International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 04, April-2019

OPTIMIZATION OF MACHINING PARAMETERS DURING CNC MILLING OF INCOLOY 800

Balwant Singh[1], Dr. P.Sudhakar Rao[2]

[1] *M.E Scholar, Department of Mechanical Engineering, NITTTR Chandigarh,*
[2]*Assistant Professor, Department of Mechanical Engineering, NITTTR Chandigarh,*

Abstract- Maintaining better surface quality generally includes additional production cost or loss of productivity. During the process high cutting frictional forces lead to rise in temperature at workpiece and tool interface which may affect the dimensional and surface quality of the product. Optimum machining parameters can reduce tool wear, to ensure better surface integrity and machining cost. In this paper, the machining parameters i.e. cutting speed (V_c), depth of cut (d) and feed rate (f) has been optimized for improved surface finish using response surface methodology (RSM). The optimization of the surface roughness (R_a) and tool wear (T_w) has been done simultaneously by multi response optimization technique and also a mathematical relation between response parameters and input process variables has been developed. The optimized process parameters obtained from machining through RSM were V_c is 2454.95 rpm, f is 437.05 mm/min and d is 0.20 mm, corresponding R_a and T_w were 0.55 µm, 143.84 µm respectively.

Keywords— Incoloy 800, Titanium Coated Cryogenic Treated Tungsten Carbide Insert, RSM, Multi Response Optimization, Milling.

I. INTRODUCTION

Surface roughness is a fundamental proportion of the mechanical nature of an item and a parameter that essentially impacts manufacturing cost. Surface roughness (R_a), cutting force (F_c), and Tool wear (T_w) are commonly used to assess machinability. An imperative piece of machining process is wearing up of tool [1, 2]. Surface roughness is a generally experienced issue in machined surfaces that has pulled in the consideration of scientists for better surface quality [3]. It is characterized as the inconsistencies of surface irregularities, which is the result of inalienable activity of the production process. Along these, surface roughness significantly affects item quality [4].
The main component of the milling process is cutting tool and tool breakage is a foremost source of unscheduled work stoppage in industrial sites using milling. Accumulation of tool damage over time commonly results in tool breakage, and has undesirable time loss and capital effects [5]. The three key elements in any elementary machining process are V_c, d and f. The output cutting parameters in machining operation are the function of input cutting process parameters [6-7].
The correlation between one or more output variables and a set of input variables can be studied by employing response surface methodology. These approaches are often used after recognizing the manageable variables and the aim of this technique is to found the factor setting that optimizes the response parameter values. There is no fixed factorial or fractional design in the Box-Behnken design (BBD) [8-9]. The design points in Box-Behnken design are less than central composite designs, thus they have less number of trials with the same number of factors and thus less expensive.

II. LITERATURE REVIEW

In anticipating the performance of any machining process the surface roughness and tool wear are paramount factors. It is important to comprehend the current trend in this area for making and optimizing the tool wear (T_w) and surface roughness (R_a) model.
Palanisamy and Selvaraj [10] This examination aimed to find the optimal responses for machining of Incoloy 800H. The experiments were conducted in CNC turning centre for the designed parameters (L_{27}OA) in dry environment. The selected machining parameters were Vc, f & d. Ra and MRR were the output responses. To attain quality of the turned components, Ra was minimized and MRR was maximized via Taguchi method. The combined effects of input variables over the responses were investigated using OA in addition to ANOVA.
Ansari [11] The developed work was concentrated to the MQL on the surface roughness for the period of the turning of incoloy 800. Experiments were considered using OA. Later tuguchi methodology was used for optimization of cutting parameters for better Ra and results were evaluated by using analysis of variance (ANOVA).
Reddy et al. [12] studied, an efficient optimization methodology using RSM and GA is introduced in minimizing surface roughness of P20 mould steel in CNC end milling process. To achieve the minimum surface roughness, the appropriate process parameters were determined
Kıvak [13] applied the Taguchi method and regression analysis evaluate the machinability of Hadfield steel with PVD TiAlN and CVD TiCN/Al_2O_3 coated carbide inserts under dry milling conditions. Analysis of variance (ANOVA) was used to determine the effects of the machining parameters on surface roughness and flank wear.
Moshat et al. [14] optimized CNC end milling process parameters to provide good surface finish as well as high material removal rate (MRR). The surface finish and material removal rate have been identified as quality attributes and were

assumed to be directly related to productivity. Individual response correlations have been eliminated first by means of Principal Component Analysis (PCA).
Tsao [15] Investigated the Optimal milling parameters using the parameter design proposed by the Taguchi method. Experimental results indicated that the optimal process parameters in milling A6061P-T651 aluminum alloy was determined effectively; the flank wear was decreased from 0.177 mm to 0.067 mm

III. EXPERIMENTAL METHODOLOGY

The intention of the present work is to optimize the T_w and R_a value for Incoloy 800 steel using RSM. During the experimentation work, Incoloy 800 workpiece {Fe –(min 39.5%) , C – (0.10%), Ni - (35%), Cr- (19-23%), Al –(0.15-0.60%) and Ti – (0.60)} having dimensions (length 50 mm, height 50 mm and width 50 mm) was machined on HURCO vertical CNC milling machine (NITTTR, Chd) with spindle motor power 11 kW using face milling cutter of 20 mm diameter.
The present work were considered three levels of design of experiment. RSM based BBD Technique was used to improve the design of experiments by Design expert software. Three input variables of cutting speed 2000, 2250 and 2500 m/min were selected with feed rate 350, 425 and 500 mm/min and depth of cut of 0.2, 0.4 and 0.6 mm. Commercially available TPKN2204PDR coated tungsten carbide inserts of given tool geometry (Shape – Rhombic, Included angle = 50˚, Cutting edge = 2) were used to conduct the research work.
Measurement of R_a was done by using Mitutoyo SJ 301 surface roughness tester and measurement of tool wear was done by Sipkon measurement system. SURFTEST instrument is a portable, self-reliant instrument for the dimension of the surface profile. Evaluation of parameters is based on a processor. The surface roughness was measured thrice for a component and the average significance was taken to determine the R_a value of the specimen. RSM (BBD) technique was used for optimization of process responses. The measured response parameters values were incorporated into the model generated by RSM.

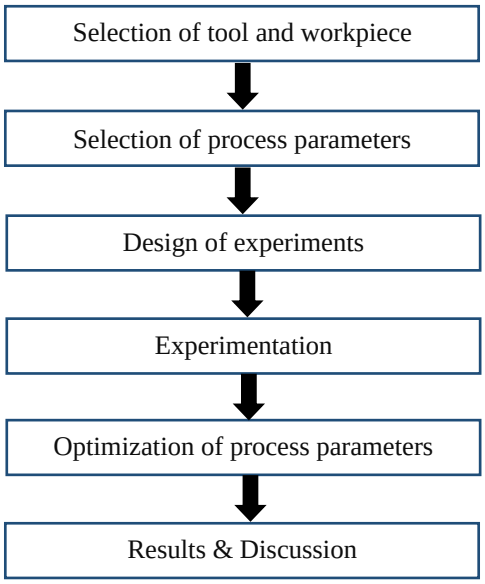


Figure 1: Methodology

The framework of methodology adopted for the present work is shown in Figure 1. ANOVA was employed to study the performance characteristics of milling operation.

IV. RESULTS AND DISCUSSION

The experiments were performed with variation in different process parameters using design of experiment approach and results were evaluated using response surface methodology. 27 experiments were designed by RSM based BBD technique. For each input parameter (*i.e.* V_c, f and d) three levels were taken for experimentation and results were calculated as shown in Table 1. After conducting the experiments for CNC milling the surface roughness values of workpiece and flank wear value of tool insert were measured using Mitutoyo surface roughness tester and Sipkon measurement system respectively. Each run of the experiment contains three trial values for better output of the surface finish. For the analysis of optimization of input parameters average of these three trial values has been taken.

Table 1
Experimental design matrix

	Factors			Responses	
Run	**Cutting Speed:A**	**Feed:B**	**Depth of Cut:C**	**Surface Roughness:1**	**Tool Wear:2**
	rpm	**mm/min**	**mm**	**µm**	**µm**
1	2000	425	0.2	0.73	123
2	2250	350	0.6	0.92	175
3	2500	500	0.4	0.86	168
4	2250	500	0.2	0.63	129.5
5	2000	500	0.4	1.8	142
6	2250	500	0.6	1.58	188
7	2250	425	0.4	1.18	161
8	2500	425	0.2	0.55	147
9	2500	350	0.4	1.02	168
10	2250	350	0.2	0.58	132
11	2500	425	0.6	1.57	208
12	2250	425	0.4	1.03	156
13	2250	425	0.4	1.28	159
14	2250	425	0.4	1.26	163
15	2250	425	0.6	1.2	183
16	2000	350	0.4	0.88	132
17	2250	425	0.4	1.25	157

4.1 Optimization of Surface Roughness and Tool Wear

The models were generated from the response parameter values in order to find the obtained models are productive or not. So, F-ratio test and ANOVA analysis has been performed. It was observed that the model generated for all the response parameters were significant.

4.1.1 Analysis of Surface Roughness and Tool Wear

The square root transformation was used for surface roughness model, therefore RSM suggests the desirability of the model is cubic as shown in Table 2. The power transformation was used for tool wear model, therefore RSM suggests the desirability of the model is cubic as shown in Table 3.

Table 2
Model significance of T_w using ANOVA

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	2.3	9	0.2558	42.17	< 0.0001	significant
A	0.04	1	0.04	6.59	0.0371	
B	0.1223	1	0.1223	20.17	0.0028	
C	1.09	1	1.09	179.06	< 0.0001	
AB	0.1456	1	0.1456	24	0.0018	
AC	0.0614	1	0.0614	10.12	0.0154	
BC	0.0252	1	0.0252	4.15	0.0812	

F-value of 42.17 indicates the model is significant. Only a 0.01% probability that F-value this large could occur due to noise

Table 3
Model significance of T_w using ANOVA

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	8268.78	9	918.75	129.44	< 0.0001	significant
A	1490.09	1	1490.09	209.93	< 0.0001	
B	52.53	1	52.53	7.4	0.0297	
C	4215.08	1	4215.08	593.84	< 0.0001	
AB	25	1	25	3.52	0.1027	
AC	55.4	1	55.4	7.8	0.0268	
BC	60.06	1	60.06	8.46	0.0227	

F-value of 129.44 indicates the model is significant. Only a 0.01% probability that F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant.

4.1.2Mathematical Modelling and Regression Analysis

The results obtained by ANOVA model were formulated as a regression analysis equation for R_a and T_w by RSM and given in equation 1 and equation 2 respectively.

ln (surface roughness) = [612.333 – 0.25005 A + 4.358 B – 2593.5925 C - 0.005349 AB – 0.08933 AC + 16.319 BC + 0.000311 A^2 – 0.005387 B^2 – 2126.6666 C^2 – (6.73165E - 06) AB^2 – 0.02441 B^2C + 6.500 BC^2]

……(1)

(Tool Wear) = - 272.218 + 0.1429A + 1.0130 B – 252.598 C – 0.000133 AB + 0.101095 AC + 0.258333 BC – 0.000014 A^2 – 0.000920 B^2 + 50.6722 C^2 **...**…….. (2)

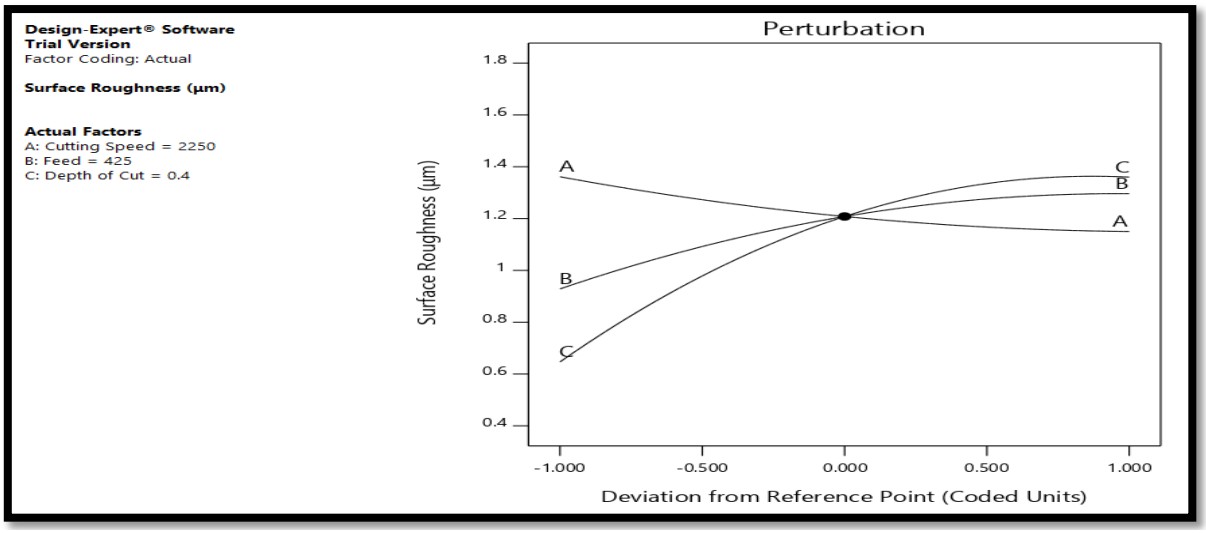


Figure 2: Perturbation plot for R_a

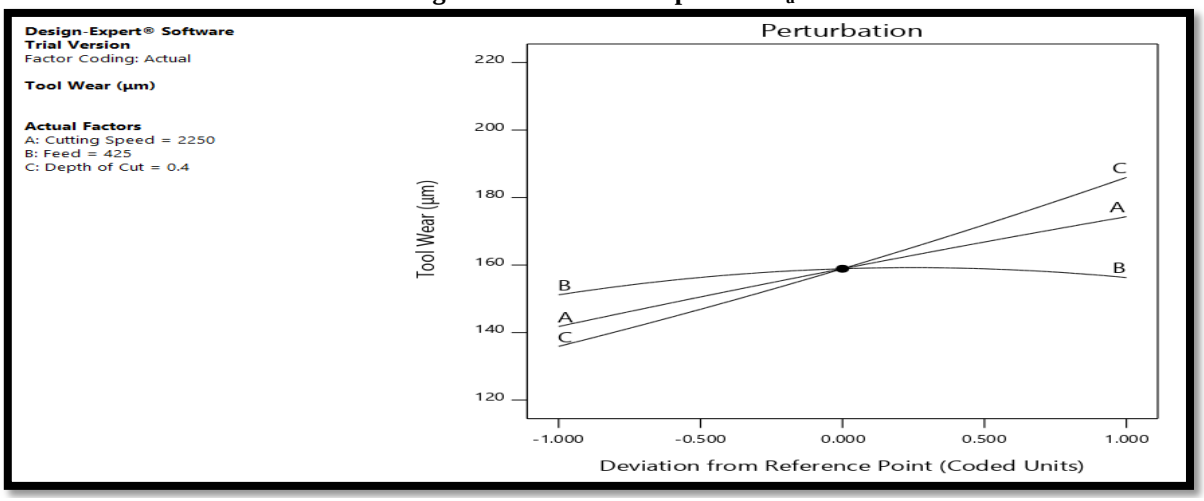
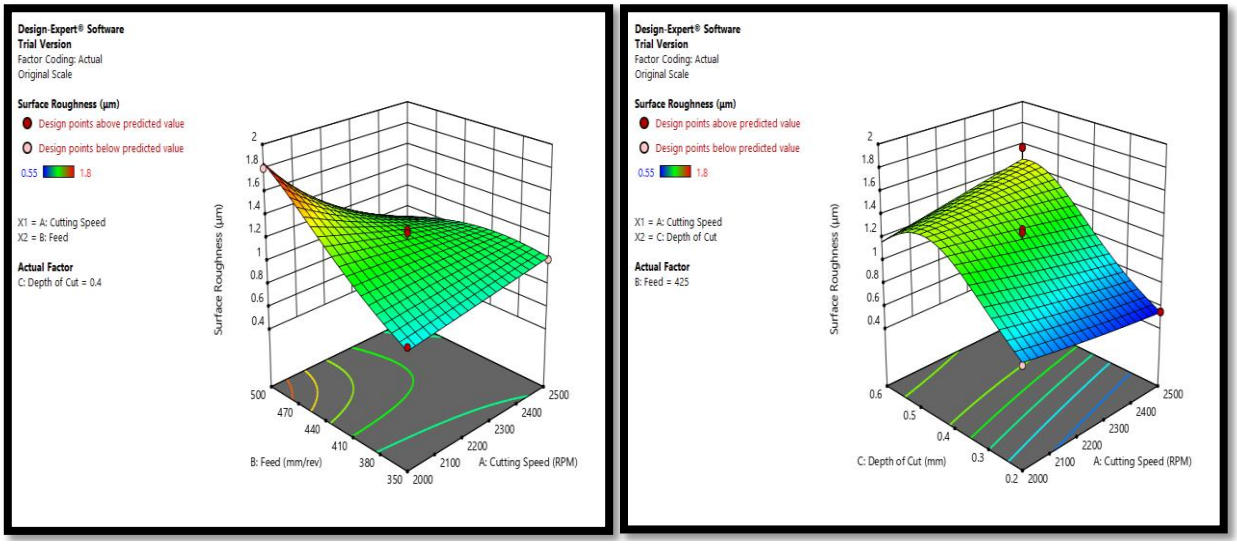


Figure 3: Perturbation plot for T_w

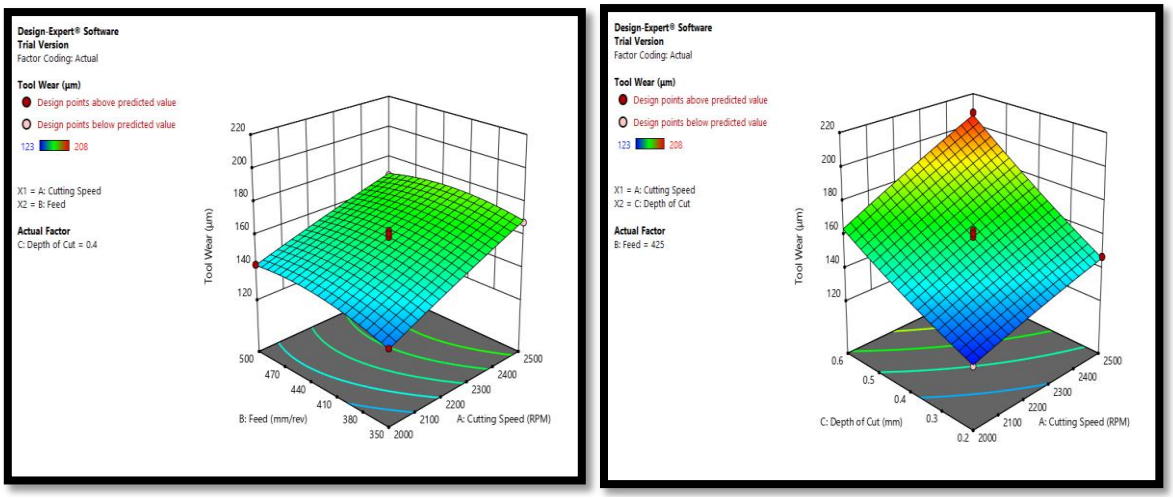
Figure 2 and 3 represents the perturbation curve to determine the effect of input responses on R_a and T_w respectively. It is clearly indicated that the depth of cut is the most influential factor in controlling surface roughness, as the slope is found to be maximum as shown in figure 2. In this case cutting speed is the next influential factor which affects the surface roughness and the feed rate has least effect on surface roughness. It is clearly indicated that the depth of cut is the most influential factor in controlling tool wear, as the slope is found to be maximum. In this case feed rate and cutting speed are the next influential factors which affect the tool wear as shown in figure 3.

3D graphs for the R_a and T_w showing relation with the V_c, f and d.



(a) Interaction between v, f and R_a (b) Interaction between v, d and R_a

Figure 4: 3D interaction plot showing effect between input parameters and surface roughness



(a) Interaction between v, f and T_w (b) Interaction between v, d and T_w

Figure 5: 3D interaction plot showing effect between input parameters and tool wear

Figure 4 (a) shows the minimum surface roughness of 0.88 µm at cutting speed of 2500 rpm and minimum feed rate of 350 mm/min, it increase with decrease in cutting speed and increase in feed rate up to 1.18 µm. In Figure 4 (b) the minimum surface roughness of 0.58 µm at cutting speed of 2250 rpm and maximum depth of cut 0.6 mm, it increases with decrease in value of depth of cut and increase in cutting speed up to 0.97 µm. The combined effect of depth of cut and feed rate indicate that the minimum surface roughness of 0.58 µm at minimum depth of cut of 0.2 mm by keeping the feed rate constant and starts increases with the increase in depth of cut, up to 0.85 µm.

Figure 5 (a) shown below indicates the minimum tool wear of 132 µm at feed rate 350 mm/min and cutting speed 2000 rpm , it starts increasing up to 168 µm at maximum cutting speed of 2500 rpm and maximum feed rate of 500 mm/min. In Figure 5 (b) the minimum tool wear of 123 µm at minimum depth of cut of 0.2 mm and at minimum cutting speed of 2000 rpm, the maximum tool wear of 208 µm at depth of cut of 0.6 mm and maximum cutting speed of 2500 rpm. The combined effect of feed rate and depth of cut indicate the minimum tool wear 132 µm at minimum depth of cut of 0.2 mm and minimum feed rate of 350 mm/min. The tool wear increases up to 188 µm with increases in the both value of depth of cut and feed rate.

4.2 Multi Response Optimization

A combination of factor levels were optimized simultaneously by selecting the required objectives for all response parameter to meet the requirements placed. The numerical multi response optimization criteria was employed to obtain the optimal input process parameter values for achieving minimum R_a and T_w. The importance for all input machining parameters is selected to be the same as shown in Table 4.

Table 4
Selected optimization criteria for RSM

Name	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Cutting Speed (V_c)	2000	2500	1	1	3
Feed (f)	350	500	1	1	3
Depth of Cut (d)	0.2	0.6	1	1	3
Surface Roughness (R_a)	0.555556	1.81818	0.892442	1	5
Tool Wear (T_w)	123	208	1	0.670423	4

Table 5
Optimized process parameters for machining

Cutting Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Surface Roughness (µm)	Tool wear (µm)
2454.95	437.05	0.20	0.55	143.84

The optimal values of R_a and tool wear were 0.55 µm and 143.84 µm respectively at V_c of 2454.95 rpm, feed of 437.05 mm/min, and depth of cut of 0.20 mm as optimum value of input process parameters. The numerical optimization found a point that gives the maximum desirability value as 0.82 which corresponds to the minimum values of R_a and T_w

V. CONCLUSIONS

In the present work, face milling of Incoloy 800 was accomplished with Titanium coated cryogenic treated tungsten carbide inserts to optimize the input process variables viz. V_c, f and d for optimum T_w and R_a. The three level BBD was employed for developing mathematical models for calculating the optimized values of R_a and T_w. The conclusions extracted from the present work are discussed as follows:

a) The optimized process parameters obtained from machining through RSM were cutting speed of 2454.96 rpm, feed rate of 437.05 mm/min and depth of cut of 0.20 mm and the corresponding obtained response parameters are surface roughness and tool wear were 0.55 µm and 143.84 µm respectively.
b) In case of surface roughness, better surface quality was obtained at high cutting speed and low depth of cut. The surface quality was observed to be derationing upon subsequent increase in depth of cut. The interaction plot suggest that the effect of depth of cut was more prominent on surface roughness than the cross ponding feed rate parameter.
c) Feed rate was found to have very less effect whereas depth of cut and cutting speed were found to have considerable impact on tool wear.

REFERENCES

[1] I. Halim *et al.*, "Ergonomic Design of CNC Milling Machine for Safe Working Posture," *4Th Mech. Manuf. Eng. Pts 1 2*, vol. 465–466, 2014, pp. 60–64.

[2] X. W. Xu and S. T. Newman, "Making CNC machine tools more open, interoperable and intelligent - A review of the technologies," *Comput. Ind.*, vol. 57, no. 2, 2006, pp. 141–152

[3] J. Gu, G. Barber, S. Tung, and R.-J. Gu, "Tool life and wear mechanism of uncoated and coated milling inserts," *Wear*, vol. 225–229, 1999, pp. 273–284.

[4] S. Engin and Y. Altintas, "Mechanics and dynamics of general milling cutters. Part II: Inserted cutters," *Int. J. Mach. Tools Manuf.*, vol. 41, no. 15, 2001, pp. 2213–2231.

[5] P. [8] P. J. Ramón-Torregrosa, M. A. Rodríguez-Valverde, A. Amirfazli, and M. A. Cabrerizo-Vílchez, "Factors affecting the measurement of roughness factor of surfaces and its implications for wetting studies," *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 323, no. 1–3, 2008, pp. 83–93.

[6] V. M. Huynh and Y. Fan, "Surface-texture measurement and characterisation with applications to machine-tool monitoring," *Int. J. Adv. Manuf. Technol.*, vol. 7, no. 1, 1992, pp. 2–10.

[7] B. S. Reddy, J. S. Kumar, and K. V. K. Reddy, "Optimization of surface roughness in CNC end milling using response surface methodology and genetic algorithm," vol. 3, no. 8, 2011, pp. 102–109.

[8] G. Campatelli, L. Lorenzini, and A. Scippa, "Optimization of process parameters using a Response Surface Method for minimizing power consumption in the milling of carbon steel," *J. Clean. Prod.*, vol. 66, 2013, pp. 1–8.

[9] P. J. Ramón-Torregrosa, M. A. Rodríguez-Valverde, A. Amirfazli, and M. A. Cabrerizo-Vílchez, "Factors affecting the measurement of roughness factor of surfaces and its implications for wetting studies," *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 323, no. 1–3, 2008, pp. 83–93.

[10] A. Palanisamy and T. Selvaraj, "Optimization of Machining Parameters for Dry Turning of Incoloy 800H Using Taguchi - Based Grey Relational Analysis," *Mater. Today Proc.*, vol. 5, no. 2, 2018, pp. 7708–7715.

[11] Md Imran Ansari, "Study the effect of minimum quantity lubrication on the surface roughness of incoloy 800 during turning operation"2014 .

[12] A. Palanisamy and T. Selvaraj, "Optimization of Turning Parameters for Surface Integrity Properties on Incoloy 800H Superalloy Using Cryogenically Treated Multi-Layer Cvd Coated Tool," *Surf. Rev. Lett.*, vol. 1850139, 2017, pp. 1850139.

[13] T. Kıvak, "Optimization of surface roughness and flank wear using the Taguchi method in milling of Hadfield steel with PVD and CVD coated inserts," vol. 50, 2014, pp. 19–28.

[14] S. Moshat, S. Datta, A. Bandyopadhyay, and P. K. Pal, "Optimization of CNC end milling process parameters using PCA-based Taguchi method," vol. 2, no. 1, 2010, pp. 92–102.

[15] C. C. Tsao, "Grey-Taguchi method to optimize the milling parameters of aluminum alloy," *Int. J. Adv. Manuf. Technol.*, vol. 40, no. 1–2, 2009, pp. 41–48.