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PARAMETRIC ANALYSIS OF DRY AND WET TURNING ON CNC LATHE USING DESIGN OF EXPERIMENT

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Abstract: In this research paper, the effects of cutting fluid and dry cutting on surface roughness and cutting force (F_z) have been examined in CNC turning of EN9 (AISI1055) medium carbon steel material and carbide with coated (TiN) tool. Full-Factorial parameter design is an important tool, which offers a simple and systematic approach to optimize a design for performance, quality and cost. ANOVA analysis were also performed to obtain Significant factors influencing Surface Roughness and Cutting Force which gives the percentage contribution of each process parameter. The Regression analysis is used to estimate the regression coefficients that minimize the error.
Keyword: CNC turning, Full factorial design, ANOVA analysis, Regression analysis, Surface Roughness, Cutting Force.

I. INTRODUCTION

Metal cutting is one of the most extensively used manufacturing processes, and its technology continues to advance in parallel with the developments in material from surface of a work-piece to achieve the desired product. The most common types of cutting process are turning, milling and drilling [1]. Turning is the process of removing material from the outer diameter of the work-piece. In the turning process, the single point cutting tool is moving with a certain velocity while the work-piece is rotating. It is used mainly to produces work-pieces with conical, curved or grooved shapes. The turning process is illustrated in Figure 1.

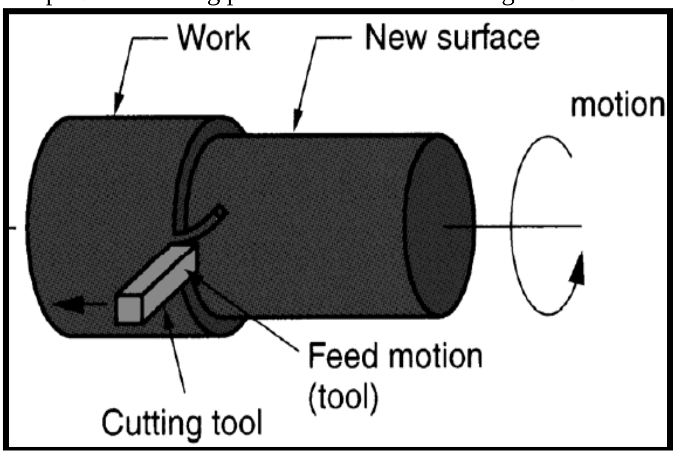


Figure 1 Turning Process.

The turning processes are carried out on a lathe machine and the automatic turning process is performed by the CNC (Computer Numerical Control) lathe machine. The typical cutting tool used in the CNC machine has a replaceable cutting edge (tool insert) [2]. Dry machining means that no cutting fluid is used during process. During dry machining process, temperature of the cutting tool is very high and this induces excessive tool wear thus decreasing tool life. [3]

II. LITERATURE REVIEW

A.S.Varadarajan, P.K.Philip (2000) has investigated on hard turning with minimal cutting fluid application (HTMF) and its comparison with dry and wet turning under parameters of speed, feed and Depth of cut by using combination of AISI 4340 steel material and SNMG 120408 with a P30 tool material[4]. Chrong-Jyh-Tzeng, Yu-Hsin Lin, Ming-Chang Jeng (2009) has investigated the optimization of CNC turning operation parameters like speed, feed and depth of cut for SKD11 (JIS) using the Taguchi and Grey relational analysis method. The cutting tool is made of carbide and coated with titanium nitride (TiN) and Water-soluble cutting fluids are mixed with water at different ratios depending on the machining operation [8]. O.Cakir, M.Kiyank, E.Altan (2004) has investigate the effect of cutting fluid, some gases applications and dry cutting on cutting forces, thrust forces, surface roughness, friction coefficient and shear angle have been examined in turning of AISI1040 steel material. Dry machining, wet machining and machining with oxygen, nitrogen and carbon dioxide gases were carried out under constant cutting speed, three level of feed and depth of cut [6]. J.M.Zhou, V.Bushlya, J.E.Stahl (2012) has investigated of surface damage produced by whisker-reinforced ceramic cutting tools in the finish turning of Inconel 718 (nickel-based super alloy). The aim of the present investigation was to study the effects of the cutting parameters(cutting speed, depth of cut and feed), tool wear and Coolant conditions on the surface damage to it occurring during dry and wet turning[7]. Chintan Kayastha, Jaivesh Gandhi (2013) has optimized Process Parameter in Turning of Copper by Combination of Taguchi and Principal Component Analysis Method. After those different level parameters (combination of feed, spindle speed, depth of cut and side rack angle) was set and turning operation to be carried out. The correlation between MRR and Ra is 0.251[9]. Gaurav Bartarya, S.K. Choudhary (2012) has an attempt to develop a force prediction model during finish machining of EN31 steel (equivalent to AISI52100 steel) hardened to 60±2 HRC using hone edge uncoated CBN tool and to analyze the combination of the machining parameters for better performance within a selected range of machining parameters like feed, spindle speed and depth of cut [13]. Vishal Francis, Ravi. S .Singh, Nikita Singh, Ali. R. Rizvi, Santosh Kumar (2013) has optimized Process Parameter for

MMR and surface roughness in turning operation by Combination of Taguchi and ANOVA Method. The Experiment was performed by high speed steel tool and mild steel work-piece in dry cutting condition. Spindle peed was found to be most significant parameter for MRR [11]. Ilhan Asilturk, Harun Akkus (2011) has optimizing turning parameters based on the Taguchi method to minimize surface roughness (Ra and Rz). Work piece made of AISI 4140 grade (DIN 42CrMo4) steel was used. The tool holder used was model MWLNR 2525M-0.8W. Al2O3 and TiC-coated (WNMA 080408) inserts were used as the cutting tool material. According to the ANOVA analysis, the feed rate has an effect on Ra and Rz [12]. Mr.Ballal Yuvraj, Dr.Inamdar K.H. and Mr.Patil P.V (2011) has described use and steps of Taguchi design of experiments and orthogonal array to find a specific range and combinations of turning parameters like cutting speed, feed rate and depth of cut constant (2mm) to achieve optimal values of response variables like surface finish, tool wear, material removal rate by using ANOVA in turning of Brake drum of FG 260 gray cast iron Material. The tool material was Carbide inserts K10 series uncoated and TiCN and TiAlN coated type and tool geometry (CNMA) [14]. H.M. Somashekara and Dr.N. Lakshmanaswamy (2012) has obtained an optimal setting of Turning parameters Cutting speed in rpm, Feed in mm/re and Depth of Cut in mm which results in an optimal value of and ANOVA analysis were also performed to obtain significant factors influencing Surface Roughness. Surface Roughness while machining Al 6351-T6 alloy with Uncoated Carbide Inserts (TNMG 160408) [15]. W.H. Yang, Y.S.Tarng (1997) has investigated from the Taguchi method to design optimization for quality, is used to find the optimal cutting parameters for turning operations like Cutting speed, feed and Depth of Cut . An orthogonal array, the signal-to-noise (S: N) ratio, and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of S45C steel bars using tungsten carbide cutting tools [16]. Hyun Wook Lee and Won Tae Kwon (2010) has investigated from the Taguchi method to determine the rough region first, followed by RSM technique to determine the exact optimum value for turning parameters like Cutting speed in m/min, Feed in mm/rev and Depth of Cut in mm. Commercial inserts of P20 (tungsten carbide insert) and AB30 (Ceramic insert) with the specification of SNGN120408 were used for turning the work materials, SM45C (AISI45) and SCM440 [17]. M. Nalbant, H. Gokkaya and G. Sur (2006) have investigated from the Taguchi method to find the optimal cutting parameters for surface roughness in turning. The analysis of variance has been employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools (inserts were TNMG160404-MA, TNMG160408-MA and TNMG160412-MA) [18]. M. Seeman, G. Ganesan, R. Karthikeyan and A. Velayudham (2009) has attempted flank wear (VB max) and surface roughness (Ra) through the response surface methodology and regression analysis. The LM 25 aluminum alloy reinforced with green-bonded silicon carbide particles of size 25μm with 20% volume fraction manufactured through stir-casting route was used for experimentation [10]. Hardip singh, Sumit shamra, Vivek awasthi Vineet kumar and Sandip singh (2013) has investigated the effect of cutting parameters like spindle speed, feed and depth of cut on surface temperature of EN-9 using HSS tool [27]. Samir khrais, Adel mahammod Hassan and Amro gazawi (2011) has evaluated surface roughness and develop a multiple regression model for surface roughness as a function of cutting parameters during the turning of flame hardened medium carbon steel(EN-9) with TiN-Al2O3-TiCN coated inserts[28]. Shrikant S. jachak and Vnay R. pandey (March 2014) has evaluated the effect of certain parameters on surface roughness in plain turning of medium carbon steel AISI 1055(EN-9) under the cutting condition [29]. B Kumaragurubaran, P Gopal, T Senthil Kumar and M Prasanna Mugunthan (2013) has experimental worked turning parameters on EN-9 steel with different cutting parameters like cutting speed, feed and depth of cut greatly influenced by response parameters like surface roughness and MRR[30].

III. PRESENT WORK

The present work aims to optimize the surface roughness value (Ra) and cutting force value (F_z) on EN-9 using full factorial and ANOVA on dry and wet turning operation. The Regression analysis is used to estimate the regression coefficients that minimize the error. The turning of EN-9 which is equivalent to AISI1055 was performed on Jyoti DX-150 CNC lathe, carbide with coated (TiN) insert (Make: seco type CNMA 120408 KR) of tool geometry was used on Seco tool holder (type SCLNR 2020 4B) at a three different side rake angle. A stain gauge lathe tool dynamometer (IECOS model 652) was used to measure the tool force. The process surface roughness (R_a), produced was measured using a portable surface analyzer in the direction parallel to work piece axis. The range of the cutting parameters selected (Table 1). The surface roughness and cutting force (F_z) were measured for all 27 experiments as per the full-factorial design of dry and wet experiment (Table 2).

Table 1: Factors and their levels in dry and wet turning operation Constant cutting speed- 220 m/min and Back rake angle-(-5º)

Sr.No.	Factors	Units	Levels		
			Low	Medium	High
1	Side rake angle	Degree	-10	-5	0
2	Feed	mm/rev	0.20	0.24	0.28
3	Depth of cut	Mm	0.4	0.8	1.2

Table 2: Dry and wet experimentation and measured responses.

Run order	Actual values			Dry Turning		Wet Turning	
	Side rake angle(degree)	Feed (mm/rev)	Depth of cut(mm)	Surface Roughness	Cutting Force	Surface Roughness	Cutting Force
1	-10	0.20	0.8	1.050	167.08	0.948	165
2	-10	0.20	1.4	1.169	177.28	0.998	174.76
3	-10	0.20	2.0	1.179	189.32	1.103	180.83
4	-10	0.24	0.8	1.171	168	1.035	167.49
5	-10	0.24	1.4	1.214	181	1.101	180.41
6	-10	0.24	2.0	1.253	191.27	1.182	189.72
7	-10	0.28	0.8	1.259	178	1.128	173
8	-10	0.28	1.4	1.279	187.82	1.207	183.53
9	-10	0.28	2.0	1.339	201.55	1.268	192.28
10	-5	0.20	0.8	1.014	150.53	0.891	149.35
11	-5	0.20	1.4	1.086	165.50	0.945	160.78
12	-5	0.20	2.0	1.105	178.06	1.039	169.66
13	-5	0.24	0.8	1.109	155.74	1.068	158.75
14	-5	0.24	1.4	1.172	166.23	1.071	164.33
15	-5	0.24	2.0	1.208	179.87	1.128	175.54
16	-5	0.28	0.8	1.189	156	1.089	153.92
17	-5	0.28	1.4	1.274	166.88	1.118	164.31
18	-5	0.28	2.0	1.268	180.39	1.201	172.87
19	0	0.20	0.8	1.106	131.22	0.982	129.10
20	0	0.20	1.4	1.138	146	1.042	143.23
21	0	0.20	2.0	1.216	164.83	1.147	152.37
22	0	0.24	0.8	1.198	136.24	1.098	138
23	0	0.24	1.4	1.212	154	1.187	156.09
24	0	0.24	2.0	1.304	169	1.246	166
25	0	0.28	0.8	1.291	143.42	1.183	141.24
26	0	0.28	1.4	1.353	158.60	1.190	155.03
27	0	0.28	2.0	1.357	171.95	1.291	163.89

IV. RESULTS AND ANALYSIS

The regression analysis of the data was undertaken using data fit and ANOVA was analyze the parameters for surface roughness and cutting force (F_z) and determine the most effected parameters on dry and wet turning operation.

A. *ANOVA of the surface roughness and force for dry and wet turning.*

The ANOVA results for surface roughness (R_a) data (table 3 and 4) showed that the selected full-factorial design was significant. Feed was found the most significant parameter 62.52% and 53.56% respectively for dry and wet turning.

Similarly the ANOVA results for cutting force (F_Z) data (table 5 and 6) showed that the selected full-factorial design was significant. Side rake angle was found the most significant parameter 51.68% and 60.36% respectively for dry and wet turning.

Table 3 Results of the ANOVA for Surface Roughness on dry turning

Symbol	**Cutting parameters**	**Degree of Freedom**	**Sum of Squares**	**Mean Squares**	**F**	**Contribution (%)**
A	Side rake angle	2	0.0323	0.0162	40.50	15.20
B	Feed rate	2	0.1329	0.0665	166.25	62.52
C	Depth of cut	2	0.0401	0.0201	50.25	18.87
Error		20	0.0073	0.0004	1	3.41
Total		26	0.2126			100

Table 4 Results of the ANOVA for Surface Roughness on wet turning

Symbol	**Cutting parameters**	**Degree of Freedom**	**Sum of Squares**	**Mean Squares**	**F**	**Contribution (%)**
A	Side rake angle	2	0.0392	0.0196	65.33	14.49
B	Feed rate	2	0.1449	0.0725	241.67	53.56
C	Depth	2	0.08	0.04	136	30.21

	of cut		17	09	.34	
Error		20	0.0047	0.0003	1	1.74
Total		26	0.2705			100

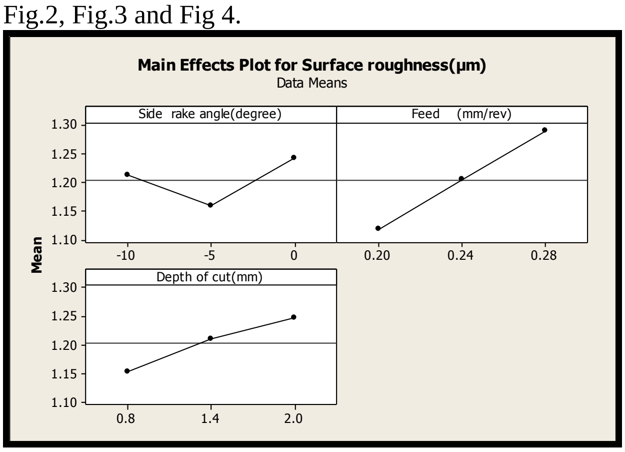
Table 5 Results of the ANOVA for Cutting force (F_Z) on dry turning

Symbol	Cutting parameters	Degree of Freedom	Sum of Squares	Mean Squares	F	Contribution (%)
A	Side rake angle	2	3938.78	1969.39	234.18	51.68
B	Feed rate	2	313.29	156.65	18.63	04.11
C	Depth of cut	2	3200.90	1600.45	190.31	42.00
Error		20	168.03	8.41	1	02.21
Total		26	7621.7			100

Table 6 Results of the ANOVA for Cutting force (F_Z) on wet turning

Symbol	Cutting parameters	Degree of Freedom	Sum of Squares	Mean Squares	F	Contribution (%)
A	Side rake angle	2	3818.70	1909.35	253.84	60.36
B	Feed rate	2	396.82	198.41	26.38	6.28
C	Depth of cut	2	1961.62	980.81	130.40	31.01
Error		20	150.44	7.53	1	2.35
Total		26	6327.58			100

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in Fig.1, Fig.2, Fig.3 and Fig 4.



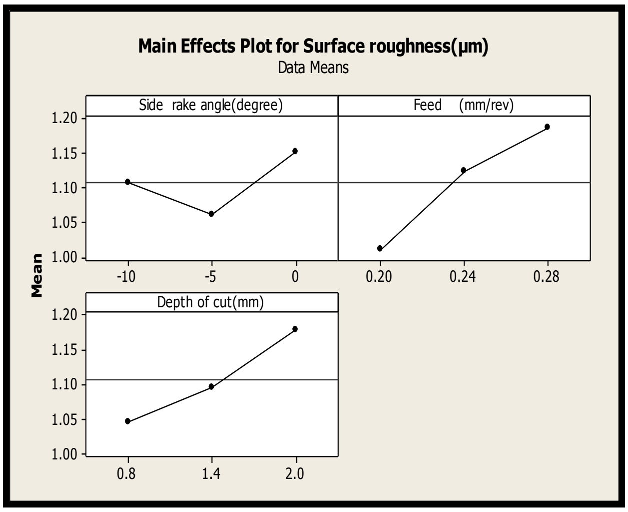
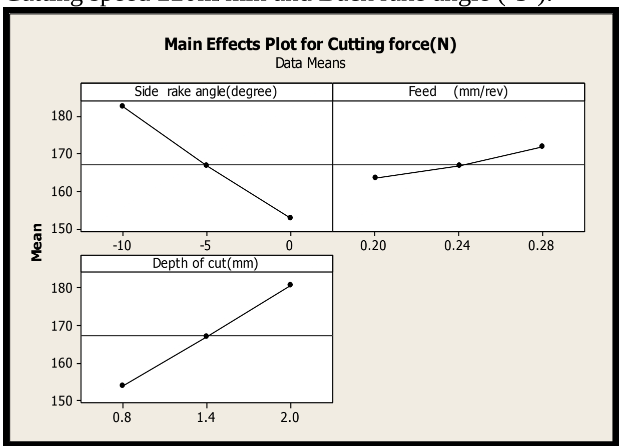


Fig.1 Main effect plot for Surface Roughness. Fig.2 Main effect plot for Surface Roughess on dry turning on wet turning According to this main effect plot fig.1 and fig.2, the optimal conditions for minimum surface roughness are Side rake angle at level 2(-5º), Feed rate at level 1(0.20mm/rev) and Depth of cut at level 1(0.8mm) during Cutting speed 220m/min and Back rake angle (-5º).



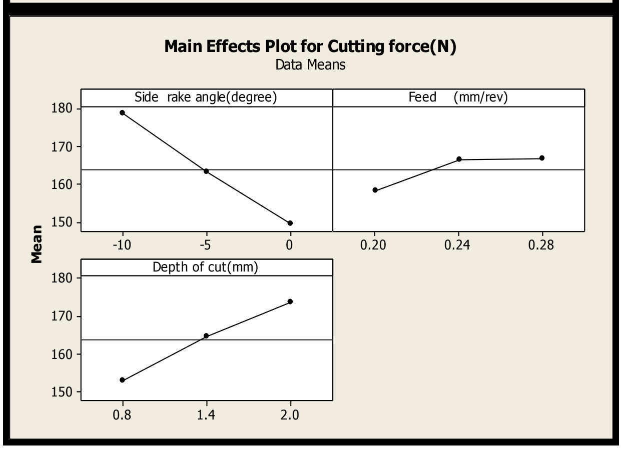


Fig.3 Main effect plot for cutting force Fig.4 Main effect plot for cutting force on dry turning on wet turning According to this main effect plot fig.3 and fig.4, the optimal conditions for minimum cutting force are Side rake angle at level 3(0º),

Feed rate at level 1(0.20mm/rev) and Depth of cut at level 1(0.8mm) during Cutting speed 220m/min and Back rake angle (-5°).

B. Regression analysis

A regression equation was developed for each desired output. The machining conditions from the validation set were given to the regression equations as inputs and the equations, in turn provided the predictions for the different outputs.

a. The Developed Regression Model for Surface Roughness on dry turning

Regression Equation:

Surface Roughness (µm) = 0.594259 + 0.00291111 Side rake angle (degree) + 2.14722 Feed (mm/rev) + 0.077963 Depth of cut (mm)

Regression Coefficients:

Table 7 Surface Roughness Regression Co-efficient

Term	Coef.	SE Coef.	T	P
Constant	0.59426	0.061684	9.63387	0.000
Side rake angle(degree)	0.00291	0.001879	1.54935	0.135
Feed (mm/rev)	2.14722	0.234866	9.14232	0.000
Depth of cut(mm)	0.07796	0.015658	4.97919	0.000

S = 0.0398581R-Sq = 82.81% R-Sq (adj) = 80.56% PRESS = 0.0500167 R-Sq (pred) = 76.47%

Analysis of Variance:

Table 8 Results for ANOVA of Surface Roughness Regression Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	3	0.175985	0.175985	0.058662	36.9249	0.000000
Side rake angle (degree)	1	0.003814	0.003814	0.003814	2.4005	0.134950
Feed (mm/rev)	1	0.132784	0.132784	0.132784	83.5820	0.000000
Depth of cut (mm)	1	0.039387	0.039387	0.039387	24.7924	0.000049
Error	23	0.036539	0.036539	0.001589		
Total	26	0.212524				

Residual Plots for Surface Roughness (µm):

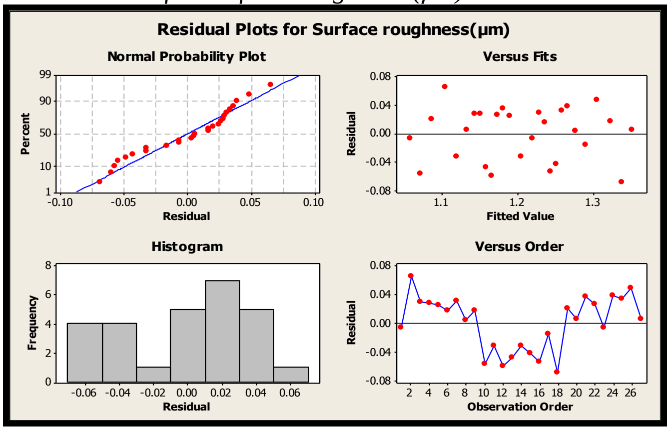


Figure 5 Residual plots for surface roughness

b. The Developed Regression Model for Cutting Force (F_z) on dry turning:

Regression Equation:

Cutting Force (F_z) (N) = 96.4276 - 2.95622 Side rake angle (degree) + 103.875 Feed (mm/rev) + 22.2231 Depth of cut (mm)

Regression Coefficients:

Table 9 Cutting force Regression Co-efficient

Term	Coef.	SE Coef.	T	P
Constant	96.428	4.3056	22.3959	0.000
Side rake angle (degree)	-2.956	0.1311	-22.5408	0.000
Feed (mm/rev)	103.875	16.3937	6.3363	0.000
Depth of cut(mm)	22.223	1.0929	20.3338	0.000

S = 2.78211R-Sq = 97.66% R-Sq (adj) = 97.36% PRESS = 253.239 R-Sq (pred) = 96.68%

Analysis of Variance:

Table 10 Results for ANOVA of Cutting Force (F_z) Regression Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	3	7443.68	7443.68	2481.23	320.566	0.0000000
Side rake angle(degree)	1	3932.66	3932.66	3932.66	508.087	0.0000000
Feed (mm/rev)	1	310.75	310.75	310.75	40.148	0.0000018
Depth of cut(mm)	1	3200.27	3200.27	3200.27	413.464	0.0000000
Error	23	178.02	178.02	7.74		
Total	26	7621.70				

Residual Plots for Cutting Force (F_z) in (N):

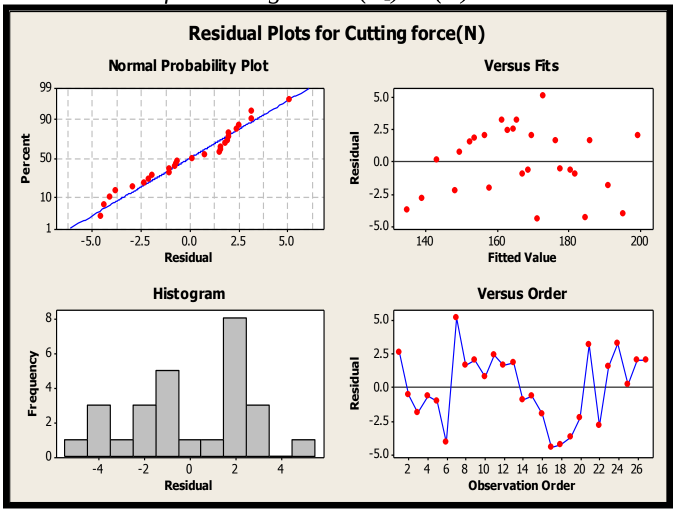


Figure 6 Residual plot for cutting force (F_z)

c. *The Developed Regression Model for Surface Roughness on wet turning:*

Regression Equation:

Surface Roughness (µm) = 0.44887 + 0.0044 Side rake angle(degree) + 2.19444 Feed (mm/rev) + 0.109537 Depth of cut(mm)

Regression Coefficients:

Table 11 Surface Roughness Regression Co-efficient

Term	Coef.	SE Coef.	T	P
Constant	0.44887	0.066971	6.70250	0.000
Side rake angle (degree)	0.00440	0.002040	2.15692	0.042
Feed (mm/rev)	2.19444	0.254994	8.60588	0.000
Depth of cut(mm)	0.10954	0.017000	6.44352	0.000

S = 0.0432738 R-Sq = 83.94% R-Sq (adj) = 81.85% PRESS = 0.0572577 R-Sq (pred) = 78.65%

Analysis of Variance:

Table 12 Results for ANOVA of Surface Roughness Regression Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	3	0.225150	0.225150	0.075050	40.0775	0.0000000
Side rake angle	1	0.008712	0.008712	0.008712	4.6523	0.0417020
Feed (mm/rev)	1	0.138689	0.138689	0.138689	74.0612	0.0000000
Depth of cut(mm)	1	0.077749	0.077749	0.077749	41.5189	0.0000014
Error	23	0.043070	0.043070	0.001873		
Total	26	0.268221				

Residual Plots for Surface Roughness (µm):

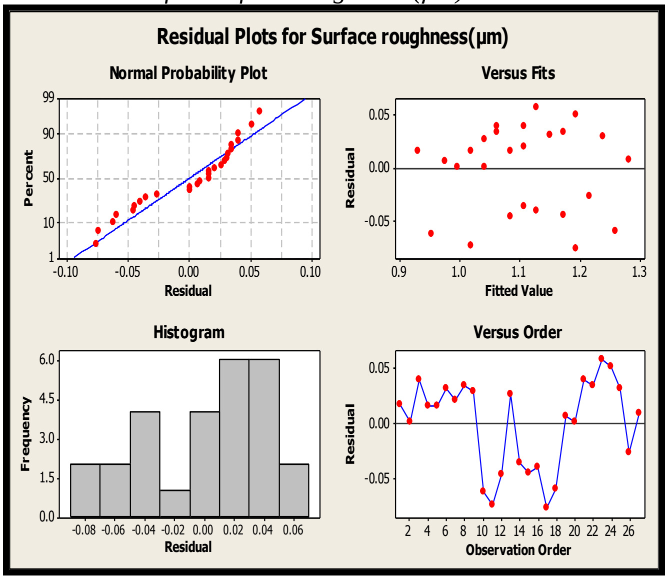


Figure 7 Residual plot for surface roughness

d. *The Developed Regression Model for Cutting Force (F_z) on wet turning:*

Regression Equation:

Cutting Force (F_z) (N) = 99.9215 - 2.91189 Side rake angle (degree) + 104.153 Feed (mm/rev) + 17.3435 Depth of cut (mm)

Regression Coefficients:

Table 13 Cutting force Regression Co-efficient

Term	Coef.	SE Coef.	T	P
Constant	99.921	5.1064	19.5678	0.000
Side rake angle (degree)	-2.912	0.1555	-18.7207	0.000
Feed (mm/rev)	104.153	19.4430	5.3568	0.000
Depth of cut(mm)	17.344	1.2962	13.3803	0.000

S = 3.29958 R-Sq = 96.04% R-Sq (adj) = 95.53% PRESS = 340.918 R-Sq (pred) = 94.61%

Analysis of Variance:

Table 14 Results for ANOVA of Cutting Force Regression Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	3	6077.18	6077.18	2025.73	186.064	0.000000
Side rake angle(degree)	1	3815.59	3815.59	3815.59	350.465	0.000000
Feed (mm/rev)	1	312.42	312.42	312.42	28.696	0.000193
Depth of cut(mm)	1	1949.17	1949.17	1949.17	179.032	0.000000
Error	23	250.41	250.41	10.89		
Total	26	6327.59				

Residual Plots for Cutting Force (Fz) in (N):

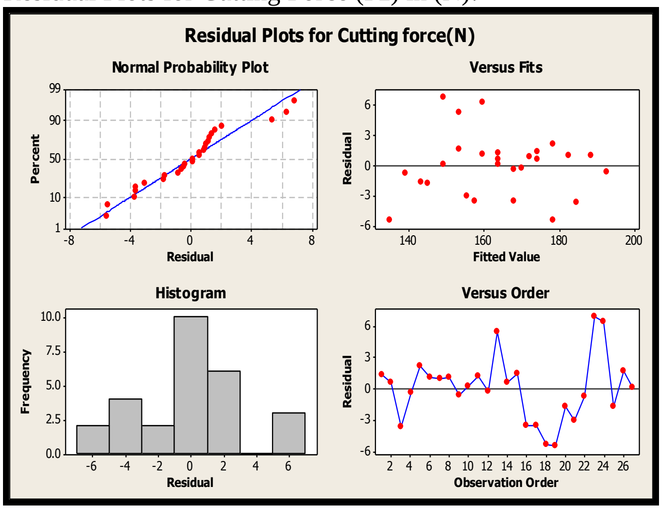


Figure 8 Residual plot for cutting force (F_z)

V. CONCLUSION

The study discuss about the application of Full-factorial, ANOVA and Regression analysis to analyze the effect of process parameters (Constant cutting speed, Side rake angle, Feed rate and Depth of cut) on surface roughness and cutting force for EN-9 under dry and wet turning operation. From the analysis of the results obtained following conclusion can be drawn:-

- The percentage contribution of side rake angle is 15.20%; feed of 62.52% and depth of cut of 18.87% on surface roughness for dry turning operation and the percentage contribution of side rake angle is 14.49%; feed of 53.56% and depth of cut of 30.21% on surface roughness for wet turning operation.
- From the ANOVA it is conclude that the feed rate is most significant parameter which contributes 62.52% in dry turning and 53.56% in wet turning operation.
- In regression analysis, the maximum test error for surface roughness regression model on dry turning is 0.066 comparing with wet turning 0.059, which is an acceptable error range.
- Optimal parameters for surface roughness are side rake angle (-5º), feed 0.20 mm/rev and depth of cut 0.8 mm for dry and wet turning operation.
- The percentage contribution of side rake angle is 51.68%; feed of 4.11% and depth of cut of 42% on cutting force for dry turning operation and the percentage contribution of side rake angle is 60.36%; feed of 6.28% and depth of cut of 31.01% on cutting force for wet turning operation.
- From the ANOVA it is conclude that the side rake angle is most significant parameter which contributes 51.68% in dry turning and 60.36% in wet turning operation.
- In regression analysis, the maximum test error for cutting force regression model on dry turning is 5.15 comparing with wet turning 6.90, which is an acceptable error range.
- Optimal parameters for cutting force are side rake angle (0º), feed 0.20 mm/rev and depth of cut 0.8 mm for dry and wet turning operation.

REFERENCES

[1] S. Kalpakjian and S. R. Schmid. Manufacturing Engineering and Technology 5th ed. Upper Saddle River, NJ: Prentice Hall, 2006.
[2] S. Kalpakjian. Manufacturing process for engineering material, 3rd ed. Menlo Park, CA: Addison-Wesley Longman, 1997.
[3] E.O. Ezugwu., “Key improvements in the machining of difficult-to-cut aerospace superalloys.” International Journal of Machine Tools and Manufacture, vol.45 (12-13), pp. 1353-1367, Oct 2005.
[4] A .S. Varadarajan, P.K.Philip, B.Ramamoorthy, “Investigations on hard turning with minimal cutting fluid application (HTMF) & its comparison with dry & wet turning.” International Journal of Machine Tools & Manufacture 42 (2002) 193–200.
[5] B. Dilip Jerold, M. Pradeep Kumar, “Experimental

comparison of carbon-dioxide and liquid nitrogen cryogenic coolants in turning of AISI 1045 steel." Cryogenics 52 (2012) 569–574.

[6] O.Çakır a, M.Kıyak b, E.Altan b, "Comparison of gases applications to wet and dry cuttings in turning." Journal of Materials Processing Technology 153–154 (2004) 35–41.

[7] J.M. Zhou, V. Bushlya, J.E. Stahl, "An investigation of surface damage in the high speed turning of Inconel 718 with use of whisker reinforced ceramic tools." Journal of Materials Processing Technology 212 (2012) 372– 384.

[8] Chorng-Jyh Tzenga, Yu-Hsin Linb, Yung-Kuang Yanga,, Ming-Chang Jengc, " Optimization of turning operations with multiple performance characteristics using the Taguchi method and Grey relational analysis." journal of materials processing technology 2 0 9- 2753–2759.

[9] Chintan Kayastha , Jaivesh Gandhi, "Optimization Of Process Parameters in Turning Of Copper by Combination Of Taguchi and Principal Component Analysis Method." International Journal Of Scientific and Publications, Volume 3, Issue 6,June 2013 ISSN 2250-3153

[10] M. Seeman & G. Ganesan & R. Karthikeyan & A. Velayudham, "Study on tool wear and surface roughness in machining of particulate aluminum metal matrix composite-response surface methodology approach." Int J Adv Manuf Technol (2010) 48:613–624.

[11] Vishal Francis, Ravi. S. Singh, Nikita Singh, Ali .R. Rizvi, Santosh Kumar, "Application of Taguchi method And ANOVA Optimization of Cutting Parameters for Material Removal Rate and Surface Roughness in Turning Operation. International Journal of Mechanical Egg. And Technology.

[12] Ilhan Asilturk, Harun Akkus, "Determination the effect of cutting parameters on surface roughness in hard turning using the Taguchi method." Measurement 44-(1697-1704)

[13] Gaurav Bartarya, S.K. Choudhary, "Effect of cutting parameters on cutting force & surface roughness during finish hard turning AISI 52100 grade steel." Procedia CIRP 1 (2012) 651-656.

[14] Mr. Ballal Yuvaraj P, Dr. Inamdar K.H, Mr. Patil P.V, "Application of taguchi method for design of experiments in turning gray cast iron." International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 3, pp.1391-1397.

[15] H.M.Somashekara, Dr.N.Lakshmana Swamy, "Optimization surface roughness in turning operation using taguchi technique and ANOVA." International Journal of Engineering Science and Technology (IJEST), ISSN: 0975-5462, Vol.4.

[16] W.H. Yang, Y.S. Tarng , " Design optimization of cutting parameters for turning operations based on the Taguchi method." Journal of Materials Processing Technology 84 (1998) 122–129.

[17] Hyun Wook Lee and Won Tae Kwon, "Determination of the minute range for RSM to select the optimum cutting conditions during turning on CNC lathe." Journal of Mechanical Science and Technology 24 (8) (2010) 1637-1645.

[18] M. Nalbant, H. Go kkaya, G. Sur, "Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning." Material and Design 28 (2007) 1379-1385.

[19] B.S.Raghuwanshi (2009), "A Course In Workshop Technology Vol.II"

[20] M.A. El Baradie, Cutting fluids. Part I. Characterisation, J. Mater. Process. Technol. 56 (1996) 787–797.

[21] R. E. Walpole, R. H. Myers, S. L. Myers, K. Ye. *Probability and statistic for Engineers and Scientists*, 8th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2007.

[22] S. Chatterjee. A.S. Hadi. *Regression Analysis by Example*, 4th ed. Hoboken, New Jersey: John Wiley & Sons, 2006.

[23] "TheMathworks".Internet: http://www.mathworks.com/

[24] A.M. Zain, H. Haron, S.N. Qasem and S. Sharif. "Regression and ANN models for estimating minimum value of machining performance." Applied Mathematical Modelling, vol. 36, pp. 1477-1492, and 2012.

[25] Suha K. Shihab, Zahid A. Khan, Aas Mohammad, Arshad Noor Siddiquee "Effect of Cutting Parameters on Cutting Forces and MRR During Turning Hard Alloy Steel With and Without Coolant." International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-1, October 2013

[26] G.K.Lal, "Introduction to Machining Science".pp.21-36

[27] Hardeep Singha, Sumit Sharmaa, Vivek Awasthia, Vineet Kumara and Sandeep Singha "Study of Cutting Parameters on Turning using EN9." International Journal Of Advance Industrial Engineering(IJAIE) ISSN: 2320-5539, Volume-1, Issue-2, June-2013, pp. 40-42

[28] Samir Khrais, Adel Mahammod Hassan , Amro Gazawi "Investigations Into the Turning Parameters Effect on the Surface Roughness of Flame Hardened Medium Carbon Steel with TiN-Al2O3-TiCN Coated Inserts based on Taguchi Techniques." World Academy of Science, Engineering and Technology 59 2011, pp. 2137-2141

[29] Shrikant S. Jachak, Vinay R. Pandey "Optimization of CNC Turning Process Parameters for Prediction of Surface Roughness By Factorial Experimentation."International Journal Of Innovative Research & Development(IJIRD) ISSN: 2278 – 0211, Volume-3, Issue-3, March-2014, pp. 405-410

[30] B Kumaragurubaran, P Gopal, T Senthil Kumar, M

Prasanna Mugunthan and N H Mohamed Ibrahim "Optimization of Turning Parameters of EN-9 Steel Using Design of Experiments Concepts."International Journal of Mechanical Engineering and Robotics Research (IJMERR) ISSN: 2278 – 0149, Volume-2, Issue-3, July-2013, pp. 182-190

