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RESEARCH ARTICLE

OPTIMIZATION OF THE RADIAL CUTTING FORCE IN TURNING OPERATION OF INCONEL718

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ABSTRACT

In this paper, the Taguchi method is used to optimize the Radial force in Turning Operation of Inconel 718 using Carbideinsert with PVD (Physical Vapor deposition) coated of TiAlN and TiN. The process parameter, cutting speed, feed rate, and depth of cut, have been selected for investigation. Experiments were conducted on the basis of Taguchi's L9 orthogonal array. The Signal to noise ratio (S/N ratio) and the analysis of variance ANOVA (general linear model) are applied to optimize the effects of the selected process parameters on Radial force. The results show that speed is the most influencing factor followed by depth of cut and feed. The confirmation experiments validate the results of the findings.

INTRODUCTION

Turning is the process whereby a single point cutting tool is held parallel to the surface of rotating work-piece in which certain feed and depth of cut is provided to the cutting tool to penetrate in the work-piece to cause the material removal with the help of friction force. It can be done manually, using a traditional form of lathe, which frequently requires continuous supervision by the operator. (Arpit Srivastava *et al.*, 2017). The Relative forces in a turning operation are important in the design of machine tools. There are three principal forces during a turning process and these are cutting or tangential force, axial or feed force and radial or thrust force (Koepfer *et al*, 2010). The cutting or tangential force acts downward on the tool tip allowing deflection of the workpiece upward. The axial or feed force acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. The radial acts in the radial direction and tends to push the tool away from the workpiece (Lanjewar *et al*, 2008). The cutting forces are determined mainly by depth of cut and feed rate, respectively more than that by cutting speed (Nicoletalungu *et al*., 2012). The cutting force components are very sensitive even to the very smallest changes in the cutting process; therefore, instead of calculating the cutting forces theoretically, measuring them in process by Dynamometers is preferred (Sanglam, H *et al*., 2007). The main purpose of the present work is to study the effect of turning process parameters on the performance radial force while machining of Inconel 718. The main applications of Inconel 718 are in aircraft gas turbine, reciprocating engine etc. Taguchi methodology is a powerful tool for identification of effect of various process parameters based on orthogonal array (OA) experiments with an optimum setting of process control parameter. In this investigation L9 array was used to carry out the experiment result. The output Radial force was measured by the varying machining condition with corresponding values in given Table 2. Minitab18 software was used. The objective of this work is to obtain optimal settings of turning process parameters to yield optimal radial force. The selection of machining parameters was done based upon review of literature. The process parameters selected are cutting speed, feed and depth of cut.

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Experiment setup

Turning Operation has been done on lathe available at Manufacturing Lab of IIT Kanpur with Kistler Dynamometer (type 5233A). The work material selected for the study was Inconel 718 (Purchased from Mallinath metal Mumbai) which was in the form of bar with a diameter of 60 mm and length of 300mm.

Turning operation was performed by using insert holder DCLNR 2525M12 (Sandvik) with PVD coated of TiAlN and TiN carbide insert CNMG120404MF1025. In the present investigation experiment consists of turning of Inconel 718 on a lathe machine. Three process parameters along with their 3 levels are given below

Table 1. Process parameters and their levels

Process Parameters	Unit	Level1	Level2	Level3
Speed (s)	rpm	250	400	640
Feed (f)	mm/rev	0.05	0.10	0.15
Depth of cut(d)	mm	0.5	0.7	0.9

RESULT DISCUSSION AND ANALYSIS

The ANOVA result show that in table 4 that speed, depth of cut and feed are the significant factors.

The percentage contribution of speed 97.71% most significant factor. Depth of cut is 1.14% and feed 1.12% so these are the less significant factor. With regarding the S/N response in table 5 that the value of S/N ratio have been found to highest for those factor levels that corresponds to the highest average response. Hence these factor levels can be termed as optimum for point of view of average response as well as S/N response. As S/N response takes in to account both the magnitude as well as variation in a response, the factor level that corresponds to highest S/N ratio are termed as optimum.

Table 2. Experimental results with L9 Orthogonal array

Exp. No.	Control Parameter Levels			Radial Force (N)	Radial force S/N Ratio (dB)
	A- Speed (rpm)	B- Feed mm/rev)	C-Depth of cut (mm)		
1	250	0.05	0.5	71	-37.02
2	250	0.10	0.7	101	-40.08
3	250	0.15	0.9	117	-41.37
4	400	0.05	0.7	92	-39.29
5	400	0.10	0.9	78	-37.85
6	400	0.15	0.5	90	-39.08
7	640	0.05	0.9	351	-50.90
8	640	0.10	0.5	318	-50.05
9	640	0.15	0.7	380	-51.59

Table 3. Response for Means

Level	A- Speed	B- Feed	C- Depth of cut
1	96.33	171.33	159.67
2	86.67	165.67	191.00
3	349.67	195.67	182.00
Delta	263.00	30.00	31.33
Rank	1	3	2

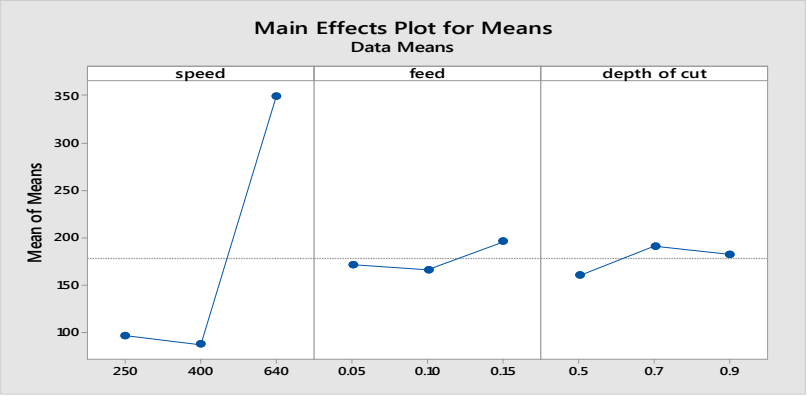

Fig. 1. Effect on process parameter on radial force

Table 4. Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
A-Speed	2	133440	97.71%	133440	66720.1	3017.49	0.000
B-Feed	2	1524	1.12%	1524	762.1	34.47	0.028
C-Depth of cut	2	1562	1.14%	1562	780.8	35.31	0.028
Error	2	44	0.03%	44	22.1		
Total	8	136570	100.00%				

Table 5. Response for Signal to Noise Ratios (Smaller is better)

Level	A-Speed	B-Feed	C-Depth ofcut
1	-39.49	-42.40	-42.05
2	-38.73	-42.66	-43.65
3	-50.85	-44.01	-43.37
Delta	12.12	1.61	1.60
Rank	1	2	3

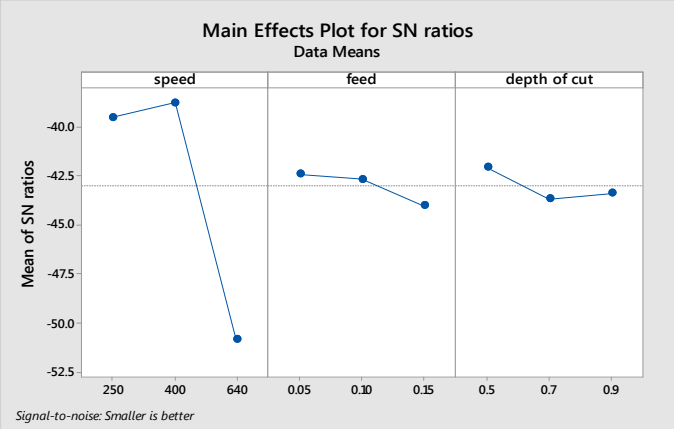

Fig. 2. Effect on process parameter on S/N ratio

As shown in figure 1, during turning operation speed vs radial force clearly depicts that when cutting speed increased from 250 rpm to 400 rpm, the radial force would be decreased because in this region, the thermal softening phenomena was dominating in compare to strain hardening on work-piece of Inconel 718, but on the other hand when cutting speed further increased beyond 400rpm , radial force was increased because due to increment in cutting speed, heat dissipation rate was enhanced so in this region strain hardening phenomena was dominating in compare to thermal softening. In feed vs radial force diagram shows that at higher value of feed, radial force was increased due to increment in friction experienced by the nose radius to shear the work-piece material. In depth of cut vs radial force diagram shows that when depth of cut was increased, radial force also increased due to high material removal rate. It can be conclude that from figure 1input parameter setting of spindle speed 400 rpm, feed 0.10 mm/rev, and depth of cut 0.5mm has been given the optimum result for the radial force when Inconel 718 was turned on lathe. As shown in figure 2, as signal to noise ratio, smaller is better. Cutting speed vs SN ratio diagram shows that minimum value of SN ratio found at higher speed. Feed vs SN ratio diagram shows that minimum value of SN ratio found at higher feed. Depth of cut vs SN ratio shows that minimum value of SN ratio found at 0.7mm.

Conclusion

Machining of Inconel 718 offers many difficulties in machining but due to high application of this super alloy, machining operation parameters optimization plays a very important role for fabrication of components using Inconel 718.

- Effect of cutting speed is most significant factor on radial cutting force in turning operation of Inconel 718. It has 97.17% contribution which is highest in compare to other input process parameter.
- Effect of feed is significant factor on radial cutting force in turning operation of Inconel 718. It has 1.12% contribution which is minimum in all three input process parameter.
- Effect of depth of cut is significant factor on radial cutting force in turning operation of Inconel 718. It has 1.14% contribution.
- Future work will consider optimization of input parameters of turning operation of Inconel 718 for cutting force and feed force. This will provide better understanding of forces during turning operation of Inconel 718 like difficult machining superalloy. Other optimization techniques such as Artificial Intelligence will be used for validation of this study. Study on thermal aspects in machining of Inconel 718 will be used for better understanding of thermal softening phenomena.

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