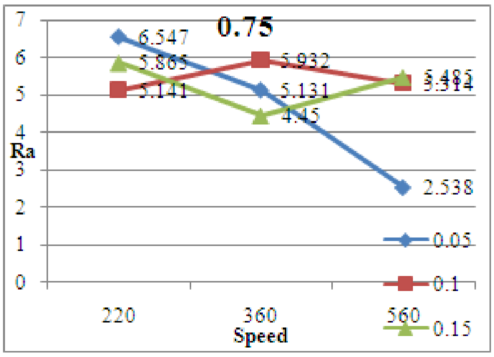
Graph: 21 Nano material added coolant



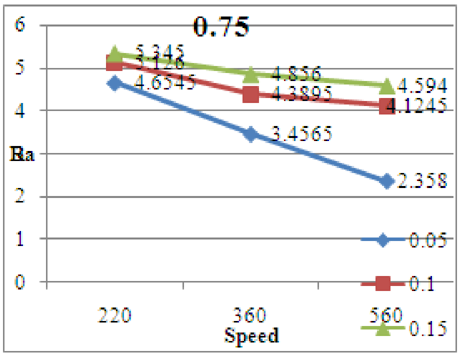
Graph: 21 Normal coolants



Graph: 22 Nano material added coolant



Graph: 23 Normal coolants



Graph: 24 Nano material added coolant

IV. Conclusion

From the above with nomal coolant and with nano material added coolant both levels High Speed and Low feed rate gives minimum surface finish. When comparing coolant type the TiO_2 added nano material coolant gives good level surface finish reading. From the ANOVA tabulations and calculation the parameters which influence the Surface Roughness are found. The factors and the levels that influencing are High speed and the interaction factor is High speed with low feed . This shows that the Surface Roughness is low at the maximum speed and at minimum feed and with perfect nano material added coolant. Depth of cut does not have much influence over Surface Roughness. From RSM method in Design Expert 8.0 7.1 software came to know the equation to calculate Ra, Ry, Rz and the correct best setting to get good surface finish.

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