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Parametric Investigation on the Tool Wear While Performing Face Milling on Inconel 718 Using Round Insert

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Abstract: Machining of Inconel 718 has become a material of great purpose in the machining industry. Since Inconel is considered to be a super alloy which possess high material property such as high thermal fatigue, high strength and high resistance to corrosion it is thus considered to be a material which is hard to machine. This paper gives an overview on the tool wear that takes place while machining. Machining was carried out in a CNC milling machine with the help of a tungsten carbide circular insert. The cutting parameters taken into consideration were cutting speed, feed rate and depth of cut. Tool wear was analysed with the help of tool maker's microscope. Statistical analysis was done on the MINITAB 18 software by using regression analysis. The regression analysis was carried out by using Response Surface Methodology (RSM) the mathematical model for each individual response has been developed from regression equations considering analysis of cutting parameters as independent variables which was found to be significantly accurate.

Key Words**:** Face milling, Inconel 718, RSM, Round insert

I. INTRODUCTION

Machining of super alloys such as Inconel 718 are tough due to its superior properties. It is a super alloy which has unusual mechanical and thermal properties. Tool wear is one of the main reasons to find out the machinability of super alloys [1]. Inconel 718 is an alloy which is extensively used during the loading conditions due to high thermal condition, high strength, and chemical stability [2].

By changing the carbide cutting tool insert geometries there is an increase in effectiveness and efficiency of machining of insert [3]. Stress reduces with increase in cutting speed, pre heating temperature and decrease of feed rate [4]. The empirical cutting force model has been established by using multiple regression analysis and the flank wear of the tool is used from the prediction model which was reversed and was found by analysis of the results from the simulation of the experiments [5]. After performing face milling minimum and maximum surface roughness was attained on material removal these parameters were investigated using RSM [6]. It has been determined that with increase in cutting speed the flank wear tends to also increase drastically. That means that with increase in flank wear rate tool life tends to become shorter and cutting tool has to be changed [7]. By considering Analysis of Variance (ANOVA) and Central Composite Design (CCD) the cutting parameters on the tool wear and surface roughness amid hard turning of Inconel 718 material could be resolved [8], [10]. By utilizing ANOVA (Analysis of Variance) strategy to locate noteworthy factor and rate commitment of each information parameter for acquiring ideal conditions. Utilizing the mean ANOVA computations, ideal yield attributes had been anticipated by MINITAB measurable programming [9].

In this present work done, an investigation has been done on the process parameters cutting speed, feed rate and depth of cut upon performance of tool wear in face milling on Inconel 718 work piece with a circular tungsten carbide cutting insert. Tool wear is measured after every single machine run. Effect of process parameters upon tool wear is investigated by using the analysis of variance (ANOVA). Response surface methodology (RSM) model is used to determine the relationship between various process parameters and tool wear.

II. EXPERIMENTAL PROCEDURE

This paper focuses on the experimental work which has been carried out in two main procedures. The aim of the first experiment carried out was to determine tool wear for different process parameters combination.

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The purpose of second experiment was to analyse effect of process parameters on the tool wear and then to find a correlation between them by using response surface methodology (RSM).

A. Work piece Material

The work piece used was Inconel 718 shown in Fig I. which is considered to have materialistic properties which makes it hard to cut and is widely used in the aerospace industry mainly in gas turbine compartment.

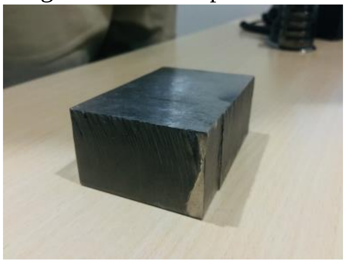

Fig I. Workpiece (Inconel 718)

Table I. chemical composition of Inconel 718

C	0.062	P	0.033
S	0.004	Si	0.12
Mn	0.0002	V	0.027
Mo	3.75	Cr	18.01
Cu	0.11	Co	0.17
Ti	0.97	W	0.12
Al	0.47	Ta	5.34
Nb	5.345	B	0.002
Mg	0.02	Zr	0.001
Sn	0.011	Fe	18.51
Ca	0.0003	Ni	52.21

The work piece used is of measurement 75mm (length), 50mm (width), and 45mm (height) as shown in Fig I. The chemical composition of Inconel 718 is given in Table I.

B. Tool material

The insert used to perform the machining has a circular shape and has a material property of tungsten carbide. The insert used is RYMX 1004-ML having grade TT3540 as seen in Fig II.

Fig II. Tungsten Carbide Cutting insert

The weakest section of any face milling insert is its corner. Since the corners are exposed to high thermal changes and constant wear. Therefore a round tool which has no corneres has been used since it is more favourable then any other tool geometry.

C. Machining process

The machining process is carried out in a CNC vertical milling machine (BOSCH MTX Micro-Milling) having a spindle speed of 50-4000rpm and a spindle power of 12NM (2.5 KW). It takes in a power supply of 3 Phase, 415V, 50Hz, 8KW. Machining is done using a circular insert of tungsten carbide material.

The different process parameters such as cutting speed, feed rate and depth of cut are inputted to find response parameters of tool wear at different levels as shown in Table II. Values of tool wear was determined with the help of the tool maker's microscope in mm after completion of the complete machining done on the work piece.

Table II. Control factors for the experiment

Parameters	Cutting speed	Feed rate	Depth of cut
Unit	RPM	mm/min	mm
Symbol	v	F	d
Minimum	500	10	0.2
Maximum	700	20	0.6

By the methods of ANOVA and RSM analysis is performed. From the results of ANOVA significant values have been determined and the p-value is found to be less than 0.05. Groups are made with respect to the cutting speed, feed rate and depth of cut. From analysis of RSM significant tests have been done to find the regression equation for tool wear. Individual model coefficients were performed to identify fit of the obtained model.

III. RESULTS AND DISCUSSION

A. Tool wear analysis

Tool wear has been determined after the end of machining process. The tool is rotated clockwise for every individual machine run. Markings have been made on each machined side of the insert. Tool wear reading is measured with help of tool maker's microscope in mm. The measured values are noted down with the help of a standard observation table generated using MINITAB 18 statistical software for different combination of process parameters as well as for the obtained tool wear as shown in the Table III. It is noted that with increase in cutting speed there was an increase in tool wear. The tool wear was found to be ranging from 0.010mm – 0.1085mm.

Table III. Standardized observation table to obtain tool wear

Cutting Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	Tool wear (mm)
500	10	0.2	0.087
700	10	0.2	0.012
500	20	0.2	0.010
700	20	0.2	0.042
500	10	0.6	0.040
700	10	0.6	0.063
500	20	0.6	0.095
700	20	0.6	0.075
431.8207	15	0.4	0.060
768.1793	15	0.4	0.070
600	6.591036	0.4	0.063
600	23.40896	0.4	0.060
600	15	0.063641	0.059
600	15	0.736359	0.1085
600	15	0.4	0.070
600	15	0.4	0.074
600	15	0.4	0.072
600	15	0.4	0.073
600	15	0.4	0.040
600	15	0.4	0.072

B. Response surface methodology

The analysis that are seen in Table. V show that factors have a significant contribution for tool wear as each term p-values has been found to be less than 0.05. However it has been seen that depth of cut has a major significance in the contribution of tool wear as it has an F =162.68. The determination coefficient R^2 is an important coefficient and it has found to high at 95.95%, which means that the response model has a good fit with the actual data as shown in Table IV.

Table IV. Estimated Coded Coefficient for tool wear

Term	Coef	SE Coef	T-Value	P-Value	VIF
CONSTANT	0.06986	0.00250	27.89	0.000	
Cutting Speed	0.00490	0.00166	2.95	0.015	1.00
Feed Rate	0.00431	0.00166	2.59	0.027	1.00
Depth of Cut	0.02119	0.00166	12.75	0.000	1.00
Cutting Speed*Cutting Speed	0.00266	0.00162	1.64	0.131	1.02
Feed Rate *Feed Rate	-0.00530	0.00162	-3.27	0.008	1.02
Depth of cut*Depth of Cut	-0.00848	0.00162	-5.24	0.000	1.02
Cutting Speed *Feed Rate	0.00081	0.00217	0.37	0.716	1.00
Cutting speed *Depth of Cut	-0.00919	0.00217	-4.23	0.002	1.00
Feed Rate*Depth of cut	0.01544	0.00217	7.11	0.000	1.00
R-Sq=96.64%		R-Sq(adj)=93.62%			
R-Sq(pred)=82.64%					

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C. Response surface plots

From the response surface plot graphs it has been noted that when the feed rate is in the range 15-20, cutting speed in the range 600-700 and tool wear was found to be ranging from 0.00-0.04 as seen in Fig. III (a).

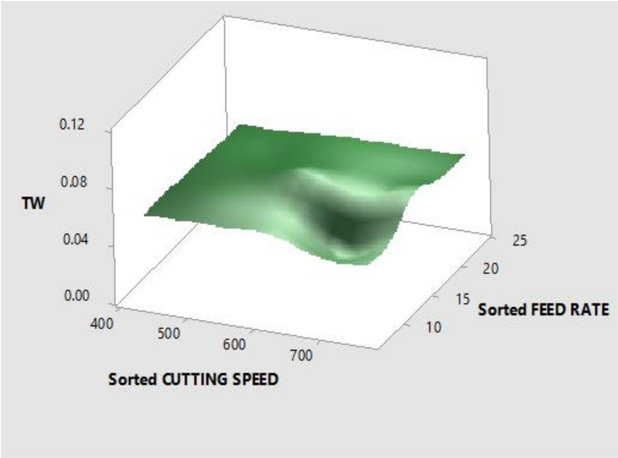

Fig. III(a). Response surface plots for tool wear versus feed rate, cutting speed.

From the response surface plot graphs it has been noted that when the depth of cut is in the range 0.2-0.4, feed rate ranging from 20-25 and tool wear was found to be ranging from 0.00-0.04 as seen in Fig. III (b).

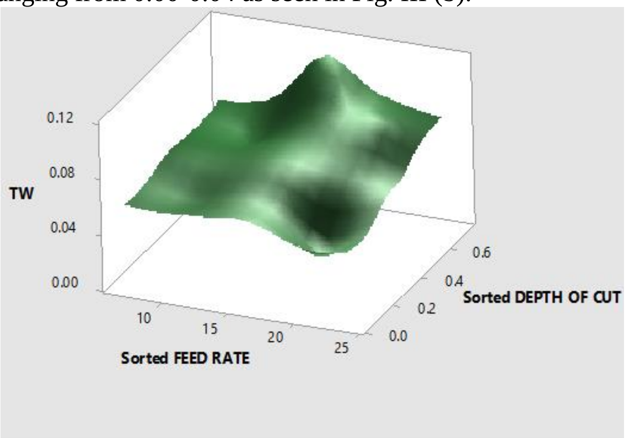

Fig. III(b). Response surface plots for tool wear versus depth of cut, feed rate.

From the response surface plot graphs it has been noted that when cutting speed is in the range 600-700, depth of cut is from 0.4-0.6 and tool wear was found to be ranging from 0.04-0.08 as seen in Fig. III (c).

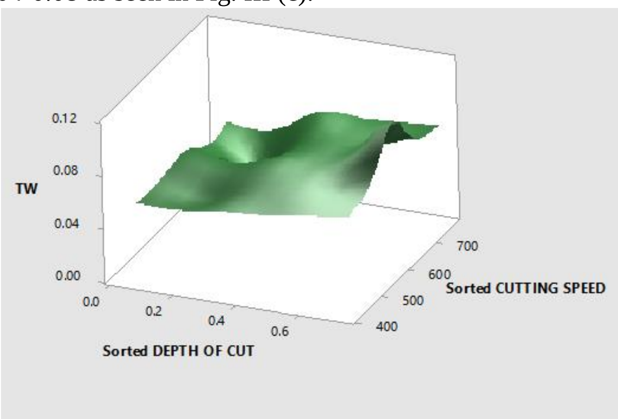

Fig. III(c). Response surface plots for tool wear versus cutting speed, depth of cut.

The Figs. III(a), III(b) and III(c) shows the estimated tool wear as a function of cutting speed, feed rate and depth of cut. For each plot variables which are not presented are held at the neutral level which are constant. The surface plots confirm the observations observed during the effect of plot analysis.

IV.CONCLUSION

- The experiment was conducted using RSM table which was developed from the MINITAB-18 statistical software.
- Regression analysis for the tool wear was carried out using the MINITAB software using the available experimental data.
- The efficiency of the regressions was found to be 96.64%.
- The output derived from the regression equations was in compliance with the experimental results.

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