PREDICTION ON VARIANCE PERFORMANCE OPTIMIZATION OF PROCESS PARAMETERS OF NIMONIC USING MINITAB SOFTWARE

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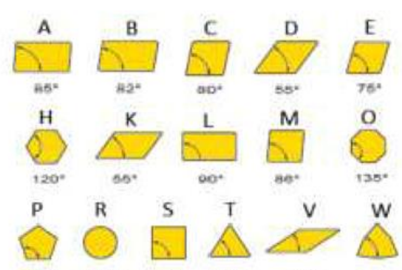
Abstract
Because of its special characteristics, Nimonic/SU (263) is a nickel-based super alloy that is sought after in a variety of engineering and marine applications, including parts for gas and jet engines, steam turbines, and nuclear reactors. It can withstand high temperatures and is highly corrosion resistant and strong. Our research aims to identify the ideal process parameters, including speed, feed, DOC on the response variable, MRR, and surface roughness (Ra), for the turning operation on Nimonic/SU (263). In order to reduce the number of experimental trials, a L9 orthogonal array with various degrees of input parameters has been employed. In order to establish the best settings for a system, the signal to noise ratio is computed in relation to the quality features of the response variables. The Analysis of Variance is performed in order to predict the most significant parameter which affects the response variables and the end results are validated with Minitab software.
Keywords: Nimonic/ SU (263), Taguchi Technique, Orthogonal array, SN ratio, ANOVA.

Introduction
Due to its special qualities sought for the numerous engineering and maritime applications, super alloy Nimonic series 718,600,700 is commonly employed in complex applications. Super alloy requires more skillful and expensive machining due to its unique properties. Therefore, the primary focus of the current study is on choosing the best process variables for turning Nimonic SU 263 using a carbide tool insert, as illustrated in Fig. 1. The super alloy Nimonic SU 263 is based on nickel. One Design of Experiment (DOE) tool for process optimization and crucial parameter identification and optimal configuration is the Taguchi method. Determine the impact of process factors on the response variables using analysis of variance (ANOVA. The input parameters such as speed, feed, degree of freedom on response variables tensile strength (Ts), material removal rate (MRR) and surface roughness (Ra) NIMONIC SU 263 is non-magnetic nickel-chromium-iron high temperature alloy having high strength, high corrosion resistance, hot and cold workability and free from stress corrosion. The high chromium content raises its oxidation resistance and the presence of high nickel content provides good corrosion resistance. The alloy shows very good levels of resistance to chloride stress-concentration cracking, ammonia. It has a good performance level at cryogenic temperatures. Since machining is a basically a finishing process with specified dimensions, stability, tolerance and surface finish, type of surface and its characteristics are very much important in manufacturing.
Carbide cutting tools are the oldest amongst the hard cutting tool materials in order to machine nickel based super alloys with the speed range of 30-80m/min. The 3D view of carbide tool insert is as shown in Fig.1 and general information on insert as listed in table 1.



Insert Style	VNMG
Material	Carbide(TiN/TiA1N)
Manufacture grade	IC907
Shape	Diamond
Length	16.6mm
Thickness	4.76mm
Application	Turning
Included Angle	35 degree(Right hand cut)
Full insert style code	VNMG160404

Table 1- Tool insert specifications

Factors affecting the quality of turning

The key mechanical input in material removal operation are speed, feed, depth of cut, tool insert, cutting force, coolant used etc. The choice of feed, speed and depth of cut is based on the customer objectives

Independent Variable

Cutting Speed

In general, speed (V) is the primary cutting motion, which relates the velocity of the rotating work piece with respect to the stationary cutting tool. The cutting speed refers to the edge speed of the rotating work piece. It is generally given in unit of surface feet per minute (sfpm) or inches per minute (in/min), or meters per minute (m/min). For a given material there will be an optimum cutting speed for a certain set of machining conditions, and from this speed the spindle speed (RPM) can be calculated. Factors affecting the calculation of cutting speed are:

The material being machined (steel, brass, tool steel, plastic, wood)

The material the cutter is made from (Carbon steel, High speed steel (HSS), carbide and ceramics).

The economic life of the cutter (the cost to regrind or purchase new, compared to the quantity of parts produced).

Feed

Feed is the relative velocity at which the cutter is advanced along the work piece. Its vector is perpendicular to the vector of cutting speed. Feed rate units depend on the motion of the tool and work piece. When the work piece rotates (*e.g.*, in turning and boring), the units are almost always distance per spindle revolution (inches per revolution [in/rev] or millimeters per revolution [mm/rev]).When the work piece does not rotate (e.g., in milling), the units are typically distance per time (inches per minute [in/min] or millimeters per minute [mm/min]), although distance per revolution or per cutter tooth are also sometimes used.

Feed rate is dependent on the:

1. Type of tool
2. Surface finish desired.
3. Power available at the spindle.
4. Rigidity of the machine and tooling setup (ability to withstand vibration or chatter).
5. Strength of the work piece.
6. Characteristics of the material being cut, chip flow depends on material type and feed rate. The ideal chip shape is small and breaks free early, carrying heat away from the tool and work.

Depth of cut

Cutting speed and feed rate come together with depth of cut to determine the material removal rate, which is the volume of work piece material that can be removed per time unit. It is the distance thatcutting tool penetrates into the work piece [3].

Response variables

Material removal rate

The material removal rate of the work piece is the volume of the material removed per minute. It can be calculated using the following relation (1.1).

MRR =MRR – Material Removal Rate (mm3/min)

Wi– Initial weight of work piece (gm)

Wf– Final weight of work piece (gm)

Dw– Density of the work piece (gm/mm3)

t - Period of trial (min)

Surface roughness

Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if small, the surface is smooth. Roughness is typically considered to be the high frequency, short wave length component of a measured surface. The parameter mostly used for general surface roughness is “Ra”. It measures average roughness by comparing all the peaks and valleys to the mean line, and then averaging them all over the entire cut-off length [3]. The surface roughness tester used for measuring the surface roughness is as shown in fig 2.

Fig2. Surface roughness tester (P.C – Mascot laboratories)

Method & Material

To achieve the required quality requirements in a specific situation, process parameters are often determined with the aid of building the parts of test specimen. A standard approach for experimental design is to use the full factorial method. However, a full factorial is acceptable only when a few factors are to be investigated. If more number of parameters are there, the full factorial method is time consuming and expensive. Hence the importance of Taguchi method for the design of experiments plays an important role. Taguchi methods of experimental design provide a simple, efficient and systematic approach called fractional factorial method for minimizing the number total experimental runs. The various parameter with level is as shown in table 1. The steps of the proposed methodology are given below,

Identification of process parameters that influence on response variable with expertise knowledge and brainstorming.

Setting of levels for identified parameters to conduct experiments.

Selection of orthogonal array (OA) to design the experimental runs for main experiments by analyzing the interaction effect between the parameters.

Experimentation for the OA setting to find the values of response variables.

rediction of optimal level for each parameter for the set objective with the response variable data using signal to noise (S/N) ratio.

Identification of critical parameters (most influencing) for the response variable with the percentage contribution of each parameter on the response variable using ANOVA techniques.

Table 1 Levels of various parameters

Parameter	Level	1Level	2Level 3
Speed in m/min	30	40	45
Feed in mm/rev	0.20	0.25	0.30
DOC in mm	0.6	0.7	0.8

Fabrication of test specimen

Machining of Nimonic (SU263) was carried out in CNC lathe and machining process involved cutting parameters such as cutting speed, feed and depth of cut. The measurements of material removal rate were made using observation of cutting time and further tested for surface roughness. The flow cart indicating the fabrication of test specimen is shown in the Fig.3. The raw material of nimonic su 263 is shown in image its dimensions are 20*160mm by using CNC turning machine and according to ASTM E8M standards and Taguchi L9 orthogonal array as shown in Fig.3(a & b).

Results and Discussions

The L9 orthogonal array with experimental results and calculated S/N ratios is shown in the table 2.

Effect of parameters on MRR

S/N Ratio plot showing the variation of mean of SN Ratios and Cutting Speed with respect to different levels of parameters on MRR. It can be seen that the 3^{rd} level of Vc that is 80m/min has the highest SN Ratio as shown in figure 4. Hence Vc =45m/min is more significant.

Fig 3 Flow chart indicating the fabrication of test specimen

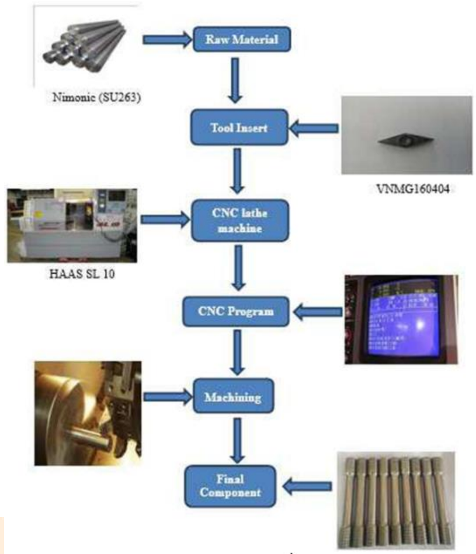


Fig. 3. (a) raw material

(b) final component

Table 2 L9 orthogonal array with experimental results and calculated results for MRR Ra S/N ratio for MRR and Ra

Exp no.	Vc in mm/min	Feed in mm/rev	DOC in mm	MRR *10³in mm³/min	a in micro meter	S/N ratio for MRR	S/N ratio for Ra
1	(1)30	(1)0.20	(1)0.6	0.194	0.336	-14.24	9.47
2	(1)30	(2)0.25	(2)0.7	0.242	0.208	-12.32	13.63
3	(1)30	(3)0.30	(3)0.8	0.299	0.217	-10.48	13.27
4	(2)40	(1)0.20	(2)0.7	0.258	0.314	-11.76	10.06
5	(2)40	(2)0.25	(3)0.8	0.328	0.239	-9.68	12.43
6	(2)40	(3)0.30	(1)0.6	0.389	0.220	-8.20	13.15
7	(3)45	(1)0.20	(3)0.8	0.294	0.210	-10.63	13.55
8	(3)45	(2)0.25	(1)0.6	0.382	0.315	-9.68	10.03
9	(3)45	(3)0.30	(2)0.7	0.464	0.268	-6.66	11.43

S/N Ratio plot showing mean of SN Ratio and DOC with respect to different levels of parameters on MRR. It can be seen that the 3rd Level of DOC that is 0.8mm has the highest SN Ratio as shown in figure 5. Hence DOC=0.8mm is more significant.

Fig 5: S/N ratio for DOC v/s MRR levels

S/N ratio plot showing mean of SN ratios and feed with respect to different levels of parameters on MRR. It can be seen that the 3 level of feed that is 0.2mm/rev has the highest SN Ratio as shown in figure 6. Hence feed=0.2mm/rev is more significant.

Fig:6: S/N ratio for feed v/s MRR levels

Effect of parameters on Surface Roughness

S/N Ratio plot showing the variation of mean of SN Ratios and Cutting Speed with respect to different levels of parameters on Ra. It can be seen that the3rd level of Vc that is 45m/min has the lowest SN Ratio as shown in figure 7.Hence Vc is 45m/min more significant.

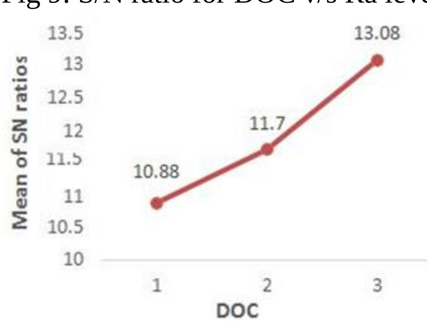
Fig 7: S/N ratio for speed v/s Ra levels

S/N Ratio plot showing the variation of Mean of SN Ratios and Feed with respect to different levels of parameters on Ra. It can be seen that the 1st level of Feed that is 0.2mm/rev has the lowest SN Ratio as shown in figure 8. Hence feed is 0.2mm/rev is more significant.

Fig8: S/N ratio for feed v/s Ra levels

S/N Ratio plot showing mean of SN ratio and DOC with respect to different levels of parameters on Ra. It is observed that the1st Level of DOC that is 0.6mm has the highest SN Ratio as shown in figure 9.Hence DOC is 0.6mm is more significant.

Fig 9: S/N ratio for DOC v/s Ra levels



Conclusions

The material utilised in this project is a super alloy called Nimonic SU 263, which is expensive and has unusual properties that make it challenging to process. In order to reduce the higher unit cost per machined item and its service life, it is crucial to choose the best specifications. Analysis employing a conceptual S/N ratio method showed that in the turning of Nimonic

SU 263. In this study, the Taguchi approach is applied to give the simple, systematic, and procedural design of experiment (DOE) technique to acquire the process optimization of their interaction effects.

For MRR,

The parameters Vc, f , Doc influence much on the response factor MRR by S/N Ratio are, Speed (Vc)=45m/min; feed=0.3mm/rev; DOC=0.8mm

The significance of each parameter is identified by ANOVA tool Speed (Vc)=48.52%; feed=45.43%; DOC=-1.2% of these three process parameters, Cutting speed (Vc) and Feed (f) has the major contribution on MRR

For Surface roughness

The parameters Vc, f , Doc influence much on the response factor Ra by S/N Ratio are, Speed (Vc)=45mm/min; feed=0.2mm/rev; DOC=0.6mm

The significance of each parameter is identified by ANOVA tool Speed (Vc)=60.67% ; feed=7.2%; DOC=-7.21% of these three process parameters,

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