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Parametric Optimization of Inconel 718 Wth Carbide Inserts in Turning Using Taguchi L-9 Orthogonal Array Method

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Abstract

This paper focuses on investigating the optimization of process parameters using Taguchi L9 Orthogonal array method for machining operations in turning of Inconel 781 with the aid of special tungsten carbide inserts. The optimization of speed(s), feed(f), Material Removal Rate (MRR) and Temperature(T) considered with relation to the tolerances achieved and accuracy of the machining is investigated. Tests are carried out with absolute accuracy in response to the optimization performance. The factors considered for testing the machining operations tends the surface quality of work material relative to the MRR are analysed. Experimental results show that the turning operation through optimized parametric approach results in developed surface machining quality, performance and less materials consumption induced.

Introduction

The importance of surface quality for the evaluation of the production of materials, machining parts, and tools for the measurement of cutting processes in machining operations. The deviation of the mean of a surface roughness measuring the surface quality influenced by the parameters of machining processes of feed, speed, DOC. The development of a model surface response methodology following the experiment been designed based on three level factorial design [1]. The Taguchi method of quality loss function involving performance characteristics by larger-the-better using transformation to analyze the quality of loss. The signal-to-noise ratio complexity-based concept design formation based on mean square deviation involving mathematical derivations in proposing a methodology [2]. The study of the application of Taguchi optimization techniques for various parameters of speed feed and depth of cut in machining reinforced epoxy hybrid composite material under dry conditions by an orthogonal array method for the milling process. The surface quality and cutting forces are optimized and studied involving the lowest cutting forces [3]. Another study showing the machining of alloy using orthogonal array method forming the best conditions for the minimalistic optimization processing experimental designs following the material removal rate and surface roughness [4], where in face milling operation the surface quality involves additional manufacturing costs of loss of productivity of examined to form an optimization technique [5]. The multiple objective optimization for machining parameters in dry machining of stainless-steel using analysis of grey rational analysis is carried out in finding of forces, material removal rate through orthogonal array method of optimization technique. The machinability as material removal rate for which confirmatory test carried out in supporting the grey rational analysis improvements in machining up to 88.8% [6]. The effect of cutting parameters on force and vibration signals in machining dependable in parameters of feed, cutting forces, radial direction and vibrational signals measured along tangential are developed using response surface methodology for better understanding [7]. The surface roughness and deviation are investigated in drilling of stainless-steel using twist drills for the optimal parameters using l-8 orthogonal array method in predicting design of experimentation confirming results showing taguchi method precisely in drilling of stainless steel [8]. Recent studies show that the EN8 steel having applications in machining parts such as axle fasteners in increasing tensile strength properties for developing optimal machining parameters for the surface roughness designing analysis of variance (ANOVA) and Taguchi design of experiments in identifying S/N ratio processing parameters [9]. The investigation of various parameters of roughness measuring methods identifying the second-order mathematical models following five roughness parameters prediction results in response optimization techniques for machining operations [10] so the technique involving developing a minimalistic approach to attain high surface quality with reduced tool wear for the combination of tool and work piece is investigated at varied temperature is a new attempt.

Experimentation

Machining operation of turning is performed on an Inconel 718 round rod of length 500mm having diameter 40mm in CNC machine. The turning operation was carried out using TCMT carbide inserts for indexable turning holder that can operating capable of 1.6cm ×1.6cm/0.6" × 0.6" having side of 16mm as shown in Figure 1. TCMT is wear resistive carbide insert having blade of high strength, toughness and stability to withstand temperature

conditions considerable. Lower cutting forces are induced with better tool life having suitable positive cutting action. The turning operations are carried out with mini FANUC Series Oi-TF CNC machine of having spindle rotations higher than 3000rpm. The tungsten carbide inserts are designed with coatings to withstand high temperature alloys. The cutting operations are carried out at different parameters of speed and feed through varying temperature conditions measured. The Surface Roughness and MRR are calculated with three conditions of incremental parametric values along with the Chemical composition and Mechanical properties shown in Table 1 & Table 2 by the cutting operation performed in the taken Specimen as shown in the Figure 1.

Table 1: Chemical composition of Inconel 718 alloy.

Elements	C	Mn	Si	Ti	Al	Co	Mb	Cb	Fe	Cr	Ni
%	0.08	0.35	0.35	6	0.8	1	3	5	17	19	52.82

Table 2: Mechanical properties.

Ultimate tensile strength (Mpa)	Yield Point (Mpa)	Elongation (%)	Hardness (HRC)
1260-1390	1041-1160	14-19	40-45

Figure 1: Turning operation performed on Inconel 718 with carbide inserts in SJ 500XL CNC

Methodology:

The design of experiments is carried out in L-9 Taguchi orthogonal array method with variables of speed, feed and temperature with interactions. The Signal-to-Noise (S/N) ratio is to measure the independent and dependent variables of designing the experimentation process for the desired and undesired values using S/N dependent of smaller-the-better method of optimization technique. The process parameters taken for the design of experimental study, follows Table 3: The DOF valued at six defining the L-9 trail conditions of Taguchi's Orthogonal array method studying the main effects than interactions. The S/N ratio measuring the surface quality (R_a) calculate considering smaller-the-better characteristics valued with

$$S/N(\eta) = -10 \times log\left(i/n \sum_{i=1}^{} * yi^2\right)$$

Table 3: Process parameters.

Parameter	Unit	level 1	level2	level 3
Cutting speed (s)	m/min	1500	2000	2500
feed (f)	mm/rev	0.118	0.21	0.346
Temperature (T)	Centigrade	190	210	260

The S/N signal-to-noise ratio taguchi method is used helped in finding the optimized parameters for machining operations having six degrees of freedom as shown in the Table 4. process parametric conditions taken at orthogonal array L-9taguchi techniques results in response variables of MRR and surface roughness for best optimization conditions of turning operating in Inconel 718.

Result analysis

The results show the improvement of machining operation is up to 81% of optimization producing the best results at temperature of 210°C having minimal surface roughness at L-6 with feed 0.2m/min. The L-9 optimization technique resulted in increased performance assessing quality economical material removal rate with less surface roughness formed. From the outcomes the parametric optimization in turning of Inconel 718 machined with TCMT inserts undergone designing performance with best cutting operations are analysed, which is shown in the Table 4. The next surface roughness is less observed at speed 2500, temperature having 260 °C and feed rate at 0.366m/min. The material removal rate is also regulated at 2500rpm as shown the Table 4.

Table 4: Parametric optimization using L-9 orthogonal array method.

				Experimental Values	L-9 orthigonal array				S/N		
Exp No.	Speed	Feed	Temperature	Ra (μm)	MRR	s	f	T	Ra (μm)	MRR	MRR
	Rpm	m/min	°C								
1	1500	0.118	190	0.275	0.3	1	1	1	0.77	3.199	-2.74
2	1500	0.129	190	1.098	0.3	1	2	2	0.75	3.661	-1.52
3	1500	0.193	190	1.356	0.3	1	3	3	0.79	4.28	-3.12
4	2000	0.210	210	0.392	0.5	2	1	2	0.734	5.33	-0.81
5	2000	0.249	210	1.167	0.5	2	2	3	0.746	4.356	8.148
6	2000	0.299	210	1.331	0.5	2	3	1	0.691	2.681	-1.89
7	2500	0.346	260	0.618	0.7	3	1	3	0.726	4.356	10.82

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8	2500	0.366	260	1.018	0.8	3	2	1	0.693	3.202	-2.49
9	2500	0.391	260	1.225	0.9	3	3	2	0.698	5.013	-0.16

Conclusion

Results show that the variance analysis having identified considerable factors for the processing factors are observed from the Table 4 showing the surface quality in turning process is carried favorable. Considering the material removal rate for the given feed, speed at given generated temperature variance in turning of Inconel shows elaborate output that minimization of material removal increasing the tool life leading to quality surface machining. As the cutting speeds shows the significant effect in any machining process with high material removal rate the necessity of optimization for best process parameters are investigated. This implies that the Optimization techniques of L-9 orthogonal array method successfully analyzed optimization for reduced tool wear, which is proportional to the MRR at varying speeds. Thus, generating high surface machining quality at less wear reasonable for economical machining process.

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