Optimising Residual Stresses in Turing Operation of Inconel 718 Material Using Taguchi Method

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Abstract: ***Nickel-base super alloy- Inconel 718 is a high strength, thermal resistant alloy in recent years because of its excellent mechanical properties both at cryogenic and elevated temperatures. It is used in aerospace, petroleum and nuclear energy industries the hardening characteristics and toughness of INCONEL 718 makes machining difficult and increases cost of manufacturing. Hence, it is difficult to cut material The challenge for manufacturing engineers is to reduce the machining cost of INCONEL 718 without effecting the surface finish and hardness of the material. This project presents the result of effect of machining parameters on the surface finish, hardness and impact of residual stresses on Inconel-718. The effect of machining parameters on the surface hardness was investigated by conducting nine experiments using CNC lathe. The machining parameters considered were cutting speed, 300<f<d***

Keywords: Inconel 718, Residual Stresses, Taguchi Method, X ray Diffraction Technique

1. Introduction

INCONEL 718 super alloy is one of the nickel-based super alloys mostly used in manufacturing of aero engine components. This alloy is often used in a solution-treated and aged condition. Inconel 718 is gamma prime (Ni3Nb) strengthened alloy with excellent mechanical properties at elevated temperatures. The important feature of INCONEL 718 composition is niobium which allows annealing and welding without hardening during cooling and heating. Niobium reacts with molybdenum to strengthening heat treatment. Other popular nickel-chromium alloys are age hardened through the addition of aluminium and titanium. This nickel steel alloy is readily fabricated and may be welded in either the annealed or precipitation hardened condition.

Arunachalam et al. [1] studied residual stresses and surface finish when facing age hardened Inconel 718 using two grades of coated carbide cutting tools. The cutting speed, feed and depth of cut were maintained constant at 60 m/min, 0.10 mm/rev and 0.5 mm, respectively and only the effect of cutting tool parameters (insert shape, cutting edge preparation, negative or positive rake angle, nose radius, and effect of coolant) was examined. They concluded that these parameters have a significant role in determining residual stresses profile, and suggested that coated carbide cutting inserts of round shape, chamfered cutting edge, negative rake type and small radius (0.8) and coolant generate small values of residual stresses, which are mostly compressive.

R.S. Pawade et al. [2] describes the efficient machining and generation of machined surfaces with high integrity assumes a lot of importance, This paper discusses experimental investigation on effect of various process and tool-dependent parameters on cutting forces, an indirect measure of machined surface integrity, in high-speed machining of superalloy Inconel 718.

M. Nalbant et al. [3] observed In this study, the Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. Experimental results are provided to illustrate the effectiveness of this approach.

B. Satyanarayanaa et al. [4] observed Inconel 718, a Nickel based super alloy which has wide applications in aerospace industry particularly in the hot sections of gas turbine engines due to their high temperature strength and corrosion resistance. It is known as being among the most difficult-to-cut materials. This paper presents an optimum process parameters (speed, feed and depth of cut) to minimize the cutting force, surface roughness and tool flank wear together in CNC high speed dry turning of Inconel 718 using Taguchi method based Grey relational analysis. The study involved nine experiments based on Taguchi orthogonal array and the result indicates that the optimal process parameters are 60 m/min for speed, 0.05 mm/rev for feed and 0.2 mm for depth of cut from the selected range. Also the significant process parameters have been found out for the above process optimization by performing ANOVA.

R. Ramanujam et al. [5]Inconel 718, a nickel based alloys, has found in many industries because of their unique combination of properties such as high strengths at elevated temperatures, resistance to chemical degradation, and have high wear resistance. The present work is focused on Taguchi based fuzzy logic loss function for the optimizing the arithmetic surface roughness (Ra and Rt) and cutting force (Fz) in dry turning of Inconel 718. This fuzzy interface system is used to identify the relationship between the responses and experimental design in order to determine the effectiveness each machining parameters in Taguchi's design of experiment concept. Machining experiments were performed at medium duty lathe using PVD AlTiN coated tungsten carbide cutting tool. Cutting speed, feed rate and depth of cut were selected as cutting parameters.

D. G.Thakur et al. [6]. The paper discuses about the effect of machining parameter on quality of part to be machined on INCONEL 718. The results are helpful in understanding surface characteristics of Inconel 718 at high speed.

FarshidJafarian et al. [7] observed Generated residual stress in the machining processes is one of the most important factors which affects significantly service quality and component life. Inconel718 superalloy is one of the hard materials which find its applications in aerospace industries. State of surface residual stress is a critical problem in the finish machining of Inconel718. The main aim of the project is to optimize the machining parameterand residual stresses were measured by X-ray Diffraction (XRD) method.

2. Problem Description

1) Investing the influence of cutting parameters on residual stresses when turning Inconel 718 using TiCN-AL2O3 coated cemented carbide insert at various cutting speeds, feed rates and depth of cut and under wet cutting condition.
2) Find the optimum combination of the cutting parameters to minimise the residual stresses using Taguchi method.

Table 2.1: Dimensions of the Inconel 718 work piece

	Before Facing Operation	After Facing Operation
Diameter(mm)	57	56.1
Length (mm)	300	240

3. Methodology

3.1 Cutting Operations

The work piece considered for the experiment was Inconel 718 and cemented carbide insert with TICN-AL2O3 coating was used as cutting tool which were shown in figures 3.1 and 4.2 respectively. The ISO designation of the cutting tool insert is TNMG 160408-MT.

Figure 3.1: Work Piece: Inconel-718

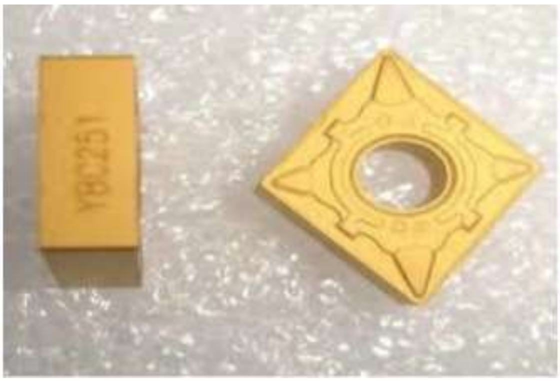

Figure 5.2: Cutting Tool: TiCN-Al2O3 coated cemented carbide

Turning tests were carried out on a computer numerically controlled (CNC) lathe machine under wet condition using ISO VG68 cutting fluid. The CNC lathe machine, located in "M. GOVIND&Sons",perecharla,Guntur, used for the experimental purpose was of simple turn type by ACE designers limited.. The cutting speeds were 300, 400 and 500rpm .the feed rates used were 0.05, 0.1 and 0.15 mm/rev. the depths of cut of 0.1, 0.3 and 0.5 mm were used. The cutting parameters and their levels were summarized in table 3.2.

Table 3.1: Specifications of CNC SIMPLE TURN 50125

Description	SIMPLE TURN 50125
Swing over bed	500
Swing over cross slide	280
Maximum turning length	1120
Distance between centres	1250
Maximum number of tools	4
Tailstock quill travel	180
Tail stock quill diameter	80

Table 3.2: Experimental factors and their values

Levels of the experimental factors	Factors		
	Speed, N(rpm)	Feed rate, f(mm/rev)	Depth of cut, d(mm)
1	200	0.2	0.4
2	250	0.1	0.3
3	300	0.15	0.2

3.2 Orthogonal array selection

Taguchi's orthogonal array selection table is shown in table 3.3. Since we considered three experimental factors and three levels for each factor, we have L9 orthogonal array from table 3.3,the experimental combinations for which were shown in table 3.4.

	Number of factors									
Number Of Levels	1	2	3	4	5	6	7	8	9	10
	2	L4	L4	L8	L8	L12	L12	L12	L12	L12
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27
	4	L16	L16	L16	L16	L32	L32	L32	L32	L32
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50

Table 3.3: L9 orthogonal array for 3 factors and 3 levels

Experiment	Factor A (Speed)	Factor B (Feed)	Factor C (Depth Of Cut
1	1	3	3
2	2	1	2
3	3	1	3
4	1	2	2
5	2	2	3
6	1	1	2

3.3 Experimental Procedure

The work piece was initially of about 32 mm diameter and 345 mm length. It was first centre-drilled on one side as shown in figure 3.3. This was necessary in order to support the work piece from both sides while turning on the lathe, and in turn, reducing the vibration of the work piece and minimizing the impact forces on the cutting tool. The work piece was attached to the lathe by the chuck, which was attached to the spindle. A tail stock assembly was used to support the work piece centre-drilled end. Turning operation was first performed on the work piece using CNC lathe to reduce the diameter to 30.9mm for a length of 160mm in order to minimize any effect of non-homogeneity on the experimental results. The nine experimental runs are performed based on the combinations from table 3.3 with each experiment carried for a length of 15mm.

Figure 3.3: work piece setup on CNC

3.4 Finding Residual Stress Using X-Ray Diffraction Technique:

Methods X-ray diffraction can be used to measure residual stress using the distance between crystallographic planes, i.e., d-spacing, as a strain gage. When the material is in tension, the d-spacing increases and, when under compression the d-spacing decreases. Stresses can be determined from the measured d-spacingAccording to Bragg's Law the X rays diffract from material at angle 2θ
$n\lambda = 2d\sin\theta$

3.5 Evaluation of Signal to noise ratio

There were three categories of performance characteristics, i.e., smaller-the-better, larger-the- better and nominal-the-better. To obtain optimal machining performance we considered smaller-the-better performance characteristic for surface hardness.

4. Results and Discussions

4.1 Residual Stresses are found in Inconel 718 material using X-Ray diffraction technique

Table 4.1: Residual Stresses are found in Inconel 718 material

Slot Number	Residual Stress (Kpa)
1	903.3
2	609.3
3	851.4
4	775.3
5	1020.1
6	562.0
7	1124.7
8	982.5
9	1149.9

Table 4.2: Machining conditions and responses

Run no.	Cutting parameters			Response	S/N ratio
	Speed, N (rpm)	Feed rate, f (mm/rev)	Depth of cut, d (mm)	Residual stress (Kpa)	
1	1	3	3	562	-59.11
2	2	1	2	775.3	-55.69
3	3	1	3	903.3	-58.6
4	1	2	2	609.3	-57.78
5	2	2	3	1020.1	-60.17
6	1	1	3	987.5	-54.99
7	3	3	2	851.5	-61.02
8	2	2	1	1149.9	-59.8
9	3	2	1	1124.7	-61.21

Table 4.3: Response Table for Means

Levels	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	717.9	887	1085.7
2	981.8	918	745.4
3	959.8	854.5	828.5
Delta	263.8	63.6	340.3
Rank	**2**	**3**	**1**

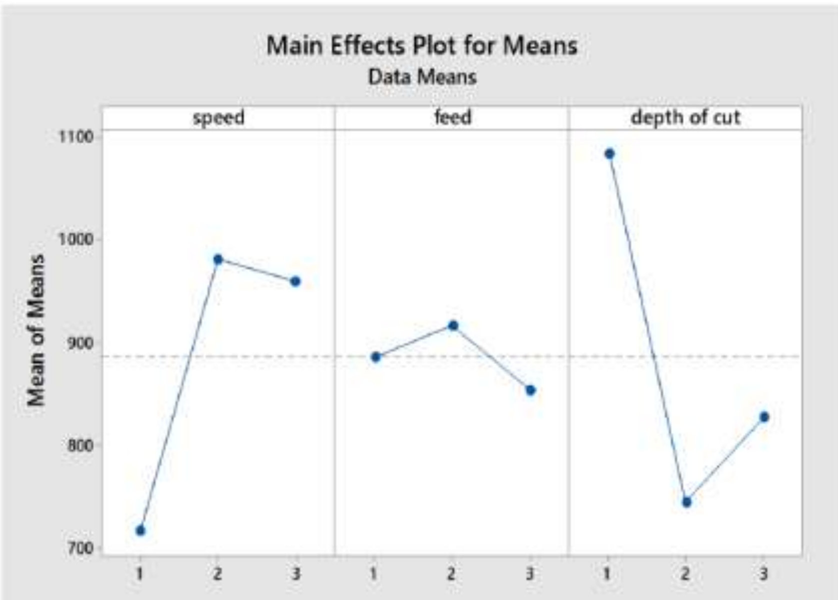

Figure 4.1: Response Graph for means

Table 6.4: Response Table for Means

Levels	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	-6.85	-58.92	-60.69
2	-9.73	-58.96	-57.36
3	-9.58	-58.27	-58.09
Delta	2.88	0.69	3.33
Rank	2	3	1

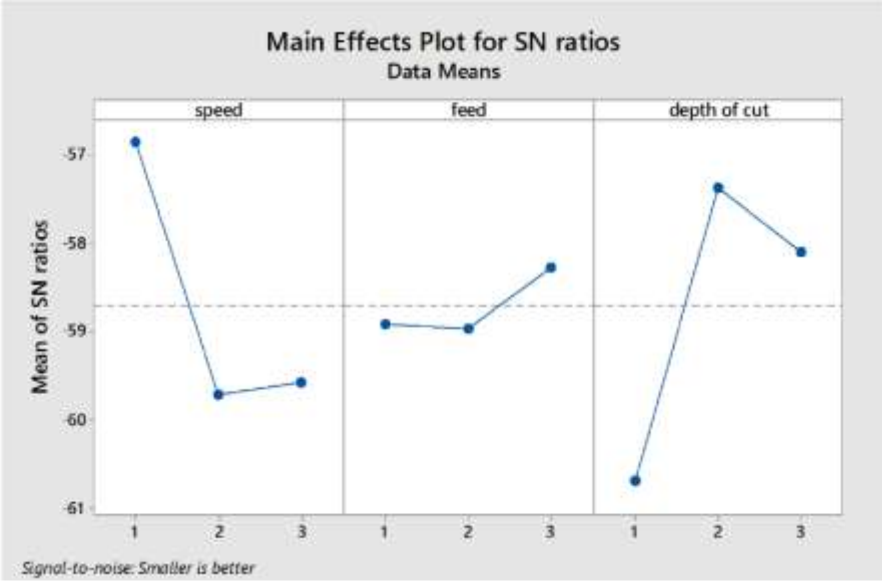

Figure 4.2: Response Graph for S/N ratios

4.2 Optimal Solution

Whatever might be the performance characterstics, a greater S/N value corresponds to a better performance**.** Therefore the optimal level of the machining parameters is the level with the greatest S/N value. Based on the analysis of the S/N ratio from Table 5.7 & and figure 5.8, the S/N ratio was maximum at 1stlevel of speed, 3rd level of feed rate and 2nd level of depth of cut. Hence the optimal combination for minimizing the surface hardness is speed 200 RPM, feed rate 0.1mm/rev and depth of cut is 0.3mm

5. Conclusion

The project presented the optimization of the surface hardness during the turning of INCONEL-718 with TiCN-Al2O3coated cemented carbide insert by using Taguchi method of DOE. The Residual stress was optimized for minimum and the required factors accountable for it were 250rpm 0.15 feed and 0.3mm depth of cut.

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