Analysis of Machining Parameters for Face Milling of Inconel 718 using Response Surface Methodology

Sachin_Kattookaren, Sanath Vimal M, Pal Pandian P, Ivan Sunit Rout

***Abstract:** The machining of Inconel 718 which is a nickel based super alloy has become a material of great importance mainly in the aerospace industry. Reason being the materials possesses properties of increase in strength at elevated temperature, high resilience to chemical reaction and high wear resistance. Gaining optimum machining parameters have become a great concern in the manufacturing industry, where economy of machining plays a very important key role in the market. This paper gives an overview of the experimentation conducted on the basis of Response Surface Methodology (RSM). Regression equations have been developed for surface roughness, by taking into consideration the machining parameters like cutting speed, feed rate and depth of cut for face milling operation performed in CNC machine. RSM analysis was carried out with the help of Mini Tab 18 software. The Mathematical equation developed after regression analysis shows to be very efficient.*

***Key words:** Face milling, Inconel 718 and RSM*

I. INTRODUCTION

Inconel 718 has been of great importance for the aerospace industry due to its properties which makes it hard to cut. The alloy possess high materialistic properties such as high resistance to corrosion, high thermal property and high strength [1]. Tool wear and surface roughness analysis has been done to optimise the machining parameters on Inconel 718 [2].

Surface roughness has been found to be lower at higher cutting speeds [3,7]. The tool geometry plays a vital role when it comes to surface finish during high speed machining of Inconel 718 [4]. Optimal conditions were obtained for surface roughness by using Grey relation grade. ANOVA was used to determine the significant input parameters which is to optimise the Grey relation grade [5,6]. From RSM the minimum and maximum surface roughness on material removal rate was attained [11].

This paper focuses on the analysis of surface roughness using Response Surface Methodology (RSM). The machining is carried out using a CNC machine and tool insert made of tungsten carbide is used. Relationship between various process parameters such as cutting speed, feed rate and depth of cut is found from RSM.

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Sachin Kattookaren & Sanath Vimal, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.

Dr Pal Pandian P, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.

Ivan Sunit Raut, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.

II. EXPERIMENT PROCEDURE

In this paper, the impact of the machining parameters, for example, cutting speed, feed rate and depth of cut is determined. The procedure parameter on surface roughness is dictated by framing the regression equation and a connection is built up between them utilising the response surface methodology (RSM).

A. Materials and processes

The machining have been completed on a BOSCH CNC vertical processing milling machine under wet machining condition. The machine has a most extreme cutting speed of 1800 rpm, feed rate of 10 m/min and 25-kW drive engine. The work piece utilised was Inconel 718 which is a Nickel-based super alloy of measurement (75×50×40) mm Fig. I. A round insert of Tungsten carbide (Grade TT3540) as shown in Fig. I was utilised for machining. Surface roughness is estimated utilising a Surface roughness tester in (µm). Cutting speed, feed rate and depth of cut were considered as input variables and several experiments were carried out at different levels of individual input parameters to obtain a various output for surface roughness. The relation between the process parameters and the surface roughness is analysed using response surface methodology (RSM) model.

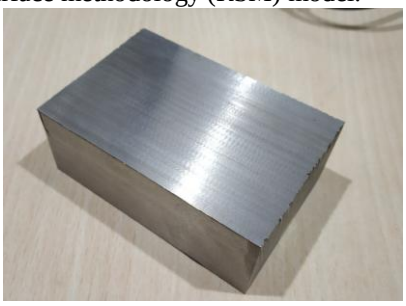

Fig I. Inconel 718 block

Fig II. Tungsten Carbide Tool insert

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III. RESULT AND DISCUSSION

Exploratory runs were conveyed by utilising certain control factors for the machining, for example, cutting speed, feed rate, depth of cut and reaction factor surface roughness as seen in Table I. Cutting insert utilised was Tungsten Carbide to machine Inconel 718 utilising the CNC milling machine.

A round cutting insert was used while machining. Mainly because the corners of the cutting insert play a very important role . Since the round insert has no corners
it has been found to be more useful as it gives an edge while machining.

Table I. Control factors and their levels for the experiment.

Parameter	Unit	Symbol	Minimum	Maximum
Cutting speed	RPM	V	500	700
Feed Rate	mm/min	F	10	20
Depth of cut	mm	D	0.2	0.6

Table II. Standardized observation table to obtain surface roughness

Cutting Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	surface roughness (µm)
500	10	0.2	0.167
700	10	0.2	0.191
500	20	0.2	0.257
700	20	0.2	0.148
500	10	0.6	0.272
700	10	0.6	0.176
500	20	0.6	0.289
700	20	0.6	0.168

The tests showing significant regression and model coefficients were done to show goodness of the fit for obtained model. These tests had been summarised with help of analysis of variance which help in identifying factors which significantly affect the response variable. The result of ANOVA along with response variable of surface roughness is carried out having a level of a = 0.05 such that the accuracy level is of 95.95%. Also the P- values have been realized at different level as shown in
Table III. Each term for the P-value has been found to be less than 0.05 which shows that the model has a significant effect on response. The determination coefficient R-Sq is an important coefficient and it has found to be high at 95.95%, which means that response model has a good fit with the actual data as shown in Table III.

A. RSM Analysis (Surface Roughness)

The design of experiments table is generated by using the method response surface methodology (RSM). Machining parameters such as cutting speed, feed rate and depth of cut have been taken into consideration to get the regression equation for the surface roughness after performing machining on Inconel 718 work piece. All the measured values for the input parameters while machining along with the surface roughness values are shown in Table II. The surface roughness values are measured using the Mitutoyo SJ210 surface roughness tester. Each value of surface roughness is measured after performing a single run on machining the work piece. Values of surface roughness are noted down in (µm) it was obtained in the range of 0.131 µm - 0.289 µm. It was noted that the surface roughness values does not increase considerably.

431.8207	15	0.4	0.212
768.1793	15	0.4	0.235
600	6.591036	0.4	0.191
600	23.40896	0.4	0.170
600	15	0.063641	0.141
600	15	0.736359	0.185
600	15	0.4	0.171
600	15	0.4	0.179
600	15	0.4	0.141
600	15	0.4	0.131
600	15	0.4	0.141
600	15	0.4	0.136

Table III. Estimated Coded Coefficient for Surface Roughness

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.18105	0.00523	34.65	0.000	
Cutting Speed	0.00847	0.00347	2.44	0.035	1.00
Feed Rate	0.02219	0.00347	6.40	0.000	1.00
Depth Of Cut	-0.03640	0.00347	-10.50	0.000	1.00
Cutting Speed*Cutting Speed	-0.01001	0.00338	-2.972	0.014	1.02
Feed Rate*Feed Rate	0.00007	0.00338	0.02	0.985	1.02
Depth Of Cut *Depth Of Cut	0.01580	0.00338	4.68	0.001	1.02
Cutting Speed *Feed Rate	-0.01587	0.00453	-3.50	0.006	1.00
Cutting Speed *Depth Of Cut	-0.00438	0.00453	-0.97	0.357	1.00
FEED RATE*DEPTH OF CUT	-0.02588	0.00453	-5.71	0.000	1.00

R-Sq=95.95% R-Sq(pred)=76.03%

R-Sq(adj)=92.30%

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The Figs. III(a), III(b) and III(c) shows the estimated tool wear as a function of cutting speed, feed rate and depth of cut. For each plot variables which are not presented are held at the middle levels which are constant. These surface plots confirm the observations observed during the effect of plot analysis.

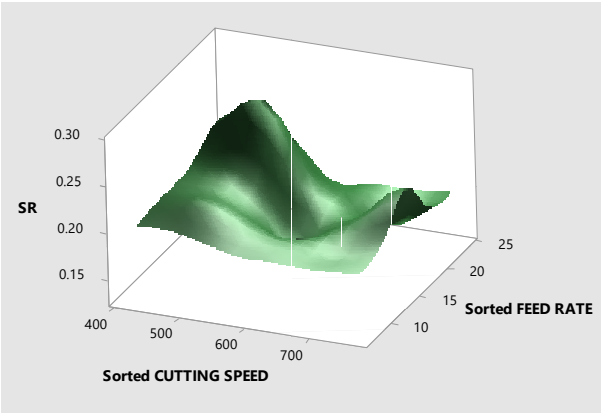

Fig. III (a) :Response surface plot for cutting speed versus feed rate and surface roughness.

Fig. III (b) :Response surface plot for feed rate versus depth of cut and surface roughness.

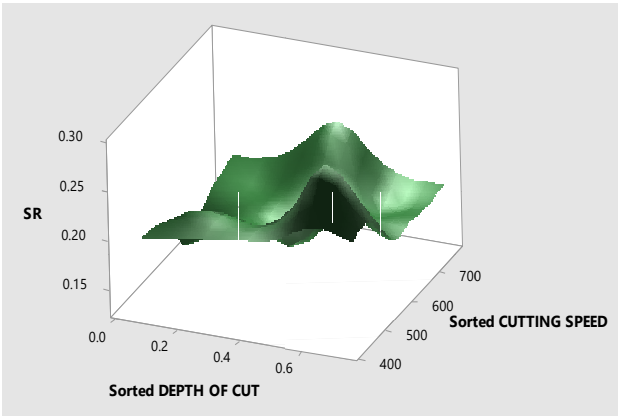

Fig. III (c) :Response surface plot for depth of cut versus cutting speed and surface roughness.

From the graph shown in Fig. III (a) it can been seen that when the feed rate is in the range of 10 and 15, cutting speed between 500 and 600 the surface roughness was found to be in the range of 0.15 and 0.20.

From the Fig. III (b). it was noted that when the depth of cut was within the range of 0.0 and 0.2, feed rate between 10 and 15 the surface roughness was found to be in the range of 0 and 0.15.

From the Fig. III (c). When the cutting speed was in the range 500 to 600 and the depth of cut between 0.0 and 0.2 the surface roughness was found to be between 0.0 and 0.15.

After performance of analysis initially on RSM, all parameters are included. The values are reduced with respect to the elimination of values which have no significant effect on the response. The final regression equation obtained after elimination of insignificant terms for surface roughness is as follows:

Regression Equation for (surface roughness) = -0.654 + 0.001850 * v + 0.03376 * f + 0.021 * d - 0.000001 * v v + 0.3950 d * d - 0.000032 * v * f - 0.02587 * f * d (1).

V. CONCLUSION

- The experiment was conduted using RSM table which was developed using MINITAB 18 software.
- The regression analysis for surface roughness was carried out using MINITAB 18 software with the available experimental data.
- Efficiency of the regression equation was 95.95%.
- The output derived from the regression equation was in compliance with the experimental results.

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REFERENCES

1. D.M. D'Addona, "*High speed machining of Inconel 718: tool wear and surface roughness analysis*", 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16, vol. 62, pp. 269-274, 2017.
2. S Thamizhmanii, R Mohideen, "*Surface Roughness and Tool Wear on Cryogenic Treated CBN Insert on Titanium and Inconel 718 Alloy Steel*", 3rd International Conference of Mechanical Engineering Research (ICMER 2015), vol. 100, pp. 1-9, 2015.
3. Dr P. Pal Pandian, Ivan Sunit Rout, *"Parametric investigation of machining parameters in determining the machinability of Inconel 718 using taguchi technique and grey relation analysis"*, International Conference on Robotics and Smart Manufacturing (RoSMa2018), Published by Elsevier, vol. 133, pp. 786-792, 2018.
4. Lin W.S., "*The reliability analysis of cutting tools in the HSM processes*", International Scientific Journal published by the World Academy of Materials and Manufacturing Engineering, vol. 30, pp. 97-100, 2008.
5. Amit Kumar, Tarun Soot, "*Optimisation of wire-cut EDM process parameter by Grey-based response surface methodology*", Journal of Industrial Engineering International, vol. 14, pp. 821-829, 2018.
6. Dinesh Thakur, B Ramamoorthy & L Vijayaraghavan, "*Optimization of high speed turning parameters of super alloy Inconel 718 material using Taguchi technique*", Indian Journal of Engineering & Materials Sciences, vol. 16, pp. 44-50, 2009.

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7. Samir Khamel, "*Analysis and prediction of tool wear, surface roughness and cutting forces in hard turning with CBN tool*", Journal of Mechanical Science and Technology, vol. 11, pp. 3605-3616, 2012.
8. Sasikumar.T and V.P. Srinivasan, "*Machining of Inconel 718 with liquid nitrogen as coolant using Response Surface Methodology",* Journal of Applied Sciences Research, vol. 23, pp. 70-78, 2015.
9. Ivan Sunit Rout and Dr P. Pal Pandian, "Relection of cutting parameters for the machinability of Inconel 718 using Grey Relational Analysis", 3rd International Conference on Design, Analysis, Manufacturing and Simulation (ICDAMS 2018), vol. 172, pp. 1-5, 2018.
10. R. Ramanujam, K. Venkatesan, Vimal Saxena, Philip Joseph, "*Modeling and optimization of cutting parameters in dry turning of Inconel 718 using Coated Carbide Inserts*", International Conference on Advance Manufacturing and Materials Engineering. ICAMME 2014, vol. 05, pp. 2550-2559, 2014.
11. M R Soleymani Yazdi, A Khorram, *"Modelling and Optimization of Milling Process by using RSM and ANN Methods",* IACSIT International Journal of Engineering and Technology, vol. 2, pp. 1793-8236, 2010.
12. Karthick, S., Devi, E.S., Nagarajan, R.V. "Trust-distrust protocol for the secure routing in wireless sensor networks", In Proceedings of 2017 International Conference on Algorithms, Methodology, Models and Applications in Emerging Technologies, ICAMMAET 2017, 2017-January, pp. 1-5, 2017. DOI: 10.1109/ICAMMAET.2017.8186688
13. Arul Teen, Y.P., Nathiyaa, T., Rajesh, K.B., and Karthick, S. "Bessel Gaussian Beam Propagation through Turbulence in Free Space Optical Communication", Optical Memory and Neural Networks (Information Optics), vol. 27, no. 2, pp. 81-88, 2018. DOI: 10.3103/S1060992X18020029
14. Vijayan, V., Parthiban, A., Sathish, T., Siva Chandran, S., Venkatesh, R. "Performance Analysis in End Milling operation", International Journal of Mechanical Engineering and Technology, Vol. 09, Issue. 11, pp. 2263-2271, 2018.
15. Sathish, T., Jayaprakash, J. "Optimizing Supply Chain in Reverse Logistics", International Journal of Mechanical and Production Engineering Research and Development, Vol. 07, pp. 551-560, 2017.
16. Sathish, T., Periyasamy, P. "Modelling of HCHS system for optimal E-O-L Combination section and Disassembly in Reverse Logistics", Applied Mathematics and Information science, Vol. 13, No. 01, pp. 1-6, 2019.
17. Sathish, T., Muthulakshmanan, A. "Design and simulation of connecting rods with several test cases using AL alloys and high Tensile steel", International Journal of Mechanical and Production Engineering Research and Development, Vol. 08,Issue 1, pp. 1119-1126, 2018.
18. Sathish, T., and Karthick, S. "HAIWF-based fault detection and classification for industrial machine condition monitoring", Progress in Industrial Ecology, vol. 12, no. 1-2, pp. 46-58, 2018

AUTHORS PROFILE

Sachin Kattookaren, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.

Sanath Vimal, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.

Dr. P. Pal Pandian, Associate Professor of Mechanical & Automobile Engineering, in Christ (Deemed to be University), Bangalore has 18 years of experience in Academics, Research and Administration. He has 24 publications in reputed Scopus / UGC Recognized / Peer-Reviewed International Journals. Also, he has presented his research in 24 International Conferences and 13 National Conferences. He has participated in 70 International and National Conferences, Seminars, Workshops and Symposiums. He has delivered 18 guest lectures in various technical and management topics.

Ivan Sunit Raut, Department of Mechanical, CHRIST (Deemed to be University), Bangalore, India.