ISBN: 978-1-948012-16-4

Contemporary Issues in Computing (CIC)

DOI: <http://doi.org/10.26480/cic.01.2020.114.117>

CrossMark

TOOL WEAR ASSESSMENT OF INCONEL 825 MACHINING BY RSM

Monojit Das^a, Sumit Dhar^b, Debashis Sarkar^c, Sourav Mandal^a, Subhash Chandra Panja^a^aMechanical Engineering Department, Jadavpur University, Kolkata 700032, India^bMechanical Engineering Department, IIT(ISM), Dhanbad 826004, India^cMechanical Engineering Department, Asansol Engineering College, Asansol 713305, India*Corresponding Author e-mail: monojitdasjg@gmail.com

This is an open access article distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 26 October 2020

Accepted 27 November 2020

Available online 03 December 2020

ABSTRACT

Inconel 825 is a hard alloy with nickel-iron-chromium base in addition of molybdenum, copper and titanium and has a superior resistance of corrosion. It is widely used in the equipment of chemical processing, handling of radioactive waste, acid production, oil and gas recovery, aerospace industry etc. Thus, manufacturing of Inconel 825 is a challenging task in which the tool life is a major factor in terms of wear and cost of production. The present study aims at evaluating the effect among four factors viz. cutting speed (V_c), feed (f), depth of cut (d) and nose radius (r) on flank wear (V_b) in dry turning of Inconel 825 using ceramic inserts. The Taguchi's L9 orthogonal array (OA) is adopted as experimental design and response surface methodology (RSM) has been applied to predict the influence of various input parameters on flank wear. It is observed from experiment result that feed and depth of cut are the two most dominating factors on tool wear. Also, the effect of different combinations of said input factors on tool wear pattern are presented here.

KEYWORDS

Inconel 825, tool wear, Taguchi L₉ Orthogonal Array, RSM.

1. INTRODUCTION

Inconel 825 is a super alloy in which nickel plays an important role and has noticeable mechanical and chemical features at elevated temperature. It may be used to produce propeller shafts, expansion bellows, etc. in a number of engineering applications like aerospace, and chemical. Inconel 825 has significantly high hardness, and toughness (Yadav et al., 2019). Proper selection of tool is a necessity for machining of the same. Material of tool with its geometry is deciding factors to achieve good surface finish on work material as per the observation of Guide, 2015 (Guide, 2015). For the machining of these alloys cutting tool material may have significant resistance to wear, thermal shock.

Strength and toughness of the tool material is to be high. As Ceramic tools exhibit better hot hardness, these tools can be used for machining of this super alloy at high speed conditions (Cantero et al., 2013).

Conduction of heat is not good on the tool and chip interference during the machining of this alloy, hence the temperature on tool is arisen. This suggests the major two important contributors of tool wears are crater and flank wear. In several tool wear experiment the flank wear provides an important level in terms of tool life (Xavior et al., 2017). For this type of alloy, the machining process is considered as high speed when the cutting speed is above 50 m/min (Devillez et al., 2007). In this study, cutting speed ranges between 68 - 108 m/min are considered. From literature survey it has been observed that most of the previous work (Suresh et al., 2012, Venkatesan et al., 2019) considered three factors viz. V_c , f and d with three

levels to study their influence as input factors on wear of tool in machining at high speed conditions. It is observed from the previous literature that this is a need to study on tool wear of ceramic tools during the machining of Inconel 825. Keeping this in mind, the present study is carried out for dry and high temperature machining conditions and study the changes in cutting tools, made of ceramic, specifically.

In the present study it is worth mentioned that four factors viz. V_c , f , d and r are considered. Each of the input factors, as stated, is having levels of three. Conducting a number of experiments, the elaborate relationship between the cutting parameters and the tool wear of the ceramic tools are developed.

2. EXPERIMENTAL SETUP

An experimental set up consisting of lathe, work piece, tool, tool holder, measuring instruments has been prepared in the workshop of the parent university. This section describes sequentially all the parts of the experimental set up as follows:

2.1 Lathe

Heavy duty lathe is employed to conduct the experiment. The power and maximum spindle speed of lathe are specified as 20HP and 800 rpm respectively. The pictorial view of said lathe is shown in Fig. 1.

Quick Response Code	This paper was presented at	Access this article online
International Conference on Contemporary Issues in Computing (ICCIC-2020) - Virtual IETE Sector V, Salt Lake, Kolkata From 25th-26th July 2020	Website: www.intelcomp-design.com	DOI: 10.26480/cic.01.2020.114.117

Figure 1: Heavy duty Lathe used in experiment.

2.2 Work piece

The work piece material chosen is Inconel 825 having 85 mm diameter. Fig. 2 depicts the specimen of the workpiece

Figure 2: Work piece material Inconel 825.

2.3 Cutting tool insert

The ceramic tools (Taegutec, CNGA 120404, Kyocera, CNGA 120408, NTK, CNGA 120412) are used for turning of Inconel 825 as shown in Fig. 3 as follows:

Figure 3: Cutting tool inserts.

2.4 Tool holder

The tool holder is DCLNR 2020 K12 which is shown in Fig. 4.

Figure 4: Tool holder.

2.5 Flank wear measurement

Flank wear measurement is done by optical microscope during the course of experiment.

Figure 5: Optical microscope.

3. EXPERIMENTAL DESIGN AND MODELLING

3.1 Experimental design

In this paper, a technique, developed by Taguchi is used. The said approach comprises of experimental plan, in which data may be obtained. The data, as collected, to be analysed to evaluate impact of these parameters. The concept of orthogonal array (OA) may be adopted to minimize the resources and time.

In the present Investigation based on the literature survey, three levels are chosen for each input parameters, which is illustrated in Table 1. Cutting parameters are key elements to be selected. It is worth mentioned that chemical composition and hardness of workpiece material and guidelines of tool manufacturer are important for selection of cutting parameters. In relation to the present study, four factors and three levels are selected. Hence Taguchi's L_9 OA is formulated and present in Table 2.

Table 1: Cutting parameters and their levels			
Parameters	Level		
	1	2	3
V_c (m/min)	68	88	108
f (mm/rev)	0.10414	0.15748	0.21082
d (mm)	0.4	0.5	0.6
r (mm)	0.4	0.8	1.2

Table 2: Taguchi's L_9 OA				
Run number	Columns (Factors)			
	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

A fresh cutting tool is used in each experiment for a fixed length of 40 mm and experiments are conducted twice at each set of cutting conditions. In this way, the experimental error may be considered as minimum. The flank wear in term of width is measured with the help of optical microscope connected to a computer and then RSM is applied.

3.2 Response Surface Methodology

Response Surface Methodology (RSM) can be used in order to get an effective and precise estimate of the flank wear. The output or response is a function of all the input parameters. The function may be a polynomial in nature. The best fit polynomial may be finally chosen based on R- square value.

The generic response function may be mentioned as follows:

$$Y = f(a, b, c, d) \quad (1)$$

Where, Y = response of input factors a,b,c,d.

For example the second order regression equation, the response surface for M factors is given by:

$$Y = A_0 + \sum_{i=1}^m A_i X_i + \sum_{i,j=1}^m A_{ij} X_i X_j + \sum_{i=1}^m A_{ii} X_i^2$$

Where A_0, A_i, A_{ij} are co-efficients, X_i = input factor, Y = response factor.

4. RESULTS AND DISCUSSION

The experiment is done as per above mentioned experimental design. The number of test involves 9 trials. The result of the trials is mentioned below.

Table 3: Experimental results

Exp. No.	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Nose radius (mm)	Normalized value of tool wear
2	68	0.15748	0.5	0.8	-0.2595904
5	88	0.15748	0.6	0.4	-0.1495113
3	68	0.21082	0.6	1.2	1.10501709
4	88	0.10414	0.5	1.2	-0.802186
1	68	0.10414	0.4	0.4	-0.4736405
9	108	0.21082	0.5	0.4	-0.2988762
8	108	0.15748	0.4	1.2	-1.7356613
7	108	0.10414	0.6	0.8	1.6957091
6	88	0.21082	0.4	0.8	0.9187395

Subsequently wear of tool is measured by OLYMPUS make Optical Microscope, Model- BX53MRF-S, Made in Japan. Then RSM is performed to estimate wear of tool, which is a function of all the four input parameters (V_c , f , d and r).

Higher flank wear is noticed on ceramic tools at $V_c = 68$ m/min, which is low speed here, and as cutting speed rises from 88 to 108 m/min, there is a noticeable decrease in flank wear which is shown in Fig. 6. Based on the test outputs, d and f are observed as two most significant factors. As can be seen in Fig. 8, the size of flank wear is increased by an increase of depth of cut for ceramic tool. Effect of feed on wear can be observed from Fig. 7. The effects of other parameters are trivial.

Figure 6: Tool wear vs. cutting speed. **Figure 7: Tool wear vs. feed.** **Figure 8: Tool wear vs. depth of cut.** **Figure 9: Tool wear vs. nose radius.**

All the images of tool wear for all these experiments are shown in the following Fig. 10.

Figure 10: Observed tool wear pictures.

Response surface is developed based on the experimental data with the help of Minitab 18 as follows:

$$V_b = 9.273 - 0.005995 V_c - 52.17 f - 27.97 d + 5.262 r + 0.000019 V_c * V_c + 171.5 f * f + 30.96 d * d - 3.349 r * r \quad (3)$$

Figure 11: Optimization plot using RSM analysis.**Table 4: The optimised parameters**

Variable	Setting
V_c	108
f	0.151553
d	0.452525
r	1.2

Fig. 11 and Table 4 describe the optimized values of input variables and cutting condition.

Figure 12: Main effects plot using RSM analysis.

The main effects plot as developed by Minitab 18 is shown in Fig. 12. It is observed that main effects plot in Fig. 12 are curvilinear in nature, whereas Fig. s 6, 7, 8, 9 are developed by Microsoft Office Excel 2010, considering straight line methods. In both, the representations are similar in pattern and nature.

Fig. s 13, 14, 15, 16, 17 and 18 are developed based on RSM and changing factors. It is worth mentioned here that these plots are drawn by taking two input parameters at a stage and other parameters are kept fixed.

Figure 13: Surface plot of V_b vs f , V_c .

Figure 14: Surface plot of V_b vs d , V_c .

Figure 15: Surface plot of V_b vs r , V_c .

Figure 16: Surface plot of V_b vs d , f .

Figure 17: Surface plot of V_b vs r , f .

Figure 18: Surface plot of V_b vs r , d .

5. CONCLUSION

In this paper, an experimental set up is prepared and developed for machining Inconel 825 with the help of ceramic cutting tool. The objective of the study is to analyse the tool wear at different cutting conditions. In this case RSM is applied to model the tool wear and find the optimized settings of input parameters. It is observed that, d and f are found to have most influence on tool wear. Moreover, higher flank wear is noticed at low speed ($V_c = 68$ m/min) and as the speed increases from 88 – 108 m/min there is a decrease in flank wear. The optimum values of input factors are observed to be $V_c = 108$ m/min, $d = 0.452525$ mm, $f = 0.151553$ mm/rev and $r = 1.2$ mm with ceramic tool under dry cutting conditions. Similar methodology may be applicable to investigate influencing machining parameters for cutting of Inconel 625, Inconel 718, EN 31 etc. Also, other cutting tools and response variables like surface roughness, MRR can be studied.

REFERENCES

- Cantero, J.L, Diaz-Alvarez, J., Miguelez, M.H., Marin, N.C., 2013. "Analysis of tool wear patterns in finishing turning of Inconel 718," *Wear* 297, p. 885–894.
- Devillez, A., Schneider, F., Dominiak, S., Dudzinski, D., Larrouquere, D., 2007. "Cutting forces and wear in dry machining of Inconel 718 with coated carbide tools," *Wear* 262, p. 931-942.
- Guide, H.M., 2015. "High-Temperature Machining," p. 2–17.
- Suresh, R., Basavarajappa, S., Samuel, G.L., 2012. "Predictive Modelling of Cutting Forces and Tool Wear in Hard Turning Using Response Surface Methodology," *Procedia Engineering* 38, p. 73-81.
- Venkatesan, K., Mathew, A.T., Devendiran, S., Ghazaly, N.M., Sanjith, S., Raghul, R., 2019. "Machinability study and multi- response optimization of cutting force, surface roughness and tool wear on CNC turned Inconel 617 superalloy using Al2O3 Nanofluids in Coconut oil," *Procedia Engineering* 30, p. 396-403.
- Xavior, M.A., Manohar, M., Jeyapandiarajan, P., Madhukar, P.M., 2017. "Tool Wear Assessment During Machining of Inconel 718," *Procedia Engineering* 174, p. 1000 – 1008.
- Yadav, R.K., Gandhi, A., Kumar, A., Mahapatra, S.S., and Nandi, G., 2019. "Effect of Feed and Nose radius on various machinability criteria in dry machining of Inconel 825," *Materials Today: Proceedings* 18 (7), p. 5231-5239.