OPTIMIZATION OF TURNING PARAMETERS FOR SUPER ALLOY INCONEL 718 ON LATHE MACHINE

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Abstract— Nickel-based super alloys play an extremely important role in space vehicles, rocket engines, experimental aircrafts, nuclear reactors, submarines, steam power plants, Petro chemical equipments and other high-temperature applications. High quality and productivity are important in several machining operations. Inconel 718 is a very hard material (48 HRC). Because of its hardness, work hardening and low thermal conductivity, machining is very difficult. Since machining is basically a finishing process with specified dimensions, tolerances and surface finish, the type of surface that a machining operation generates and its characteristics are of great importance in manufacturing. Effects of numerous parameters of turning process like cutting speed, depth of cut, feed rate have been examined to reveal their impact on surface finish using Taguchi Methodology. In the present experimental study, effect of cutting conditions such as cutting speed, feed rate and depth of cut on the turning ability of Incone1 718 is discussed based on the taguchi orthogonal array. Nine experimental runs are based on an L9 orthogonal array of Taguchi method were performed. Cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness, Tool wear and material removal rate. The analysis of variance (ANOVA) is also applied to identify the most significant factor. Finally, confirmation tests were performed to make a comparison between the experimental results and developed model. Experimental results have shown that machining performance in the turning process can be improved effectively through this approach.

Key words: Inconel 718 super alloy, Turning parameters, Taguchi L9 Orthogonal array, Minitab, ANOVA

I. INTRODUCTION

1.1 Introduction to Super Alloys

Superalloys are complex, high-performance alloys, which have a high tolerance of oxidising environments and high temperatures. They are typically classified according to their predominant matrix element; nickel, cobalt, or iron, and they contain multiple alloying elements including the refractory metals (Nb, Mo, W, Ta), chromium, and titanium. They exhibit high mechanical strength, creep resistance and corrosion resistance, especially at high temperatures . These properties make them more challenging to produce and costlier than other alloys, but they are also critical for components in industries such as aerospace.

1.1.1 Properties Of Super alloys Super alloys are intended for use in high-temperature applications, which means they need to maintain their shape at elevated temperatures close to their melting points (above 650 °C or 1200°F). When alloyed with certain elements, at extreme temperatures super alloys can maintain high strength, stability, and corrosion and oxidation resistance.

1.1.2 Nickel-based super alloys

High strength
High thermal resistance
High corrosion resistance
Mach inability
Shape memory
Low coefficient of thermal expansion

1.1.3 Cobalt-based super alloys

Higher melting point compared to nickel- or iron-based alloys Superior hot corrosion resistance compared to nickel or iron-based alloys Higher thermal fatigue resistance and weld ability compared to nickel-based alloys

1.1.4Iron-basedsuperalloys

High strength at room temperature.¬ High resistance to creep, oxidation, corrosion and wear of these three categories, nickel-based alloys have the widest range of applications, particularly in the aerospace industry. The essential solutes in the nickel-based alloys are aluminium (Al) and titanium, with concentrations of less than 10 wt. %. This allows the generation of a two-phase equilibrium microstructure that consists of the phases known as gamma (γ) and gamma-prime (γ'). The matrix of superalloys is composed of the γ-phase, while their primary hardening is a result of the γ'-phase. The hightemperature strength, as well as other mechanical properties of superalloys, are also a result of the presence of the γ'-phase.

1.1 Specimen Material

Inconel 718 is a Nickel – chromium super alloy . The chromium content provides good hardness penetration, and the nickel content ensures uniform hardness and high strength. Inconel 718 Chromium - Nickel alloy can be oil hardened to a relatively high level of hardness. The desirable properties of the Inconel 718 include superior toughness, good ductility and good wear resistance in the quenched and tempered condition.

1.2 Turning

The working principle of a lathe is to remove the excess material in the form of chips, form a rotating work piece held between two centers, with the help of a cutting tool fed against the work piece. Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, 4 and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. The operations of lathe as shown in below Fig 1.1 Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

With the work piece rotating.
With a single-point cutting tool, and
With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

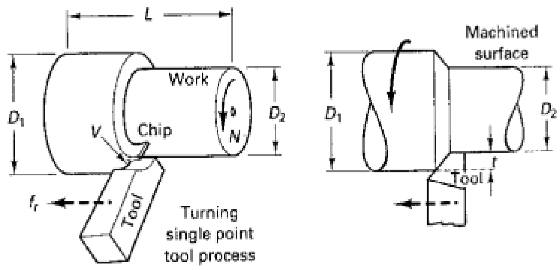


Fig 1.1 Operations of Lathe

Taguchi Orthogonal Array designs

Taguchi Orthogonal Array (OA) design is a type of general fractional factorial design. It is a highly fractional orthogonal design that is based on a design matrix proposed by Dr. Genichi Taguchi and allows you to consider a selected subset of combinations of multiple factors at multiple levels. Taguchi Orthogonal arrays are balanced to ensure that all levels of all factors are considered equally. For this reason, the factors can be evaluated independently of each other despite the fractionality of the design.

Selection of Orthogonal Array

Taguchi has tabulated 18 basic orthogonal arrays that are called standard orthogonal arrays. In many case studies, one of the arrays from Table - 3.2 can be used directly to plan a matrix experiment. An arrays name indicates the number of rows and columns it has, and also the number of levels in each of the columns. Thus, the array L4 (23) has four rows and three 2-level columns. The L18 (21 3 7) has 18 rows; one 2-level column; and seven 3-level columns. Thus, there are eight columns in the array L18 (21 3 7). When there are two arrays with the same number of rows, the second array will be represented by a prime, thus, the two arrays with 36 rows are referred to as L36 and L'36. The 18 standard orthogonal arrays along with the number of columns at different levels for these arrays are listed in Table - 3.1.

Orthogonal array	Number rows	Maximum number of Factors	Maximum number of columns of these levels			
			2	3	4	5
L_4	4	3	3	-	-	-
L_8	8	7	7	-	-	-
L_9	9	4	-	4	-	-
L_{12}	12	11	11	-	-	-
L_{16}	16	15	15	-	-	-
L'_{16}	16	5	-	-	5	-
L_{18}	18	8	1	7	-	-
L_{25}	25	6	-	-	-	6
L_{27}	27	13	-	13	-	-
L_{32}	32	31	31	-	-	-
L'_{32}	32	10	1	-	9	-
L_{36}	36	23	11	12	-	-
L'_{36}	36	16	3	13	-	-

Fig 1.1 Standard orthogonal arrays

II. LITERATURE REVIEW

Dr. B. Satyanarayana et all Dry machining is a machining process without the use of coolant, and it has become more popular for finishing process. Thus, it is especially crucial to select the machining parameters to obtain the desired surface roughness of machined Inconel 718. The experiments are planned as per the L27 orthogonal array with three levels defined for each of the factors in order to develop the knowledge base. The ANN model of surface roughness is developed with feed rate, cutting speed and depth of cut as process parameters. The necessary experimentation is carried out and the surface roughness values are recorded. A mathematical model is also developed using multiple linear regression, which gives relationship among the variables. The results are validated using Artificial Neural Network approach and Optimum values of input parameters are predicted. Mathematical model for Surface Roughness was developed using Regression Analysis. The proposed Ra formulations are empirical, based on experimental data. This is proved by the high values of the correlation coefficient, R2(99.43 % for Ra) which was taken as the fitness measure in each case. Further, the developed model is tested for its accuracy and adequacy using Artificial Neural Network

Pooja Petkar, S.S Karidkare et all In this study an experimental investigation of cutting parameters (cutting speed, feed rate and depth of cut) in turning operation of Inconel 718 was done and influence of cutting parameters on surface roughness, tool wear, material removal rate was studied. The machining was performed using tool such as carbide coated insert. Taguchi method is used to find optimum result. Orthogonal array, signal to noise ratio and used to study the performance characteristics in turning operation. The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by cutting speed followed by depth of cut. it is observed that the depth of cut is most significantly influences the 27 Surface Roughness. For all response variables depth of cut was found most significant & feed was most insignificant factor.

V.M. Prajapati, H. Thakkar, S.A. Thakkar and H.B. Parikh CNC milling is one of the most commonly used in industry and machine shops today for machining parts to precise sizes and shapes. The objective of this experimental investigation is to conduct research of machining parameters of the machine impact on product quality and productivity of the process. For the analysis input parameters like feed rate, spindle speed and depth of cut selected as a control factors in Taguchi technique of response variable optimization with keeping operating chamber temperature and the usage of different tool inserts constant. And the product quality in terms of Surface roughness and productivity as material removal rate is measured. An orthogonal array of L3 was used and ANAOVA were performed to find out the significance of each of the input parameters on the Surface roughness and material removal rate. It concluded that In case of surface Roughness. Spindle speed is most significant control factor and hence the optimum recommended parametric combination for optimum surface Roughness is SS (2000) FR (1500) DOC (0.6). This was accomplished with a relatively small number of experimental runs, given the number of control and noise factors, suggesting that Taguchi parameter design is an efficient and effective method for optimizing surface roughness in a milling operation.

N.D. Misal and M. Sadaiah et all The present work is focused on estimating the optimal machining parameters required for photochemical machining (PCM) of an Inconel 718 and effects of these parameters on surface topology. An experimental analysis was carried out to identify optimal values of parameters using ferric chloride ($FeCl_3$) as an etchant. The parameters considered in this analysis are concentration of etchant, etching time, and etchant temperature. The experimental analysis shows that etching performance as well as surface topology improved by appropriate selection of etching process parameters. Temperature of the etchant found to be dominant parameter in the PCM of Inconel 718 for surface roughness. At optimal etching conditions, surface roughness was found to be 0.201 µm. Findings of the above study are as follows: Higher temperature resulted in better surface finish as the etchant reacts with more grain area for uniform surface alterations. As the etchant 28 concentration increases, the surface roughness decreases. The optimum surface finish, as 0.201 µm was observed at temperature 55°C, etchant concentration 600 g/L, and time 40 min. Time shows less effect on surface roughness as compared to temperature and concentration.

III. METHODOLOGUY

Steps Involved In Taguchi Method

The general steps involved in the Taguchi Method are as follows:

Define the process objective, a target value for a performance measure of the process. This may be a flow rate, temperature etc. The target of a process may also be a minimum or maximum for example, the goal may be to maximize the output flow rate. The deviation in the performance characteristic from the target value is used to define the loss function for the process.

Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels that the parameters should be varied at must be specified. For example, a temperature might be varied to a low and high value of 400C and 800C. Increasing the number of levels to vary a parameter at increases the number of experiments to be conducted.

Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter.

Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure. Complete data analysis to determine the effect of the different parameters on the performance measure.

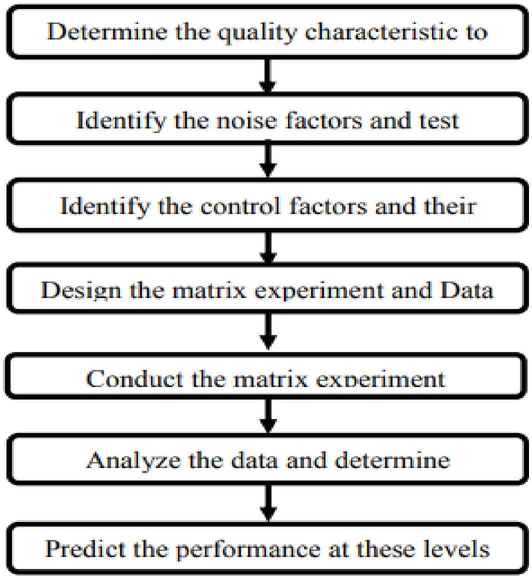


Fig 1.2 Steps in Taguchi method

Selection of Materials

The work material selected for this experiment is Inconel 718 of Ø 17 mm, length 200 mm in the present study. The turning operation is performed in 9 steps of 4, 5, 6 mm length each over the total length of varying depth of cut. The chemical composition of Inconel 718 as shown below the table 3.2. The chemical composition of Inconel 718 sample can be seen in Table below

COMPONENTS	Ni	Cr	Mo	Co	Nb	C	Al	Mn	Ti
PERCENTAGE (%)	50-55	17-21	3.2	1	5.3	0.08	0.6	0.35	1.23

Table 1.2 Chemical Composition of Inconel 718 Super alloy

Physical Properties Of Inconel 718 Alloy

Density 8.19 g/cm3

Melting point 1370 – 1430 °C

Modulus of elasticity 204.9 kN/mm²

Thermal expansion 10.4 x 10-6/ºc (25 0 -1000 c)

Thermal conductivity 11.4W/m.K (79.1Btu-in./ft2hr.°F)

Poisson's ratio 0.281 - 0.294

Fig 1.3 work piece before machining

Tool specifications:- LENGTH : 12 mm

WIDTH : 4 mm CORNER RADIUS : 0.8 mm ,WEIGHT : 223 Grams

Fig 1.4 Tool

IV. RESULTS AND DISCUSSION

MINITAB 16

MINITAB 16 is a computer program designed to perform basic and advanced statistical functions. It combines the user-friendliness of Microsoft Excel with the ability to perform complex statistical analysis.

Signal-to-noise rations (S/N ratios) vs. the control factors

Means (static design) vs. the control factors.

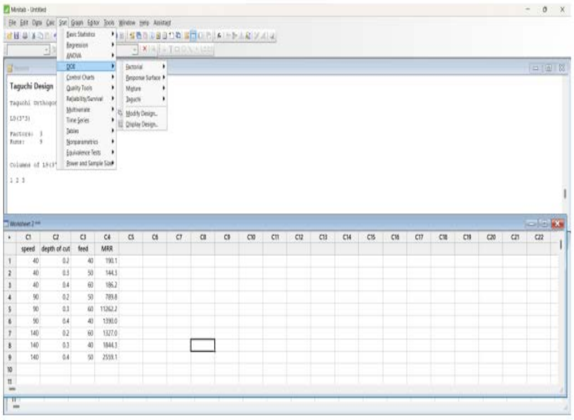


Fig 1.5 The MINITAB 16 work sheet with the Taguchi design

Features of Minitab

There are so many features in MINITAB 16. Some of the important features are listed below.

DATAS

CALCULATION

STATISTICS

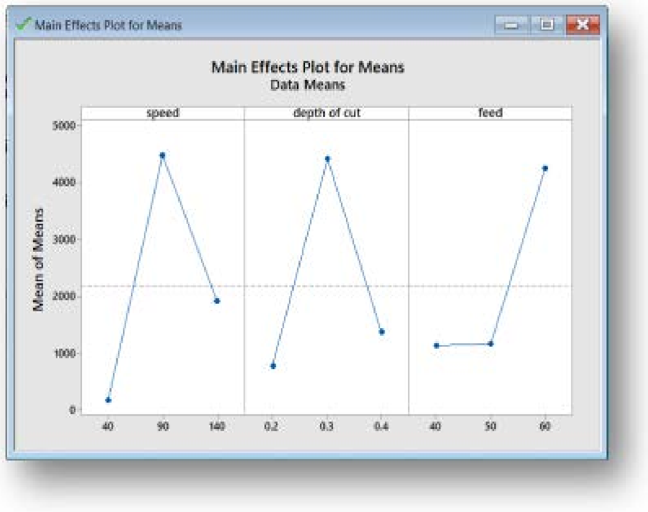
GRAPH

TOOLS

MINITAB 16 was the most popular statistics package in use in the social sciences. It was first used in teaching and research, although some users regarded it as a more limited research tool. No one found MINITAB 16 difficult to use.

Run	CUTTING SPEED (m/min)	FEED (m/rev)	DEPTH OF CUT (mm)	MACHINING TIME (min)	MRR (mm^3/min)	SURFACE FINISH (μM)
1	40	40	0.20	130	193.065	0.88
2	40	50	0.30	165	144.297	1.02
3	40	60	0.40	204	186.183	1.12
4	90	50	0.20	20	789.75	0.42
5	90	60	0.30	24	1162.19	0.62
6	90	40	0.40	18	1389.97	0.9
7	140	60	0.20	14	1326.97	0.42
8	140	40	0.30	10	1844.27	0.59
9	140	50	0.40	12	2559.1	0.64

Table 1.3 Material Removal Rate



Graph 1.1 MRR versus cutting speed, feed, depth of cut

Based on the above Figures:

Consider the Cutting speed; the effect on MRR is maximum at 140 and minimum at 40.

Consider the feed rate; the effect on MRR is maximum at 60mm and minimum at 40mm

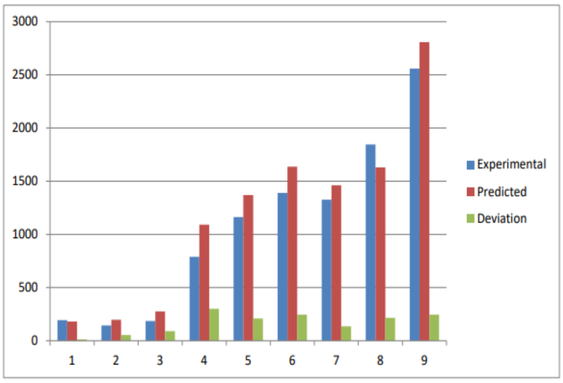
Consider the depth of cut, the effect on MRR is maximum at 0.2 and minimum at 0.4.

For the MRR, S/N ratio is considered as larger is better characteristic, maximum values of each parameter are selected as the optimum level combination

CONTROL FACTORS	OPTIMUM LEVEL	RANK
CUTTING SPEED	90	1
FEED RATE	60	2
DEPTH OF CUT	0.3	3

Table 1.4 Optimum combination for MRR

Comparison between predicted and experimental values of material removal rate



Graph 1.2 Graph for predicted and experimental values of MRR

ANOVA CALCULATIONS

SOURCE	DOF	SUM OF SQUARES	MEANS OF SQUARES	F-VALUE	% OF CONTRIBUTION
Cutting speed	1	4518452	4518452	72.59	82.46
Feed rate	1	555389	555389	8.92	10.14
Depth of cut	1	94241	94241	1.51	1.72
Error	5	311227	62245		94.32
					TOTAL = 94.32%

Table 1.5 ANOVA Calculations

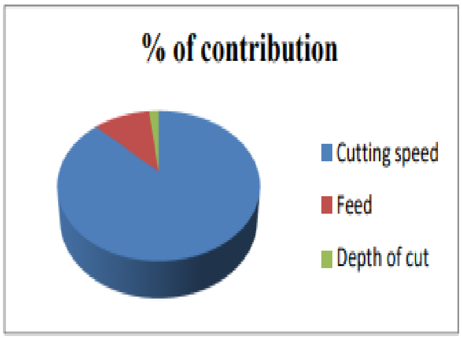


Fig 1.6 Percentage of contribution

V. CONCLUSION

It is observed that the effect of Cutting speed is maximum Material removal rate(MRR) followed by feed and depth of cut has least effect on MRR. Final, Optimum parameters are cutting speed 90 m/min , feed rate 60 mm/rev and depth of cut 0.3mm according to their priority involved parameters are ranked as 1, 2, 3 for cutting speed, feed rate, depth of cut, using those values Develop regression equation helps to find the predicted material removal rate (MRR) at 4.8% of error, the maximum % of contribution of cutting speed is 82.59%, the feed is about 10.14% and the depth of cut is about 1.72% and error is about 5.68% by ANOVA calculations. Surface roughness values are determined with respect to the input parameters used. It is observed that the Initial weight of tool is 223 grams and the weight of the tool piece after the Machining is 221 grams. Hence, the tool wear is 2 grams.

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