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ARTICLE

Investigation and Mathematical Modelling of Optimized Cutting Parameters for Surface Roughness of EN-8 Alloy Steel

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ABSTRACT

The work done in this work deals with the efficacy of cutting parameters on surface of EN-8 alloy steel. For knowing the optimal effects of cutting parameters response surface methodology was practiced subjected to central composite design matrix. The motive was to introduce an interaction among input parameters, i.e., cutting speed, feed and depth of cut and output parameter, surface roughness. For this, second order response surface model was modeled. The foreseen values obtained were found to be fairly close to observed values, showed that the model could be practiced to forecast the surface roughness on EN-8 within the range of parameter studied. Contours and 3-D plots are generated to forecast the value of surface roughness. It was revealed that surface roughness decreases with increases in cutting speed and it increases with feed. However, there were found negligible or almost no implication of depth of cut on surface roughness whereas feed rate affected the surface roughness most. For lower surface roughness, the optimum values of each one were also evaluated.

1. Introduction

Nowadays each and every company want to get the maximum return with retaining good quality that is possible through selection of optimum parameters and understanding of modern trends with prior analysis. These demands are still attracting the attention of researchers towards the work on process parameters and searching the optimal parameter framework which is used for attaining the process effectively. The process parameter also comprises the internal and external basics of the process. To obtain the robust process with error free it is needed to enhance the performance of cutting process, it is imperative to optimize the process parameters. In the view of significant of machining process, critical reviews that were attained by the various researchers on different materials are discussed.

Sharma et al. [1] conducted experiment on AISI 52100 steel using a carbide-coated tool in turning operations using different cutting parameters. The surface roughness was also measured subjected to the effect of cutting parameters such as approach angle, speed, feed rate and

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depth of cut. They concluded that the surface roughness increased with increasing feed rate. The speed had somewhat effect on the roughness, and the surface roughness decreased slightly with increasing approach angle and depth of cut.

Fnides et al. [2] worked on grade X38CrMoV5-1 steel, hot work steel and they found good strength to high temperature and its ability for polishing empower it to answer the most harsh case in hot dying and moulds under pressure.

Selvaraj and Mohan [3] reported the work on dry turning of AISI 304 Austenitic Stainless Steel (ASS). For this, they planned design of experiments based on Taguchi's technique and eventually the confirmation tests were conducted to match the predicted with the experimental ones for its proficiency in the examination of surface roughness.

Kuram et al. [4] used three distinct vegetable-based cutting fluids for knowing the thrust force and surface roughness during drilling of AISI 304 austenitic stainless steel with HSSE tool. They investigated usefulness of vegetable cutting oils to mitigate thrust force and improving surface finish at all machining conditions.

Selvaraj and Chandramohan [5] carried out work on dry turning of cast duplex stainless steels (ASTM A 995 Grade 4A and ASTM A 995 Grade 5A) using TiC and TiCN coated cemented carbide cutting tools. They found reversible relationship trends between rising cutting speed and surface roughness up to some point. It was obtained usefulness of alpha fiber in the austenite phase of 4A work piece material in surface finishing. In addition to this, surface finish of grade 4A was found to be better than other material.

Hatem [6] designed of experiment to obtain surface quality of the turning and model of surface roughness with the cutting speed, feed rate for different materials at constant depth of cut (0.5mm). They also tried to understand the actual difficulties comes into governing the finish of machined surfaces while adjusting the process parameters to get a surface finish.

Sastry et al. [7] produced aluminum and resin work pieces by machine-turning, and their surface quality and metal removal rate were analyzed along with potential effects of variables such as cutting speed, feed and depth of cut onto two different work pieces. They also modelled using Response Surface Method (central composite design) and validated the adequacy of the models.

Ficici et al. [8] studied the optimal cutting condition for drilling operation of stainless steel by varying cutting parameters through the Taguchi optimization technique and they statistical showed the results (at a 99.5% confidence level) that the drill modification condition (A), cutting speed (B) and feed rate (C) influence the surface roughness in the drilling process by 74.25%, 13.72%, and 6.25%, respectively. The interaction of AxB had a much higher significant effect at 4.50% while interactions of AxC and BxC had no significant effect on the surface roughness. Deviations between actual and predicted S/N ratios for the surface roughness were found eligibly small with 99.5% and 90% confidence levels respectively.

Korat and Agarwal [9] studied EN24 material in CNC turning for knowing the consequence of the process parameters viz. coolant condition, cutting speed, feed, depth of cut, nose radius, on response characteristics viz. material removal rate, surface roughness. It was shown that ANOVA (S/N Data) results shows the nose radius, feed rate, depth of cut, cutting speed and coolant condition affects the surface roughness by 65.38 %, 25.15 %, 3.06 %, 1.41 % and 0.09 % respectively.

Bhateja et al. [10] showed the effect of cutting parameters on EN-24 alloy steel and least roughness value for TNMG in the first step of step turning, second step of step turning, third step of turning. Thus, from the examination, it was concluded that the optimality of TNMG is known reason being the constancy from step 2, as well as lesser that Ra value of uncoated and coated step 3 (turning).

Ali et al. [11] presented a FEM model for predicting surface roughness for the face milling process in dry conditions and were found satisfactory results between predicted and calculated ones. It was concluded that FEM as beneficial tool for not only predict the value of feed cutting force to control the surface roughness rather than conducting experiments but lead to reduced machining time as well the manufacturing cost also.

Vipindas [12] applied Taguchi method for knowing the surface quality of Al6061 in turning operation and found feed as significant factor.

Gandhi [13] was employed principal component analysis (PCA) to eliminate response correlation and convert into uncorrelated quality indices called principal components and was confirmed better methodology for reducing the number of response variables.

Tulsiramarao [14] reported on the work of surface finishing of mild steel and alloy steel work pieces and obtained minimum surface roughness at 1600 rpm spindle speed, 0.1 mm depth of cut and 500 inch per min of feed rate.

Das et al. [15] studied on machining of hardened AISI4340 steel with multi-layered coated carbide insert using full factorial design of experiments (DOE) on turning and, determined the best combination of machining parameters and found feed as the most significant parameter followed by cutting speed. However, depth of cut did impact the surface roughness but at least.

Sahijpaul and Singh [16] used custom design approach through JMP statistical software and was found to be lower surface roughness of EN-8 with decrease in cutting fluid concentration.

Patel et al. [17] found that for surface roughness the most significant parameters are speed, feed and nose radius as the most significant parameters while depth of cut (DOC) as the least significant parameter for roughness and, for material removal rate (MRR); DOC, feed and speed was observed as most significant and nose radius as the least.

Begic-Hajdarevic et al. [18] investigated that the better surface roughness could be achieved in high-speed milling of hardened tool steel during up-cut and down-cut process but with severity of tool wear.

Sarıkaya and Güllü [19] used AISI 1050 steel for turning machining using design of experiments and then it was modelled mathematically for surface roughness, namely Ra and Rz, through response surface methodology (RSM). The results indicated feed rate as the most influenced parameters on the surface roughness.

Kumar et al. [20] used Al-4.5Cu/TiC metal matrix composites for knowing the dry turning characteristics and their results indicated significant lower formation of BUE at larger value of cutting speed and vice-versa. The length of chip and the number of chip curls increased with an increase in cutting speed at given feed rate and depth of cut. At the same machining condition, C-type chips was changed to segmental type chip with the addition of weight percentage of reinforcement.

From the literature review, it was discovered from aforesaid that surface roughness and machining efficiency are foremost intentions but work on modelling and optimization were found very few for EN 8 Steel in CNC Turning by the use of different cutting parameter [21-26]. It was noted that the effect on surface roughness of work piece material by the specifying varying process parameters by employing empirical approach have not been yet explored, so it remains still the matter of attraction to work in the area of optimization of cutting parameters of EN 8 Alloy steel in CNC Turning.

The purpose of this research is to explore the systematic procedure of design of experiment & response surface methodology & hence to get optimum value of cutting parameter for CNC lathe machine to get the desired value of surface roughness for EN-8 steel.

2. Experimental Details

2.1 Material Detail

In this study EN-8 alloy steel is used, can be seen in Table 1. In this experiment carbide insert (DNMG 150608) as a cutting tool material made by Sandvik Coromant Limited was used. Dimension of tool was 15 mm × 0.6 mm × 0.8 mm and, dimension of tool holder as per ISO was DDJNL 20 × 20 K 15 where, D is clamping system, D is insert shape (55° Diamond shape), J is approach angle, N is clearance angle, L is left hand, K is tool length(152.4 mm) and 15 is insert edge length, respectively. The approach angle of the tool holder was 93° and 20×20 is taken as tool height × tool width. Typical turning, thread cutting and parting tools used in CNC Lathe used for current work is referred in Figure 1. And, photography of material samples is shown in Figure 2.

Table 1. Chemical Composition of EN-8 Steel.

Elements	C	Mn	Si	Cr	Mo	Others	Fe
Wt.(%)	0.399	0.643	0.175	0.013	0.002	Balance	98.653

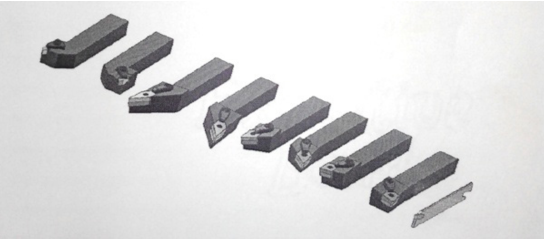


Figure 1. Typical Turning, Thread Cutting and Parting Tools used in CNC Lathe.

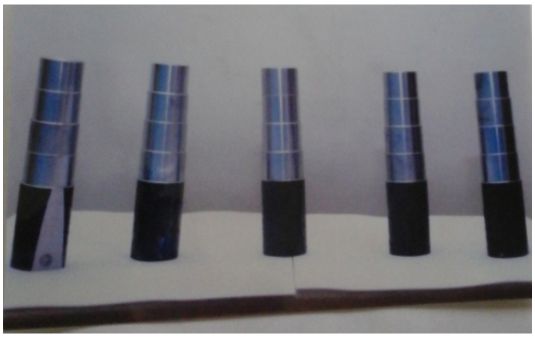


Figure 2. Photographic view of Test Specimens

2.1.1 Machining Details

The experiment was performed on CNC lathe machine, Make of HMT- STALLION-100 SU, can be seen in Figure 3. The STALLION-100 SU turning centre is devised to execute a various machining processes such as straight, taper turning, drilling, boring and contouring with linear and circular interpolation, internal and external threading (Parallel or taper) etc. The machine is appropriate for chucking and bar types of work pieces, also. CNC machine tool (machining and turning centres) is advanced type of numerically controlled machine tools used to fabricate a form of complex parts.

Figure 3. Pictorial view of STALLION 100 SU.

The feed drive for the saddle (Z-axis) and the feed drive for the cross slide (X-axis) are by AC servomotors, which are coupled with ball screw by bellow coupling. The standard rapid traverse rates for both Z and X-axes are 18000 mm/min. The standard turret has 8 tooling stations with wedge lock system. Tailstock system with MT-3 taper and live centre is provided on an auxiliary bed to increase the prospects of the machine without disturbing the distinctive features. The tailstock unit is flexible to the auxiliary bed or different work piece lengths.

2.1.2 Cutting Parameters Details

The major operating parameters affects the quality of surface finish in turning are the cutting speed (V), Feed rate (fr) Depth of cut (d) and Tool nose radius (r). For all metal cutting processes, "speed and feed" are imperative parameters. To narrate these parameters, it can be seen the Figure 4 showing the important geometry of fundamental machining parameters.

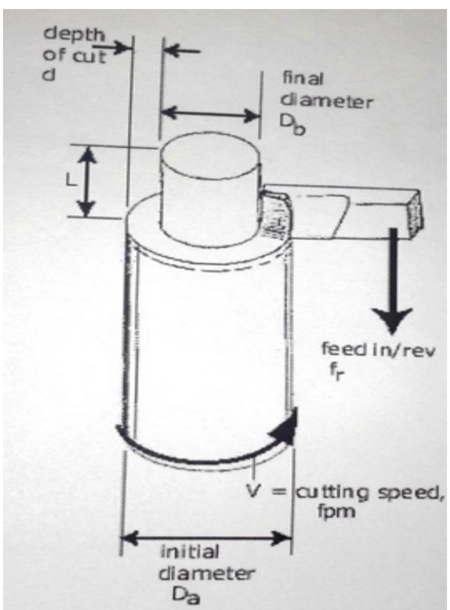


Figure 4. Geometry of Fundamental Machining Parameters.

For finishing operations, the rate of advance will be obsessed with the identified surface roughness for the finished product. The depth of cut will count on the particularized accuracy. The machining parameter, their range and levels used for experiment work are shown in Table 2.

2.2 Selection of Methods

In this we select the factors which affect the surface finish most. The factor in an experiment may be either quantitative or qualitative. If they are quantities, thought should be given as to how this factor is to be controlled at the desired value & the number of levels at which runs are to be constructed. These levels may be designated specifically or selected at random from the set of all achievable factor levels.

In choosing a response or depended variables, we must be assured that the response to be measured really provide the information about the problem under study. In this study response is surface roughness taken.

This step is of primary importance in the experimental process. It must be determined the difference in the true response the wish to detect & magnitude of the risk they are willing to tolerate so that an appropriate sample size may be chosen. We also determine the order in which the data will be collected. It is always necessary to maintain a balance between statistical accuracy & cost. A cost mathematical model for the experiment must be proposed, so that a statistical analysis of the data may be performed. We used central composite design which is very good for the analysis of second order equation.

Response Surface Methodology

Its idea can be to improve the response or to figure out the underlying mechanism. If the input factor is assessable and there are only scarce where response surface methodology becomes an efficacious tool for studying this relationship. A sequential experimentation tactics is considered, which eases a productive search of the input factor space by using a first order experiment followed by a second-order experiment. Evaluation of a second-order experiment could be executed by supposing the response surface relationship with a fitted second-order regression models to be efficiently estimated are considered which is based on central composite designs. A central composite design for two variables is referred to as, can be shown in Figure 5. The design may be sub divided into three parts. Components of central composite design (CCD) used is shown in Table 3. Design for k = 3, 4, 5, 6 Note That with 5 and 6x-vaiables, the size of the experiment is reduced by using a half-replicate of the 2^k factorial. With a half-replicate, α becomes $2^{(k-1)/4}$. Experimental planned data based on CCD for test run can be shown in Table 4 and, their actual corresponding run data are referred in Table 5 and Table 6.

Table 2. Machining Parameter Ranges and Their Levels.

S. No.	Parameter	Unit	Symbol	Range	Levels				
					−1.68	−1	0	1	1.68
1.	Cutting Speed	m/min	A	110.5 to 225.5	110.5	139.25	168.0	196.75	225.5
2.	Feed	mm/rev	B	0.04 to 0.2	0.04	0.08	0.12	0.16	0.2
3.	Depth of Cut	mm	C	0.2 to 1.0	0.2	0.4	0.6	0.8	1.0
4.	Nose Radius	mm	D	0.8	0.8	0.8	0.8	0.8	0.8

Table 3. Components of Central Composite Design.

Number of points					
No. of x-variable k	2^k Factorial	Axial	Center	Total N	Value of α
3	8	6	6	20	1.682
4	16	8	6	30	2.000
5	16	10	6	32	2.000
6	32	12	6	53	2.378

Table 4. Treatment Combination for (Three variable-five level) Experiment coded form.

Run	Factor 1 A: Cutting speed (m/min)	Factor 2 B:Feed (mm/rev)	Factor 3 C: Depth of cut (mm)
1	−1	1	1
2	1	1	−1
3	−1.68	0	0
4	−1	−1	1
5	0	−1.68	0
6	−1	1	−1
7	0	0	0
8	0	0	0
9	1.68	0	0
10	1	1	1
11	0	1.68	0
12	0	0	−1.68
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	1.68
17	0	0	0
18	−1	−1	−1
19	1	−1	1
20	1	−1	−1

Table 5. Treatment Combination in terms of Actual Factor.

Run	Factor 1 A: Cutting speed m/min	Cutting speed (N) rpm	Factor 2 B: Feed mm/rev	Factor 3 C: Depth of cut mm
1	139.25	1458	0.16	0.8
2	196.75	2116	0.16	0.4
3	110.5	1239	0.12	0.6
4	139.25	1654	0.08	0.8
5	168.0	1737	0.04	0.6
6	139.25	1478	0.16	0.4
7	168.0	1857	0.12	0.6
8	168.0	1938	0.12	0.6
9	225.5	2331	0.12	0.6
10	196.75	2145	0.16	0.8
11	168.0	1910	0.2	0.6
12	168.0	1938	0.12	0.2
13	168.0	1737	0.12	0.6
14	168.0	1807	0.12	0.6
15	168.0	1883	0.12	0.6
16	168.0	2026	0.12	1.0
17	168.0	1737	0.12	0.6
18	139.25	1478	0.08	0.4
19	196.75	2206	0.08	0.8
20	196.75	2270	0.08	0.4

Table 6. Experimental Observations.

Run	Factor 1 A: Cutting speed m/min	Factor 2 B: Feed rate mm	Factor 3 C: Depth of cut mm	Response Surface Roughness
1	−1.00	1.00	1.00	1.56
2	1.00	1.00	−1.00	1.58
3	−1.68	0.00	0.00	1.47
4	−1.00	−1.00	1.00	0.87
5	0.00	−1.68	0.00	2.02
6	−1.00	1.00	−1.00	1.78
7	0.00	0.00	0.00	0.98
8	0.00	0.00	0.00	1.07
9	1.68	0.00	0.00	1.21
10	1.00	1.00	1.00	1.61
11	0.00	1.68	0.00	2.01
12	0.00	0.00	−1.68	1.6
13	0.00	0.00	0.00	1.05
14	0.00	0.00	0.00	1.11
15	0.00	0.00	0.00	1.115
16	0.00	0.00	1.68	1.116
17	0.00	0.00	0.00	0.58
18	−1.00	−1.00	−1.00	2.54
19	1.00	−1.00	1.00	0.66
20	1.00	−1.00	−1.00	0.7

2.3 Mathematical Modelling

Once the experimental design become final, the subsequent step is to fit the given data in mathematical model using regression analysis. Most of the engineering problems involve more than one variable. For example, surface roughness in the machining depends upon the feed, speed, depth of cut, nose radius, tool material etc. The general equation of fitting the second order model is

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_1 X_2 + \beta_{11} X_1^2 + \ldots\ldots + e_u;$$

where β is called regression coefficients.

Surface roughness measurement

In this study, direct method measurement method is used i.e., stylus type to measure the surface roughness of the specimen. The surface roughness meter used in our experiments is manufactured by MITUYOYO-JAPAN, make of JIS'94.

3. Results

First of it was drawn the ANOVA table to examine the good competence of the model. ANOVA Table is shown in Table 7 the calculation is done at 95% confidence level. In Prob>F column the values which are less than 0.05, are significant. In this case A, C, AB, AC are considerable model terms. It means that these terms influence the model to a great extent. Also, the lack of fit test is not significant. It means that these factors are adequately explaining the behavior of surface roughness.

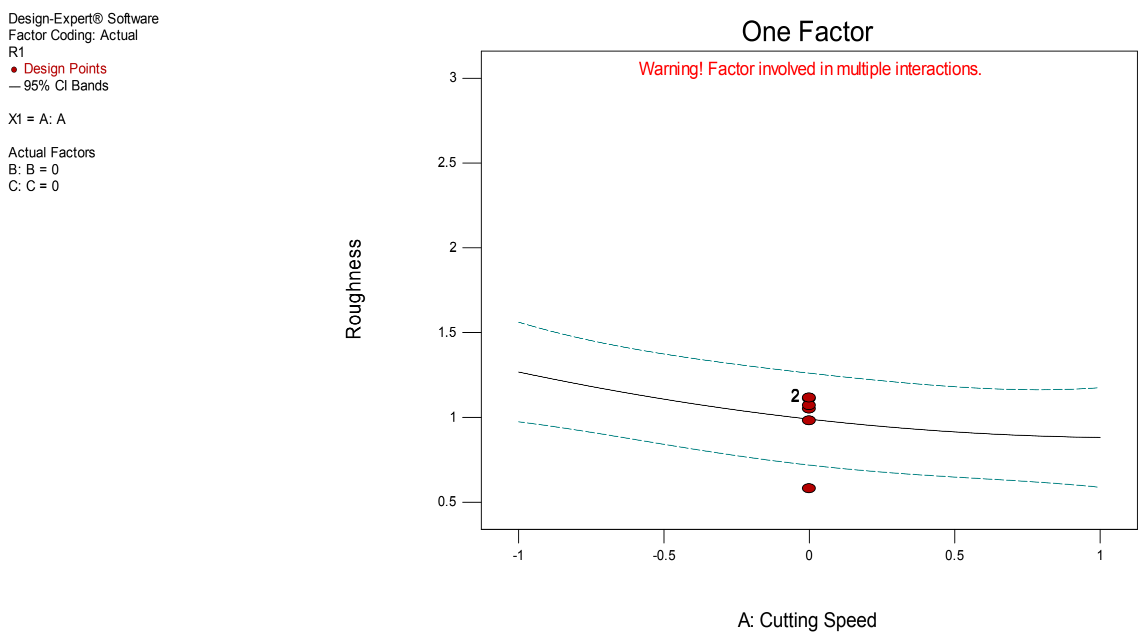


Figure 5. Surface Roughness vs Cutting Speed

Table 7. Analysis of Variance (ANOVA) Test for Surface Roughness.

Source	Sum of Square	DOF	Mean Square	F value	P-value Prob>F	
Model	4.04	9	0.45	5.05	0.0092	significant
A-cutting speed	0.51	1	0.51	5.72	0.0378	
B-feed rate	0.22	1	0.22	2.50	0.1449	
C-depth of cut	0.54	1	0.54	6.06	0.0336	
AB	0.45	1	0.45	5.07	0.0480	
AC	0.44	1	0.44	4.97	0.0500	
BC	0.29	1	0.29	3.25	0.1018	
Residual	0.89	10	0.089			
Lack of Fit	0.68	5	0.14	3.28	0.1093	Not significant
Pure Error	0.21	5	0.042			

3.1 Model Formation

The model has been formed with the help of software Design Expert's Version 9.0.2. The second order model given by the software is given below.

Surface roughness =

+0.99043	
-0.19311	*cutting speed
+0.12764	* feed rate
-0.19873	* depth of cut
+0.23750	* cutting speed * feed rate
+0.23500	* cutting speed * depth of cut
+0.19000	* feed rate * depth of cut

3.1.1 Surface Roughness vs Cutting Speed

It is unambiguous from the Figure 5 that with increase in cutting speed, the value of surface roughness decreases that is the surface becoming smooth. The reason is that at low cutting speed, the cutting forces are high & hence the work material take up a new shape, i.e., a tougher built-up edge. Owing to rise in temperature it was found to be decrease in frictional stress occurring on the rake face with the higher cutting speed and cutting forces which may be reason to shape up the form of build edge but with less strength. Combination of these two effects were found valuable for surface finish. It was also noted that at relatively small cutting, temperature could not rise as per required that may cause for the formation of the built-up edges. On the other side, it was also noted that if the cutting speed further increases, the cutting become again progressively favour for shaping the built-up edge. In the end, at sufficiently high speed, the built edge fade totally & surface finish become insensitive of cutting speed.

3.1.2 Surface Roughness vs Feed Rate

As is vivid in Figure 6 with the increase in the value of feed, the surface roughness value increases drastically, at low feed rate, the fracture takes place which is very few when it was compared with high feed. With very small crevice in surface, it consistently ushers to roughness on surface fewer and vice versa. In addition to this, increase in feed assisted to increases in roughness which causes ultimately increased in forces and chattering phenomenon. This behavior caused for improper machining with faster traverse. It has also proved that [27] that $h = f^2/8r$, where, h, is peak to valley height, r is tool nose radius, and f is feed.

3.1.3 Surface Roughness vs Depth of Cut

As shown in Figure 7 initially with the increase in value of depth of cut there is very slight Decrease in surface roughness and on further increase there is very slight decrease in surface roughness. With the increase in depth of cut it was observed mounting in normal pressure which subsequently into seizure on the rake face and also assist in the shaping as the built-up edge [28,29]. Figure 8 shows the actual vs predicted data. This graph represents the differences between the actual values and the values that are predicted by the model. R^2 is the squared correlation of actual and predicted values and, as such, contains all the data that have been used for model estimation to judge the model's predictive power, it represents a measure of in-sample predictive power. Figure 9 shows the run vs

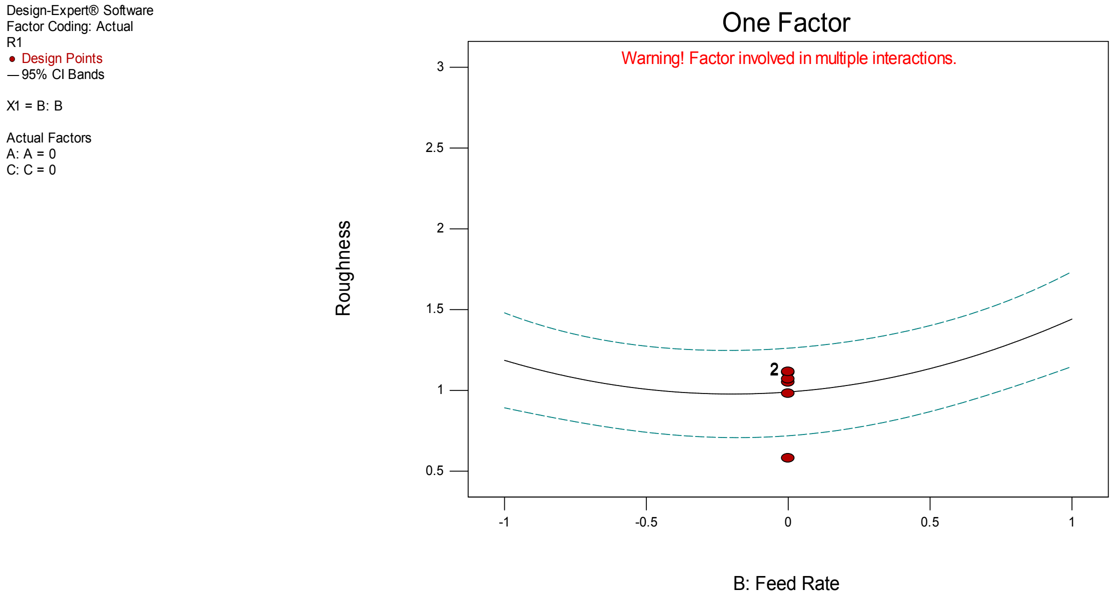


Figure 6. Surface Roughness vs Feed rate.

residuals which represents the residuals in each run. Figure 10 shows the contours in 3 d surfaces where contours along with three dimensional surfaces are shown in Figure 10, 11 and 12 with the help of these contours, the value of response can be calculated, can be seen in Table 8, at any point in the designated region. Figure 10 shows relationship between response surface between feed rate and cutting speed where the third parameter depth of cut kept constant at the middle value. Figure 11 shows response surface between the depth of cut and cutting speed where the third parameter feed rate kept constant at the middle value. Figure 12 shows relationship between response surface between the feed rate and depth of cut where the third parameter cutting speed kept constant at the middle value.

Table 8. Optimization Results.

No.	Cutting speed	Feed rate	Depth of cut	Surface Roughness
1	196.75	0.08	0.8	0.778
2	196.75	0.08	0.4	1.085
3	196.75	0.16	0.4	1.436
4	139.25	0.16	0.4	1.817
5	139.25	0.08	0.4	2.417

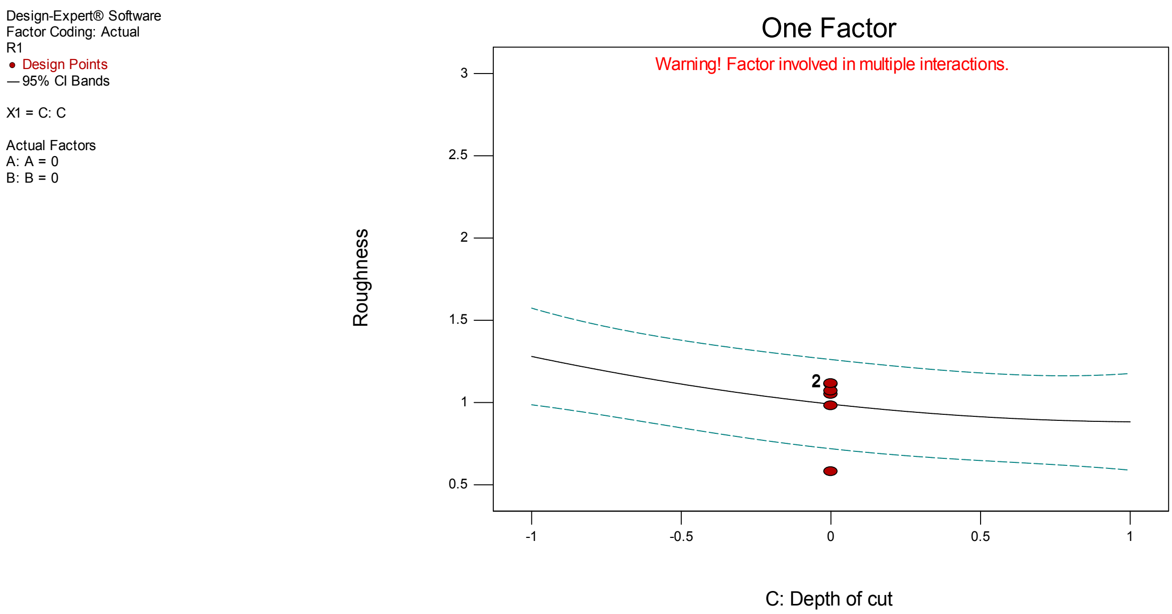


Figure 7. Surface Roughness vs Depth of cut.

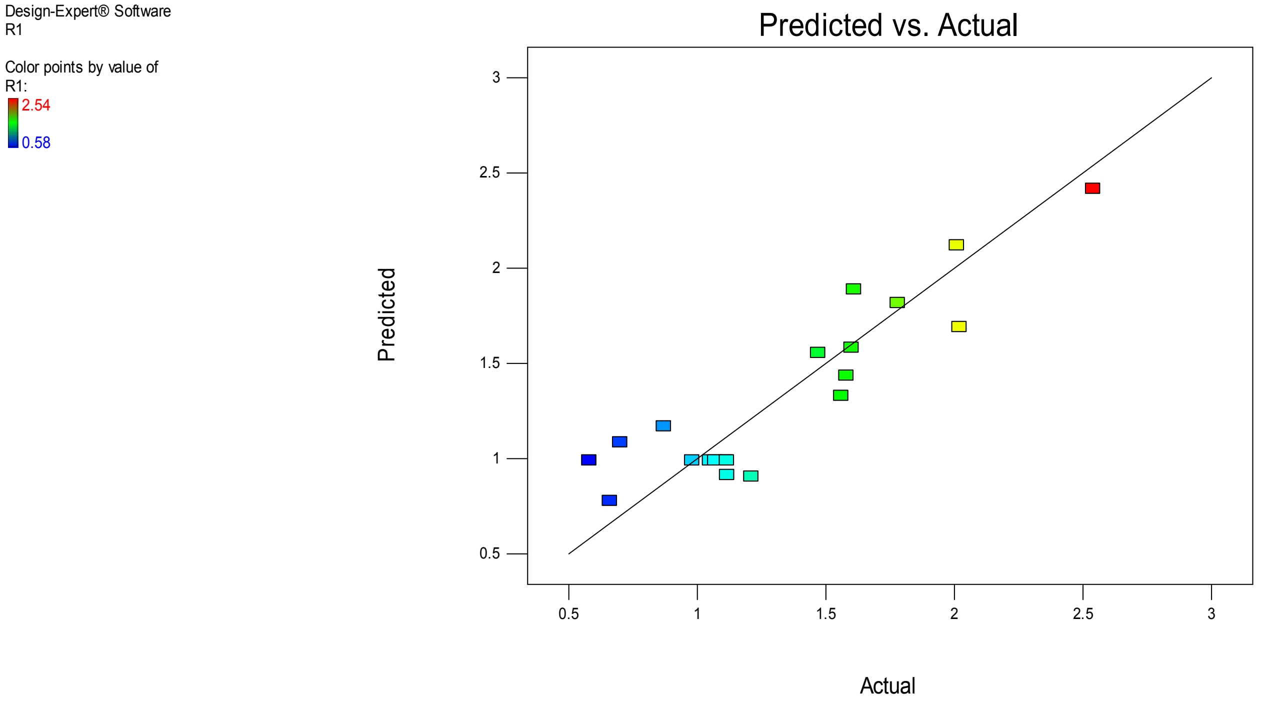


Figure 8. Observed vs Predicted

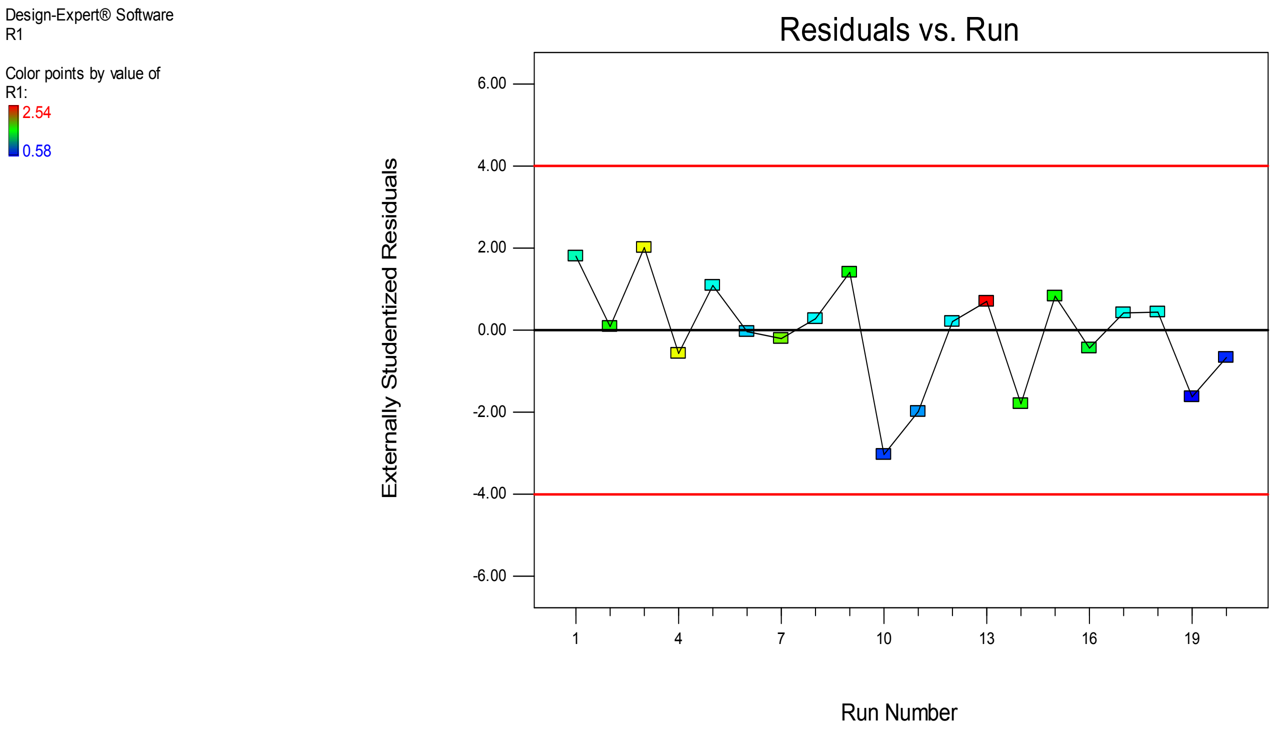
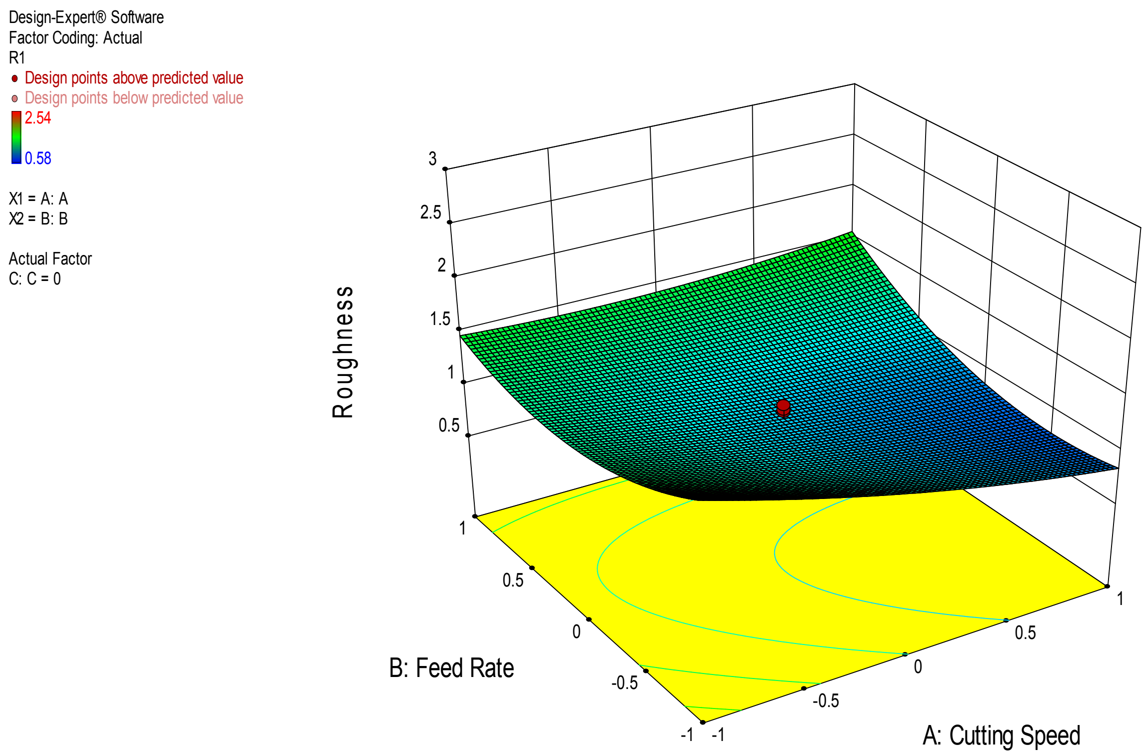


Figure 9. Run vs Residuals



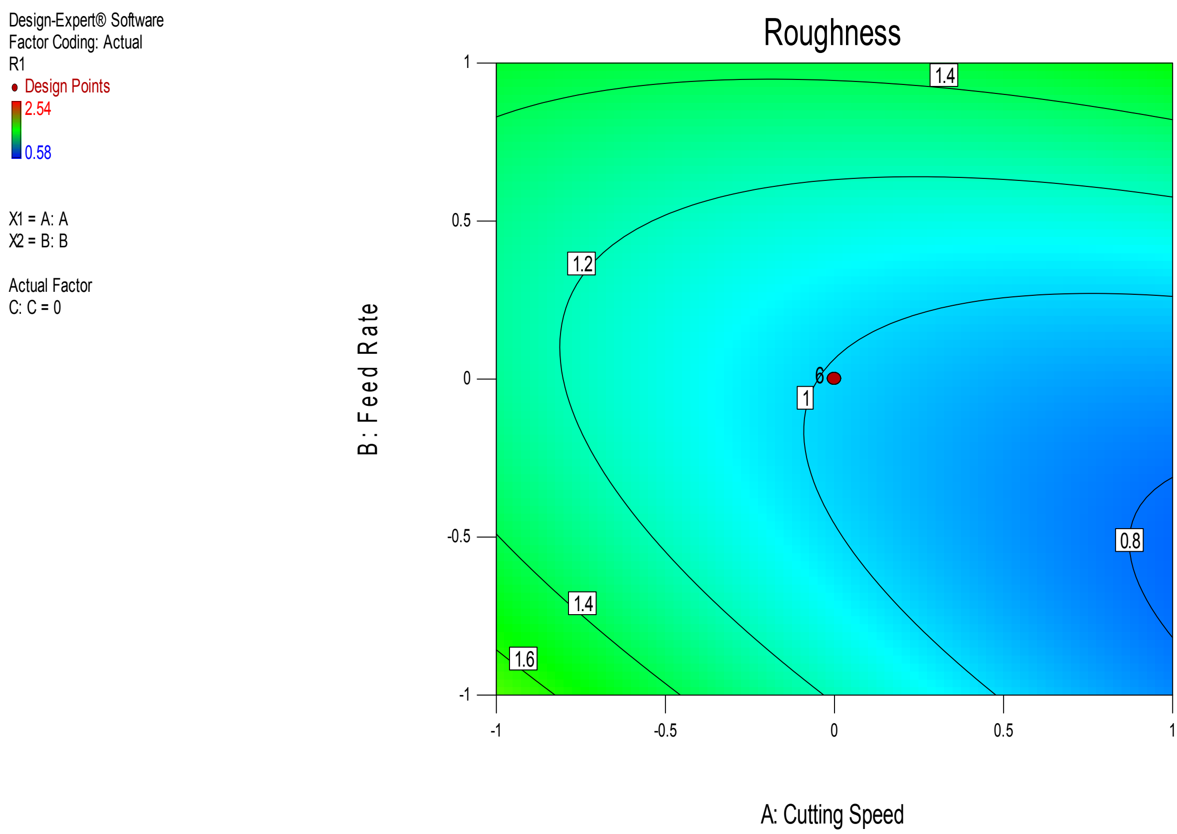


Figure 10 (a&b). Contours along with 3D surface for cutting speed and feed rate

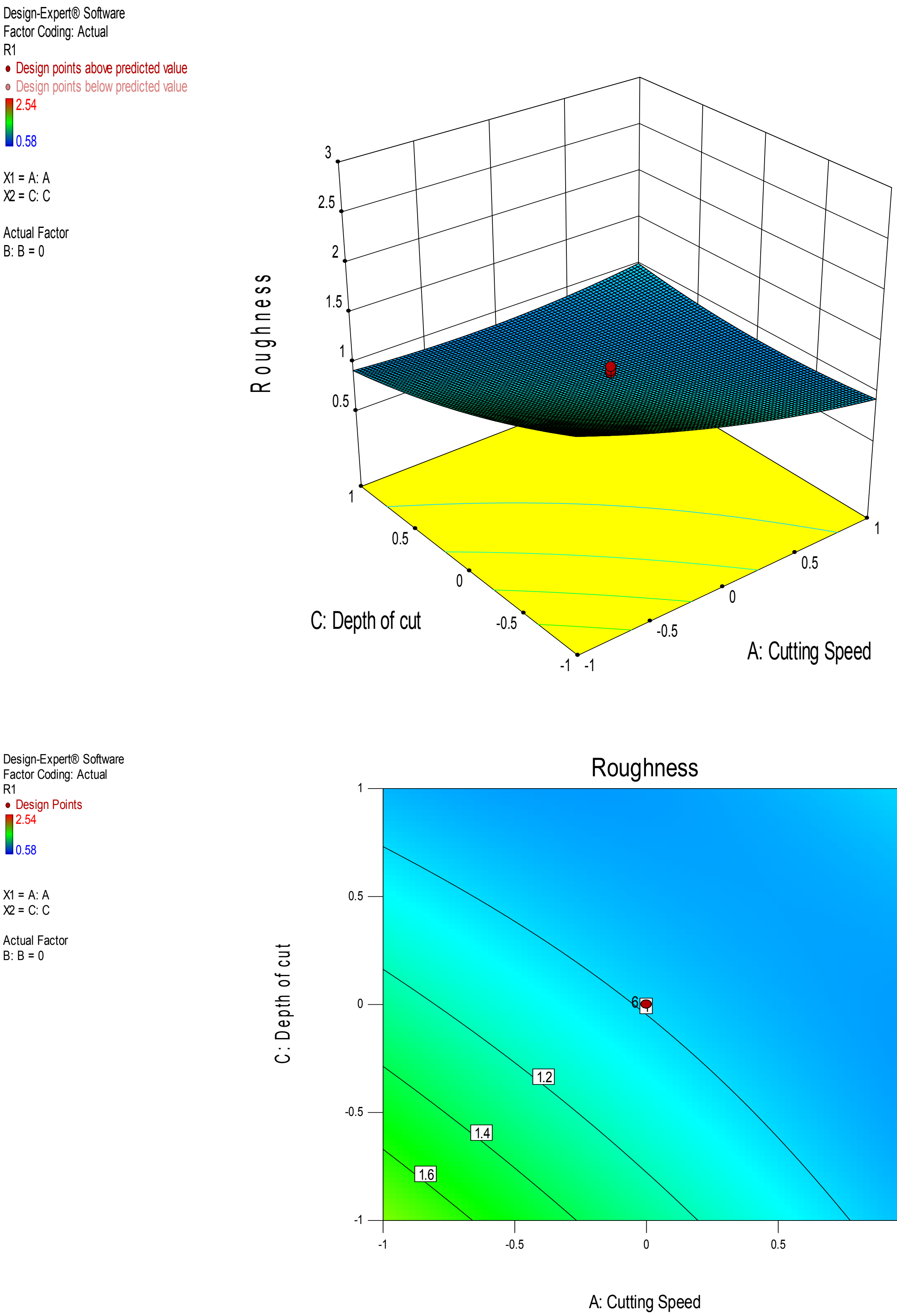


Figure 11 (a&b). Contours along with 3D surface for depth of cut and cutting speed

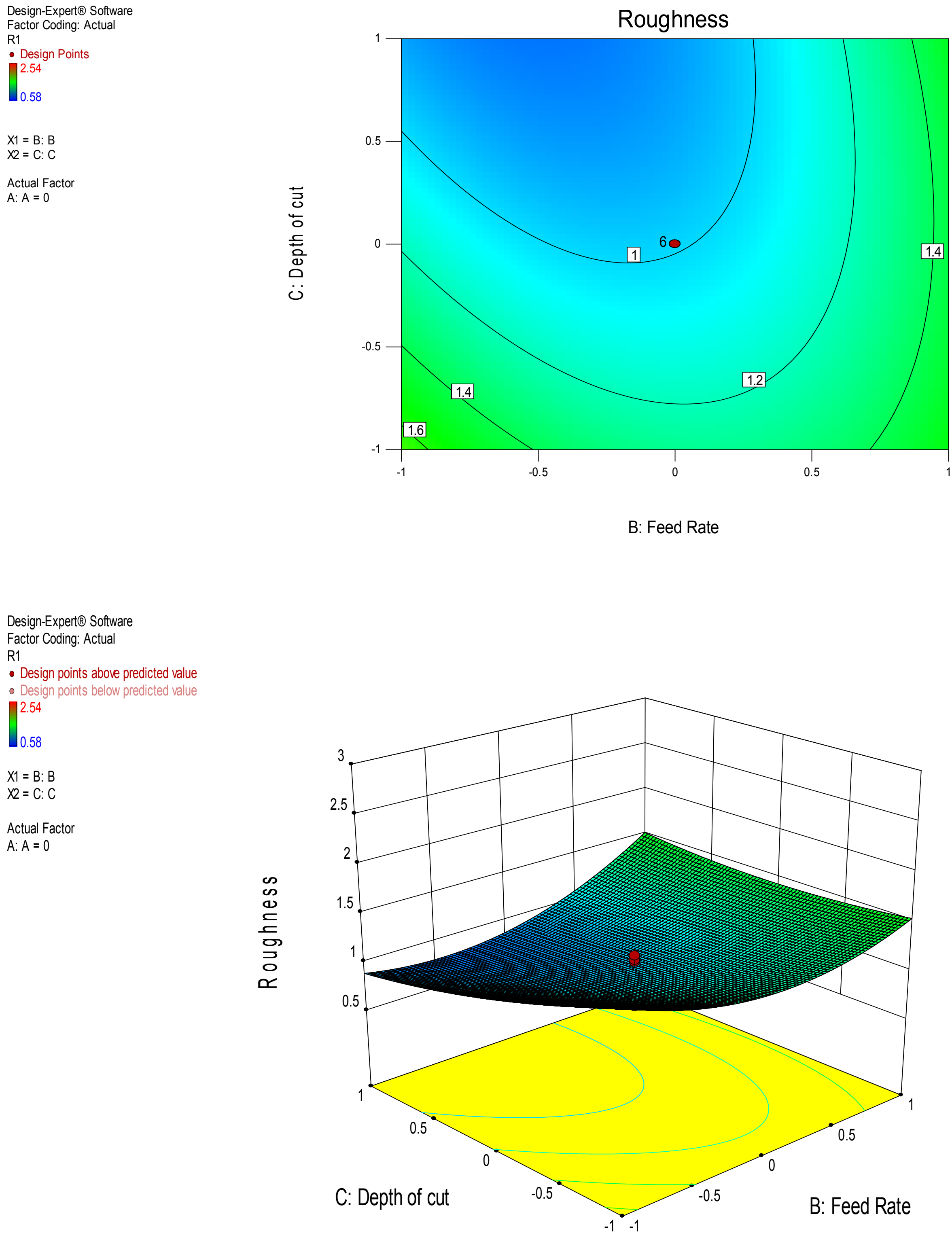


Figure 12 (a&b). Contours along with 3D surface for feed rate and depth of cut.

3.2 Discussions

Effect of tool angle on the roughness

Increasing the feed rate and cutting speed increases the cutting temperature [30], which can lead to the softening and burning of the matrix material [31]. Therefore, decreasing the surface roughness for higher feed rates at a high cutting speed might be explained by the adhering of the uncut metallic fibers to the softened matrix under high cutting temperatures.

As it is very well known that cutting forces usually increase with an increase in the feed rate, but the necessity of cutting forces on the cutting speed was found to be varying [32]. It can be understood that as cutting force increases as in the feed rate increases, and there becomes a larger influence on the cutting force for higher cutting speeds. However, the variation of cutting forces remains vary as the cutting speed changes and can be considered in three cutting speed ranges, including (I) low cutting speeds (100-175 m/min), (II) moderate cutting speeds (175-375 m/min), and (III) high cutting speeds (375-500 m/min). In the low cutting speeds, the effect of cutting speed on resultant cutting force is not noteworthy; in the moderate speed, the cutting force increases as with the cutting speed; and whereas in at higher cutting speed, the cutting force weakens as with cutting speed increases. The nonuniform disparity of the cutting force towards cutting speed is steady; as reported by other researchers [31-33]. Since high cutting speed works as a source of temperature so cutting force variation can be correlated to cutting temperatures with the relevance of cutting force. Therefore, at low cutting speeds, it is obvious the of not having comparable cutting temperatures for softening the cutting tool, and hence dry friction predominates. The softening/degrading of the cutting tool in the cutting zone occurs at a critical speed and causes a reduction in cutting forces [32].

In the term of tool angle, one we need the show the effect of the lead angle on the surface roughness which showed nonlinearly variation as with the lead angle and with the cutting speed. The minimum R_a is achievable for a lead angle of 5° for low cutting speeds and 0° for higher cutting speeds, which is revealed the high roughness values for lower cutting speeds as compared to those for higher cutting speeds.

In the terms of rake angle and relief angle, it is observed that surface roughness increases as with the radial rake angle and primary radial relief angle in the general. This may be happened due to the deterioration of tool causing from larger rake angle along with relief angle. At the same time, a radial rake angle also offers an improved surface finish because of easily chip flow [34]. As stated by parallel shear zone concept, larger positive radial rake angle provides higher shear angle [35]. Due to formation of sharp cutting edges on the periphery lateral cutting force extensively reduces. On the other side the excessive rake angle weakens the tool and there becomes chance of acceleration amplitude in feed direction [36]. Consequently, the side surface roughness first decreases and then increases. It is very well known that larger relief angle weakens the friction effect between radial relief surface and side surface of the workpiece due to shortening of the contact length, which causing reduction in adjacent surface roughness with primary radial relief angle [37]. In cutting process, high speed induced cutting temperature causing thermal load is the reason for creating thermal load which induces residual tensile stresses whereas mechanical load caused by cutting force makes the reason for generating residual compressive stress. Consequently, residual compressive stress may increase or decrease with the change in cutting force caused by varying these cutter geometric angles [38]. Accordingly, roughness value may vary.

4. Conclusions

This work presented a central composite design approach to study the impact of turning parameters on surface roughness. The following conclusions are drawn from research:

1) Feed rate has the higher effect on the surface roughness. The surface roughness increases very sharply with the increase in feed rate.

2) The surface roughness decreases with the increase in cutting speed and depth of cut has very small effect.

3) Optimal cutting parameters for minimum surface roughness are determined.

4) Closeness between the predicted value and measured showed the adequacy of the developed model for surface roughness on the machining of EN 8.

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