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A STUDY OF SURFACE ROUGHNESS IN DRILLING OF AISI H11 USING RSM

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Introduction

In the manufacturing industries, various machining processes (turning, milling, drilling etc.) are adopted for removing the material from the workpiece to obtain finished product. Among the various metal removing processes, drilling is the one of most important metal removing process as compared to other traditional machining processes. Drilling is use for making the hole in the work pieces. Hole making is a most important machining process in manufacturing. During the drilling, the drill rotates and fed into the work piece to remove the material in the form of chips that move along the fluted shank of the drill. Different drilling tools and hole making methods are used for drilling. The selection of different tools and methods depends on the type of workpiece, size of the hole, the quantity of holes, and the quantity of the holes in given time periods. Also, drilling is used as an initial process for many machining operations, such as reaming, tapping and boring. Drilling process is widely used in the aerospace, aircraft and automotive industries.

During the drilling of the workpiece, it has long been recognized that the drilling conditions (drill point geometry, drill and workpiece materials, drilling parameters like feed rate and spindle speed) affect the performance of the operation to a greater extent. These drilling conditions should be selected to optimize the economics of drilling operations. So it can be achieved by empirical modeling of performance as a function of machining conditions using design of experiments (DOE). The proposed work will be employed for optimization of drilling conditions for minimum surface roughness using response surface methodology based on face cantered design.

DRILLING

In manufacturing industries, the production of holes in workpiece is a common and most important process. There are many tools and processes for producing the holes. The selection of tools and process mainly depends on type of material, the size of the hole, quantity of holes produce in given time periods. Among the many hole making process, drilling is a major and commonly use hole making process. For some of processes, drilling is the initial process, such as reaming, tapping and boring. As the drill rotates and feed into the work piece, material is removed in the form of chips that move along the fluted shank of the drill. Drilling process involves relative motion between the drill and the work piece. Generally, the drill rotates and feed into the work piece for large workpieces, but sometimes workpiece rotate and feed into the drill. Figure 2.1 show the drilling process in which the drill is fed into the workpiece.

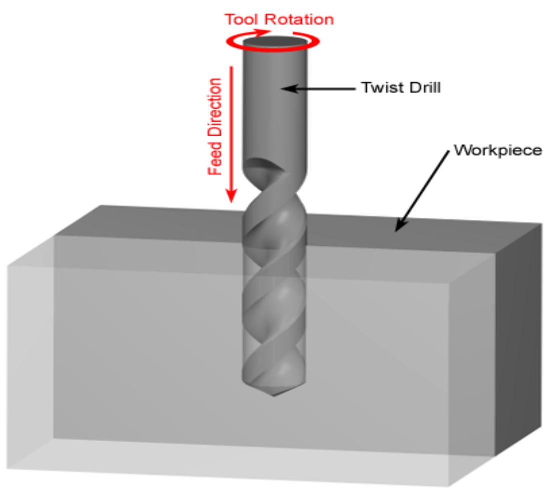

Figure 1: Drilling process

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DESIGN OF EXPERIMENTS

Design of experiment procedure is a powerful approach to improve product design or improve process performance. This procedure constitutes a systematic method concerning the planning of experiments, collection and analysis of data with near-optimum use of available resources. It is possible to identify the process conditions that influence product quality and costs, which in turn enhance the product manufacturability, quality, reliability and productivity.

The advantages of design of experiments are as follows:

- Numbers of trials are significantly reduced.
- Important decision variables which control and improve the performance of the product or the process can be identified.
- The optimal setting of the parameters can be found out.
- Experimental error can be estimated.

On the basis of planning of experiments, design of experiment includes number of techniques like factorial design, Taguchi method, centre composite design etc.

In the present work, response surface methodology based on face cantered design has been used to plan the experiments and subsequent analysis of the data collected.

OBJECTIVES

Thus objectives of the present study are:

1. Optimizations of drilling conditions for minimum surface roughness during drilling of AISI H11 die steel using tungsten carbide drill.
2. Development of surface roughness prediction model in terms of drilling conditions using RSM based on face centered design.
3. To investigate the effect of drilling conditions (spindle speed, feed, and depth of hole) on surface roughness during drilling of AISI H11 die steel.

4. LITERATURE REVIEW

*Metal machining has been an interesting topic of research for decades. Early research efforts include topics, such as, chip formation, heat generation at tool-chip and tool-work interfaces, tool wear, tool life, cutting force analysis, machinability power requirements, manufacturing cost and productivity etc. With more emphasis on quality of surface finish with high production rate, in past few decades, research efforts seem to have been diverted towards the study of surface finish/roughness in metal machining. It may be due to the reason that the surface finish/roughness has great importance with regard to friction, wear, fatigue resistance etc. of the machined part/surface.

*Profile of a surface is the total vertical departure, at a cross section, from a fixed datum. The long period component of the surface profile is called waviness and the short period (i.e., closely spaced) one is called roughness. Surfaces obtained from machining processes are more vulnerable to damage of surface integrity than the surfaces obtained from cold working and polishing processes. However, by proper selection of machining parameters, quality surface finish and good surface integrity may be obtained. Studies have been reported on mathematical modeling and selection of machining parameters for optimization of surface roughness in recent past. A brief review of research on the topic is presented below.

*Madival (1998) employed artificial neural network to investigate the effect of drilling parameters on surface roughness during the drilling of composite. An attempt has also been made to developed surface roughness prediction model using ANN. The cutting speed and feed have been considered as drilling parameters. The result clearly shows that surface finish decreases with increase in feed rate for all the values of cutting speed.

*Lin and Chen (1999) experimentally investigate the effect of cutting speed, feed and type of drill on drill wear, torque, hole quality and thrust force during the drilling of carbon fiber-reinforced composite materials. It has been revealed that as the cutting speed increases the wear of drill also increase and the thrust force increases with increase in drill wear. It has also been found that tool wear is the major problem encountered when drilling carbon fiber reinforced composite materials at high speed.

*Davim and Reis (2002) Used Taguchi methodology to investigate the effect of cutting speed and feed rate on delamination during the drilling of carbon fiber reinforced plastic (CFRP). The ANOVA has also used to investigate the most significant parameter.

The cutting speed and feed rate have been considered as drilling parameters. The cutting speed has been found most significant parameter that affects the delamination factor. The delamination factor increases with increase in cutting speed as well as with increase in feed rate.

*Tosun and Muratoglu (2003) experimentally investigated the effect of feed rate and cutting speed on surface roughness during the drilling of Al/17% Sic of metal-matrix composites. For drilling purpose HSS, TiN coated HSS and solid carbide drills have been used. The result shows that the surface roughness decrease with increase in feed rate at all the spindle-speed for all the drills. Also, with increase in speed, the surface roughness increases with HSS drills but the surface roughness is not clear in the TiN coated HSS and solid carbide drills.

*Nouari et al. (2005) experimentally investigated the effect of machining parameters on tool wear, hole diameter deviations and surface roughness during the dry drilling of aluminum alloy 2024 using coated tungsten carbide drill, uncoated tungsten carbide drill and HSS drill. The drilling experiments were performed on rigid instrumented drilling bench. The result shows that minimum hole deviation and minimum surface roughness has been achieved with in terms of maximum and minimum hole diameter deviations and surface roughness are obtained for the uncoated and coated tungsten carbide drills. The HSS tool is found not suitable for dry machining of aluminum alloy 2024. The cutting speed has been found most significant parameter that affects the surface roughness, tool wear and hole deviation during the dry drilling of aluminum alloy A2024.

RESEARCH GAP

The review of the research presented above reveals that work has been carried out to investigate the effect of machining parameters on surface roughness during drilling of various ferrous and non ferrous metals. The AISI H11 steel is widely used as a main material in die making industries, where superior machinability is the most important factor. A study of surface roughness during drilling on this material will be quite useful. In the present work the response surface methodology based on face cantered design has been selected for development of prediction models and optimization of drilling parameters for minimum surface roughness. An effort has also been made to investigate the effect of drilling parameters on surface roughness during drilling of AISI H11 steel.

METHODOLOGY

To develop the prediction models using response surface methodology based on face centered design, first step is to conduct the experiments according to design matrix. The design matrix has different combinations of input (independent) parameters. Second step is to measure the dependent (response) parameters. In the present work feed, spindle speed and depth of hole have been consider as input parameters while surface roughness is consider as response. After collection of data, next step is to develop the prediction model using regression analysis. The significance of model terms is to be check using ANOVA analysis. ANOVA is commonly used to perform test for significance of the regression model, significance on individual model coefficients and lack-of-fit of the model. Next step is investigation of the effect of drilling parameters on surface roughness through contour plots interaction plots and 3D plots. Final step is optimization of drilling parameters for minimum surface roughness.

1.1 INTRODUCTION

In this chapter we will discuss about experimental work which includes selection of drilling parameters, selection of range of drilling parameters, formation of design matrix using RSM based on face centred design, selection of work-piece material, experimental set-up, measurement of surface roughness.

The process parameters that were chosen for experimentation are given as under:

1. Spindle speed (RPM)
2. Feed (mm/rev.)
3. Depth of hole (mm)

Table 1:

Factor	Name	Units	Type	Subtype	Minimum (-1)	Maximum(+1)
A	Spindle Speed	(RPM)	Numeric	Continuous	400	1200
B	Feed	(mm/rev.)	Numeric	Continuous	0.01	0.02
C	Depth of hole	(mm)	Numeric	Continuous	10	20

FORMATION OF DESIGN MATRIX

In the present work RSM based on face centered design has been used to plan the experiments. Total 20 numbers of experiments has been finalized according to RSM based on face centered design. Out of 20 experiments, 8 are the factorial points, 6 are the star point and 4 are the centre points.

Table 2:

S. No.	A:Spindle Speed (RPM)	B: Feed (mm/rev.)	C:Depth of hole (mm)
1	400	0.01	10
2	1200	0.01	10
3	400	0.02	10
4	1200	0.02	10
5	400	0.01	20
6	1200	0.01	20
7	400	0.02	20
8	1200	0.02	20
9	400	0.015	15
10	1200	0.015	15
11	800	0.01	15
12	800	0.02	15
13	800	0.015	10
14	800	0.015	20
15	800	0.015	15
16	800	0.015	15
17	800	0.015	15
18	800	0.015	15
19	800	0.015	15
20	800	0.015	15

ANOVA for surface roughness prediction model

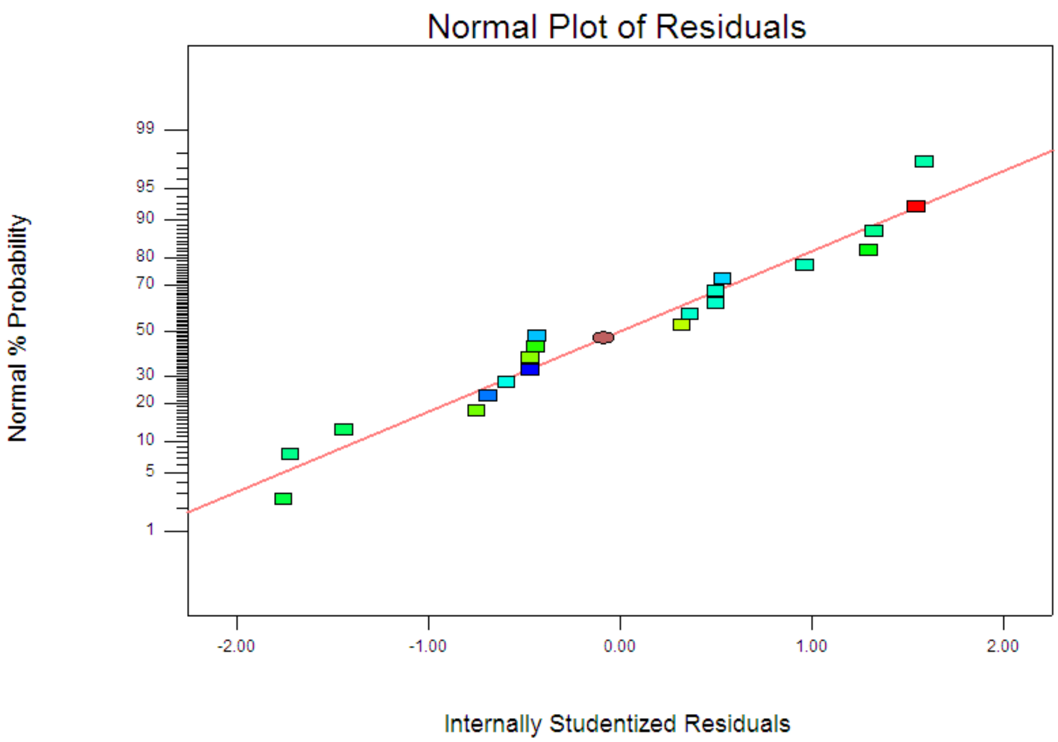


Figure 2:

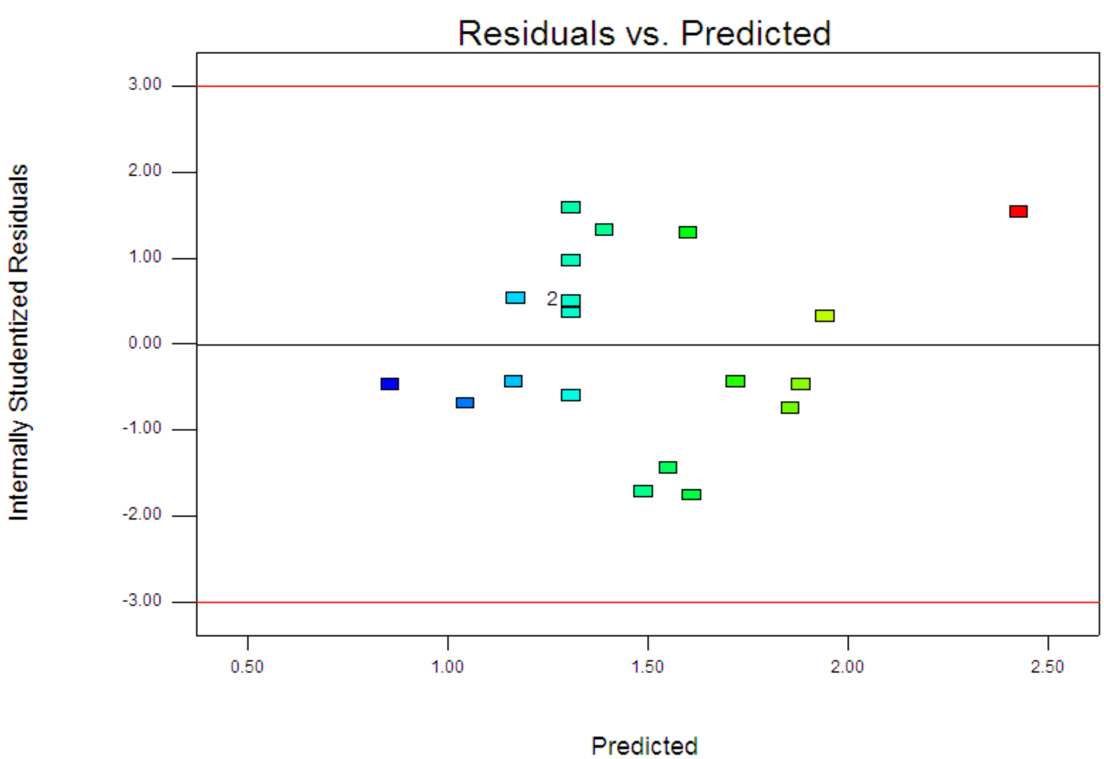


Figure 3:

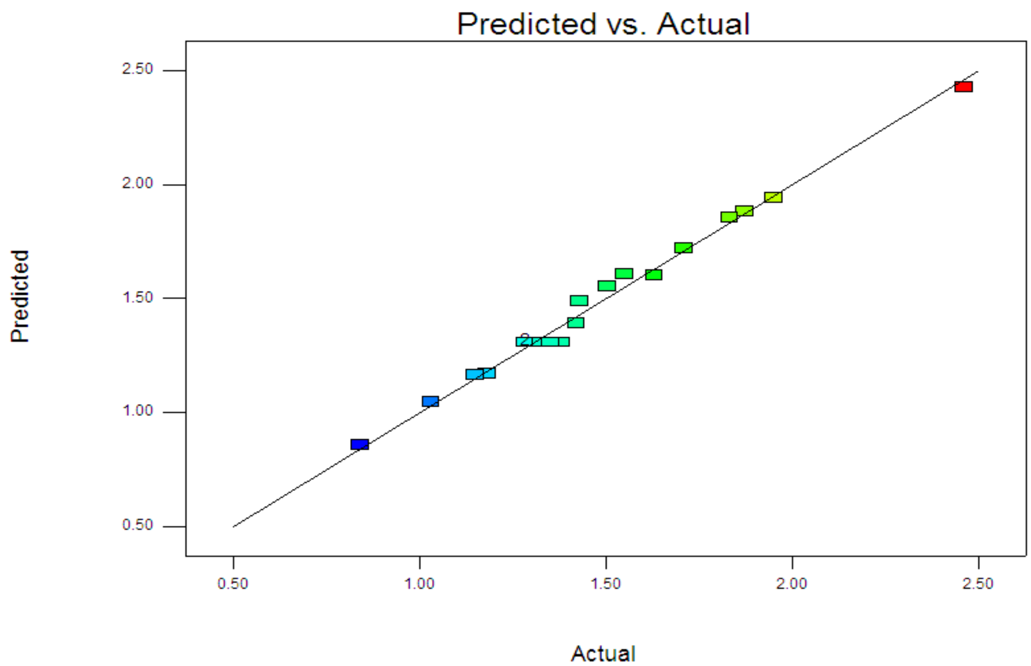


Figure 4:

ANOVA analysis for surface roughness

Table 3:

Source	Sum of squares	Degree of freedom	Mean square	F-Value	p-value Prob> F
Model	2.465	9	0.274	119.475	<0.0001S
A-Spindle Speed	0.232	1	0.232	101.064	< 0.0001
B-Feed	0.496	1	0.496	216.181	< 0.0001
C-Depth of hole	0.998	1	0.998	435.378	< 0.0001
AB	0.021	1	0.021	8.989	0.0134
AC	0.012	1	0.012	5.241	0.0451
BC	0.000	1	0.000	0.005	0.9426
A^2	0.431	1	0.431	187.928	< 0.0001
B^2	0.017	1	0.017	7.445	0.0212
C^2	0.051	1	0.051	22.102	0.0008
Residual	0.023	10	0.002		
Lack of Fit	0.018	5	0.004	3.373	0.1041NS
Pure Error	0.005	5	0.001		
Cor Total	2.488	19			
Std. Dev.	0.0479		R-Squared		0.991
Mean	1.478		Adj R-Squared		0.982
C.V. %	3.239		Pred R-Squared		0.947
PRESS	0.131		Adeq Precision		46.359

Surface roughness prediction model

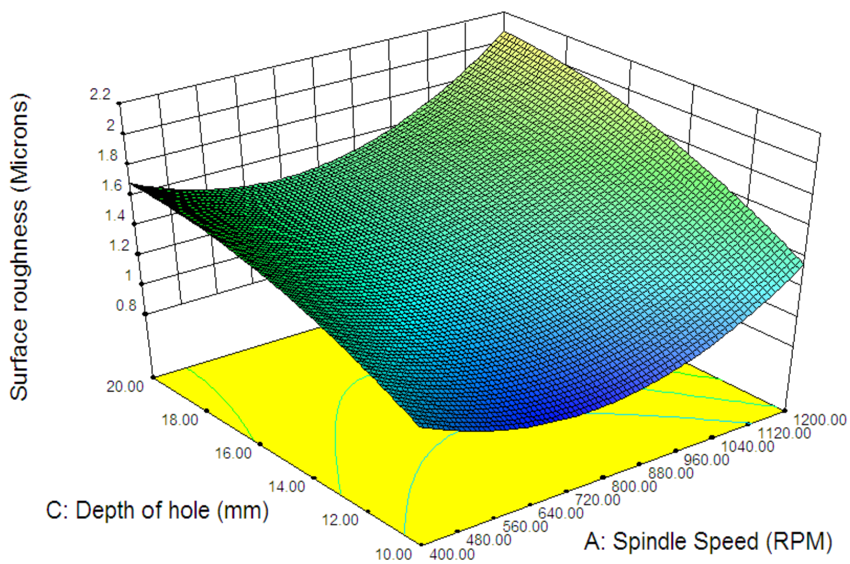
The regression model for surface roughness in terms of coded factors is shown as follows:

$$Surfaceroughness = 1.31 + 0.15 * A + 0.22 * B + 0.32 * C + 0.051 * A * B + 0.039 * A * C + 0.40 * A^2 + 0.079 * B^2 - 0.14 * C^2 \quad (4.1)$$

While, the following quadratic equation is the empirical model in terms of actual factors

$$Surfaceroughness = 0.996 - 0.0042 * Spindle\ speed - 70.3 * Feed + 0.21 * Depth\ of\ hole + 0.025 * Spindle\ speed * Feed + 0.00019 * Spindle\ speed * depth\ of\ hole + 0.000024 * Spindle\ speed^2 + 3150.9 * Feed^2 - 0.0054 * Depth\ of\ hole^2$$

EFFECT OF DRILLING PARAMETERS ON SURFACE ROUGHNESS



3D plot for surface roughness between spindle speed and feed at constant depth of hole (15mm)

Figure 5:

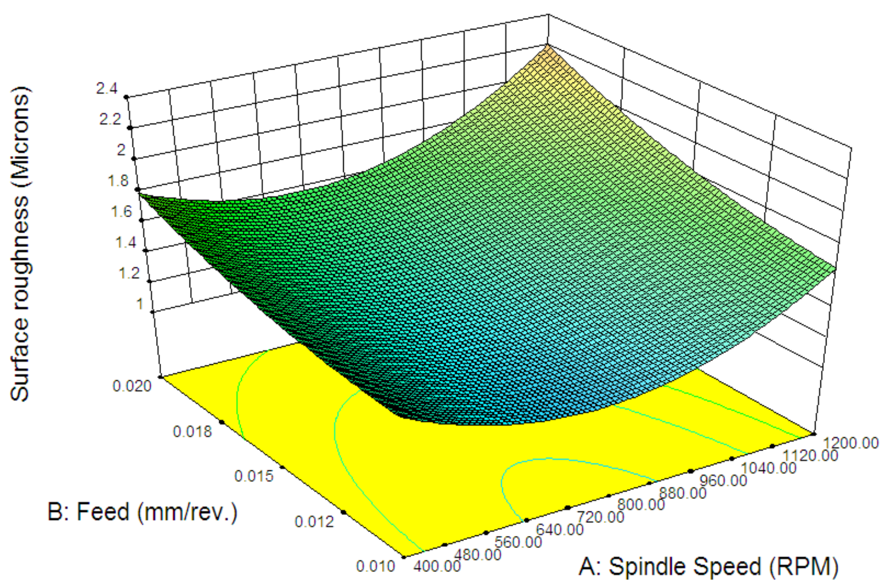


Figure 6:

3D plot for surface roughness between spindle speed and depth of hole at constant feed (0.015mm/rev.)

OPTIMIZATION OF DRILLING PARAMETERS FOR MINIMUM SURFACE ROUGHNESS

Table 4:

Name	Goal	Lower limit	Upper limit
A:Spindle Speed (RPM)	is in range	400	1200
B:Feed (mm/rev.)	is in range	0.01	0.02
C:Depth of hole (mm)	is in range	10	20
Surface roughness (Microns)	minimize	0.841	2.46

Table 5:

S.NO	Spindle Speed (RPM)	Feed (mm/rev.)	Depth of hole (mm)	Surface roughness (Microns)	Desirability	Remarks
1	733.62	0.010	10	0.719965	1	Selected

Optimization results for surface roughness

CONCLUSION AND FUTURE SCOPE

For surface roughness;
1) Surface roughness increases with increase in feed, increase in depth of hole while with spindle speed, surface roughness initially decreases as the spindle speed increases from 400 RPM to 733 RPM, afterward, surface roughness increases with increase in spindle speed from 733 RPM to 1200 RPM.
2) The minimum surface roughness 0.7199 microns has been obtained at spindle speed 733 RPM, depth of hole 10 mm, and feed 0.010 mm/rev.
3) All the three independent parameters (spindle speed, feed and depth of hole) seem to be the influential drilling parameters that affect the surface roughness.
4) The mathematical prediction models between surface roughness and drilling parameters, has been developed. The predicted results are in good agreement with the measured ones. These relationships are applicable within the ranges of tested parameters.
5) The surface roughness prediction model clearly shows that the feed seems to be the most significant factor that affects the surface roughness.
6) The quadratic effect of spindle speed, feed and depth of hole has also been appears for surface roughness

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