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INFLUENCE OF CUTTING PARAMETERS ON SURFACE ROUGHNESS IN TURNING OF INCONEL 718 WITH COATED CARBIDE TOOLS

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Abstract: Inconel 718 is mostly used in an aerospace engine parts and the gas turbine components because of their mechanical properties to withstand excessive loads even at higher temperature. Surface quality is one of the most specified customer necessities. Main indication of surface quality on mechanical parts is surface roughness. In the present study, an attempt has been made to examine the effect of machining parameters on the performance measures of surface roughness. This paper utilizes response surface methodology for prediction of surface roughness. Cutting experiments were conducted under dry cutting conditions for understanding the machining performance and surface characteristics of Inconel 718.

Keywords: Inconel 718, Surface roughness, Response Surface Methodology (RSM),

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1. INTRODUCTION

In mechanical engineering, metal cutting is one of the most significant methods of producing mechanical components. Turning is one of the processes of removing surplus material to produce a cylindrical part which cannot be finished by milling process. The demand of dimensional tolerances and better surface quality product has forced manufacturing industries to improve the quality and machining technology continuously. Surface roughness is influenced of cutting factor selection (cutting speed, feed rate, depth of cut) and process condition (tool material, tool geometry, tool wear, etc.) and depend on type of material to be machined [1].

Nickel-base Inconel 718 is mostly used in modern manufacturing owing to its unique properties. This material consists of nickel, chromium, molybdenum as major element. This material having high strength, hardness, and creep-rupture properties at high temperatures and corrosion resistance [2], Inconel 718 is frequently used in as aircraft engine parts, steam turbine, automotive sector etc. It was concluded that more than 50% of aero gas turbine engine parts were made of Inconel 718 [3].However, due to techno-mechanical characteristics such as lower thermal conductivity, work hardening, presence of abrasive carbide particles, hardness, affinity to react with tool material, etc. makes it difficult to machine. Hence, it is classified as “Difficult-to-machine materials”. Generation of good surface finish on the Inconel 718 components with cost effective machining is a challenge to the industries [4-6].

During machining process surface finish, specified dimensions tolerances and type of surface generation and its characteristics are of great importance in manufacturing. There are various tools which are used for the finished machining of Inconel 718. However, carbide cutting tools are the oldest amongst the hard cutting tool materials. Tungsten carbides are mostly used for continuous cutting operations.

Various researchers studied the machinability of Inconel 718. Thakur et al. [7] presented a general survey on the machining of superalloy Inconel 718 with tungsten carbide tools. They showed that the best surface roughness was obtained at cutting speed of 45–55 m/min, with feed rate of 0.08 mm/rev and the depth of cut 0.5 mm. Jindal et al. [8] developed the relative qualities of physical vapor deposition (PVD) TiN, TiCN, and TiAlN coatings on cemented carbide substrate (WC-6 wt% Co alloy) during machining of Inconel 718. Li et al. [9] discussed the high-speed cutting of Inconel 718 with coated carbide and ceramic inserts. They suggested that use of ceramic inserts of KY2000 with negative rake angle and carbide inserts of KC7310 in high-speed turning of Inconel 718.

Various design methods such as factorial design, response surface methodology (RSM) and Taguchi methods are now widely used as experimental approach. Taramen [10] performed a contour plot method to optimize tool wear, surface finish, and tool force for turning operations. Alauddin [11] also used response surface methodology to optimize the surface finish in end milling Inconel 718. They recommended selecting a combination of cutting speed and feed that reduces machining times without increasing the surface roughness. Choudhury and El-Baradie [12] used response surface methodology for assessing machinability of inconel 718.

The main objective of this work is to develop a model for surface roughness based on cutting speed, feed and depth of cut using response surface methodology. Surface roughness contour is developed from the cutting parameters selected. RSM is used to recognize the factors which control the surface roughness.

2. MATERIALS AND METHODS

In this experimental study, work material used was Inconel 718. The main elements in the Inconel 718 are chromium which attains high temperature oxidation resistance, where as other alloying elements are important to guarantee high-temperature strength, especially creep resistance. The experiments were conducted on a high precision HMT made lathe. These alloys are used in aero engines parts, specifically for the manufacture of turbine blades, which operate at high pressure and temperature. Typical major compositions of Inconel 718 are given in Table 1.

Table 1
MAjor Composition of Inconel 718

Elements	Ni	Cr	Mo	Co	Ti
% Wt	53.50	18.60	2.95	0.19	0.97
Elements	Al	V	Nb	Cu	Fe
% Wt	0.59	0.024	5.15	0.140	17.30

Table 2
Selected Machining Parameters and Its Levels

S. No.	*Coded factors*	*Actual Factors*	*Levels*		
			(-1)	*(0)*	*(+1)*
1.	A	Cutting speed, v m/min	50	70	90
2.	B	Feed rate, f mm /rev	0.10	0.125	0.150
3.	C	Depth of cut, d mm	0.2	0.3	0.4

A cylindrical bar of 60 mm diameter and 350 mm length has been used as test specimen. A PVD coated fine-grained high carbide based inserts (made by Kenmetal widia India Limited, Bangalore) were used. The ISO designations of the inserts used were CNMG120408.They were clamped mechanically on tool holder with ISO designation MCLNR2525M12. For machining of

Table 3
Central Composite Experimental Design

Run No.	*Cutting speed (A)*	*Feed rate (B)*	*Depth of cut (C)*
1.	0	0	0
2.	-1	-1	1
3.	0	1.681793	0
4.	1	-1	1
5.	-1	1	1
6.	1.681793	0	0
7.	-1.68179	0	0
8.	0	-1.68179	0
9.	0	0	0
10.	-1	1	-1
11.	1	-1	-1
12.	0	0	1.681793
13.	0	0	0
14.	0	0	0
15.	0	0	0
16.	0	0	0
17.	-1	-1	-1
18.	1	1	-1
19.	0	0	-1.68179
20.	1	1	1

Inconel 718, the machining parameters chosen for this work are cutting speed, feed rate, and depth of cut.The selected machining parameters and its levels are presented in Table 2. Based on central composite design (CCD), a total of 20 experiments were performed with carbides tools using a combination of different levels of factors. These 20 runs design were shown in the coded form in Table 3.

3. RESULTS AND DISCUSSIONS

The RSM was used for modelling and statistical analysis of machining parameters in the turning process to obtain the machining performance regarding surface roughness. The empirical quadratic model developed for Ra during the turning of Inconel 718 is given below:

$$\text{Surface roughness Ra} = +3.89812-0.033593\times v-23.05335\times f-1.47496\times d-0.017500\times vf-0.0031\times vd+8.50\times fd+.00022\times v^2+98.02193\times f^2+1.53018\times d^2$$

Analysis of variance ANOVA has established the significance of these models. The calculated values of F-ratio for regression models are greater than the standard value of F-ratio. The calculated lack of fit for surface roughness models is less than the tablet value at 99% confidence level, which indicates that the quadratic models are adequate.

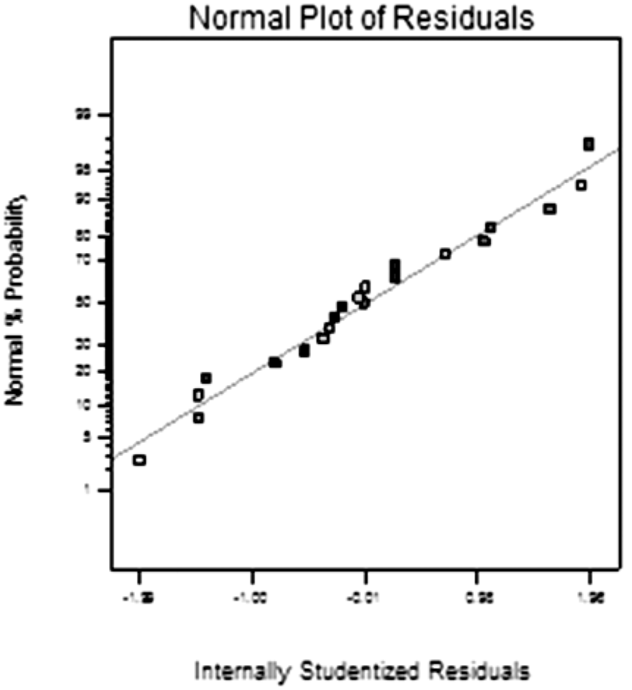

Figure 1: Normal Plot of Residuals for surface roughness Ra

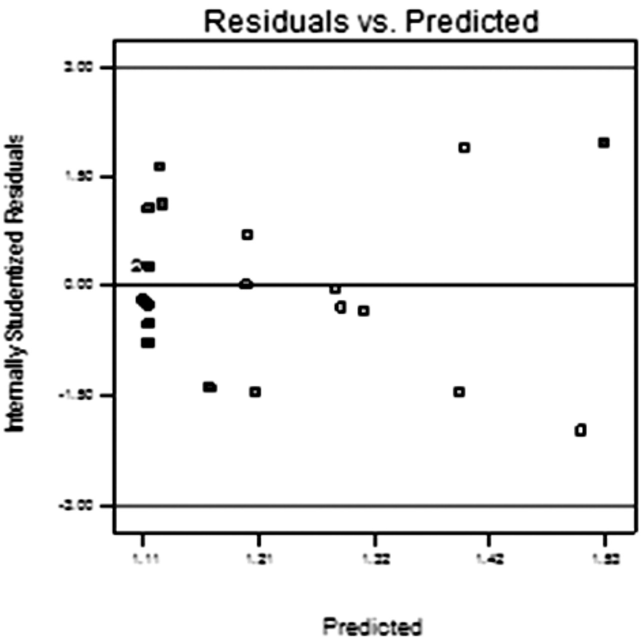

Figure 2: Plot of residuals vs. predicted response (surface roughness)

The normal probability plot was drawn for residuals and shown in Fig. 1

The linearity of this normal plot confirms the normal distribution of the data. Fig. 2 shows the standardized residuals on predicted values. The residuals do not show any obvious pattern and are distributed in both positive and negative directions. This implies that the model is adequate and there is no reason to suspect any violation of the independence or constant variance assumption. Fig. 3 shows the effect of the all cutting parameters i.e. cutting speed, feed and depth of cut on surface roughness Ra. The actual factors are A: v = 70 m/min, B: *f* = 0.125mm/rev, d= 0.3 mm. This graph indicates that as feed increases the surface roughness Ra increases and is the most influential cutting parameter. The cutting speed is other influential factor and depth of cut is having least effect on surface roughness Ra.

The response calculated from these models can be represented through surface plots also. The typical three-dimensional (3D) surface plot shown in Figs. 4, 5, and 6 illustrate the effect of cutting speed and feed, feed & depth of cut, cutting speed and depth of cut on surface roughness Ra. The three-dimensional (3D) surface plots show that when feed increases, the surface roughness increases and when cutting speed increases the surface roughness

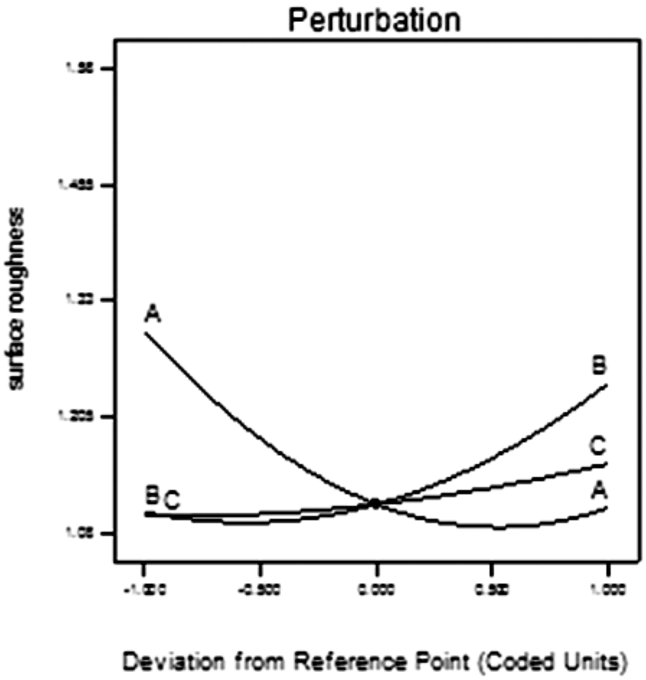

Figure 3: Effect of cutting parameters on surface roughness Ra

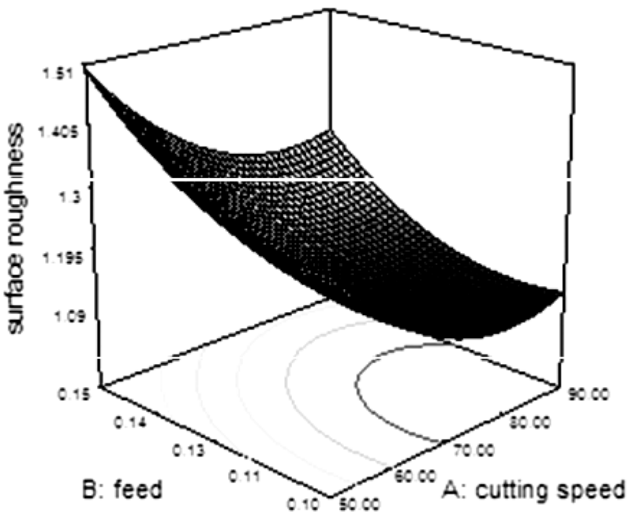

Figure 4: 3D surface plot between *v and f*

decreases. Whereas depth of cut has minor effect on surface roughness change However, at cutting speeds higher than 60 m/min, there is small increase in surface roughness with an increase of cutting speed. It is due to increase in temperature with increase of cutting speed at the cutting zone that leads to the softening of the material and thus reduces the surface roughness. The minimum value of surface roughness is at 60-70 m/min.

Further it is observed from 3D plot that increase of feed rate increases the surface roughness. It is due to the principle of metal cutting that any increase in feed rate increases the cross-section, leading to higher surface roughness. Depth of cut has minimum effect on the surface roughness.

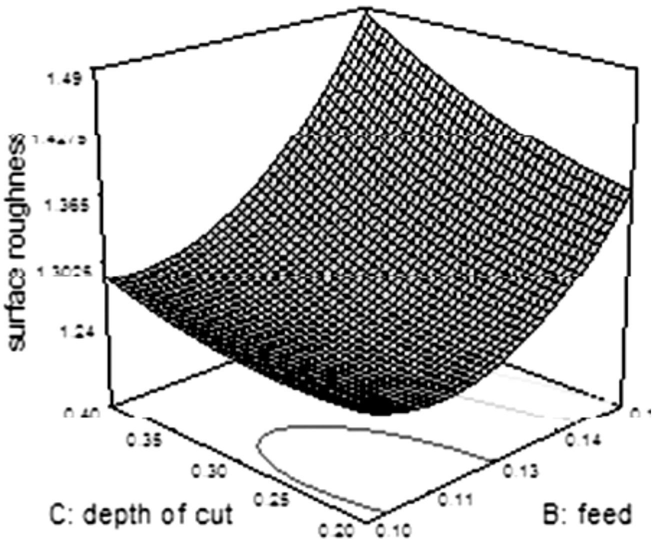

Figure 5: 3D surface plot between *f* and *d*

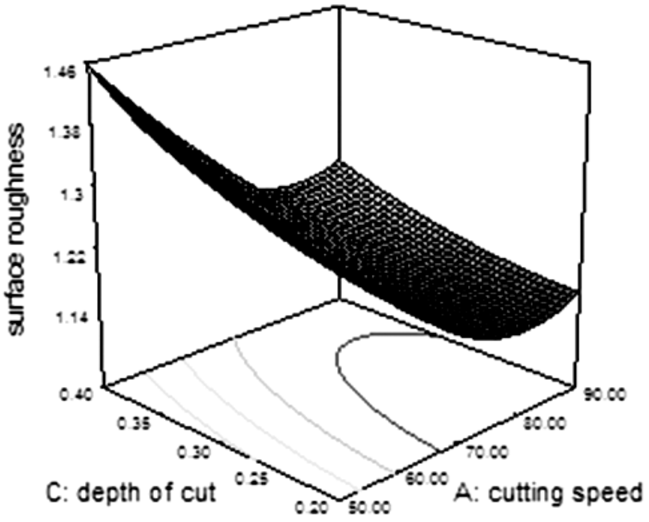

Figure 6: 3D surface plot between v and d

4. CONCLUSIONS

This paper presents the findings of an experimental investigation of the effect of cutting speed, feed rate, and depth of cut on surface roughness in finish turning of Inconel 718 using carbide tools and following conclusions are drawn.

- The Centered Composite Design of experiments is beneficial as it saves number of experimentations required.

- Depth of cut has less significant effect on surface roughness.
- In surface roughness model the feed rate influences the surface roughness most significantly followed by cutting speed and depth of cut.
- Good surface finish can be achieved when cutting speed rate is at high level of the experimental range (90 m/min.); whereas feed and depth of cut are set nearer to their low level of the experimental range (0.10 mm/rev and 0.2 mm).

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REFERENCES

[1] P.Thangavel & V. Selladurai, “An experimental investigation on the effect of turning parameters on surface roughness”, Int. J. Manufacturing Research, Vol. 3, 2008, pp. 285-299.

[2] R. Arunachalam & M. A. Mannan, “Machinability of nickel-based high temperature alloys”, Machining Science and Technology, Vol. 4, 2000, pp. 127-168.

[3] E.O. Ezugwu, Z. M. Wang & A. R. Machado “The machinability of nickel-based alloys: a review”, Journal of Materials Processing Technology, Vol. 86, 1999, pp. 1-16.

[4] C. T. Sims, N. S. Stoloff & W. C. Hagel, “Superalloys II-High Temperature Materials for Aerospace and Industrial Power”, New York: Wiley, 1987.

[5] M. Rahman, W. K. H. Seah & T. T. Teo, “The machinability of Inconel 718”, Journal of Materials Processing Technology, Vol. 63, 1997, pp. 199- 204.

[6] D. Dudzinski, A. Devillez, D. Moufki, Larrouquère, V. Zerrouki & J. Vigneau “A review of developments towards dry and high speed machining of Inconel 718 alloy”, International Journal of Machine Tools & Manufacture, Vol. 44, 2004, pp. 439-456.

[7] D.G. Thakur, B. Ramamoorthy & L. Vijayaraghavan, “Study on the machinability characteristics of super alloy Inconel 718 during high speed turning”, Mater. Des., Vol. 30, 2009, pp. 1718-1725.

[8] P.C. Jindal, A.T. Santhanam, U. Schleinkofer & A.F. Shuster, “Performance of PVD TiN, TiCN and TiAlN coated cemented carbide tools in turning”, Int. J Refract Metals Hard Mater. Vol. 17, 1999, pp. 163-177.

[9] L. Li, N. He, M. Wang & Z.G. Wang, “High speed cutting of Inconel 718 with coated carbide and ceramic inserts”, Journal of Materials Processing Technology, Vol. 129, 2002, pp. 127-30.

[10] K. Taramen, “Multi-machining output multi independent variable turning research by response surface methodology”, International Journal of Production Research, vol. 12, 1974, pp. 233-245.

[11] M. Alauddin, M. A. El Baradie, & M. S. J. Hashmi, “Optimization of surface finish in end milling Inconel 718”, Journal of Material Processing and Technology, Vol. 56, 1996, pp. 54-65.

[12] I.A. Choudhury & M. A. El-Baradie, “Machinability assessment of Inconel 718 by factorial design of experiment coupled with response surface methodology”, Journal of Material Processing and Technology, Vol. 95, 1999, pp. 30-39.