Optimization of Face Milling Parameters on Surface Roughness of SAE 1541

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Abstract-The aim of this study is limited to optimise surface roughness of SAE 1541 material.This is done by optimising face milling process parameters like cutting speed,feed,depth of cut and coolant flow rate.The setting of experiment is done by Design of Experiment (DOE) by Taguchi technique, S/N ratio, ANOVA. Finally effects of process parameters on surface roughness (Ra) in face milling studied and optimum solution is carried out. Mathematical model is generated by Regression Analysis and it is validated by confirmation tests. Thus, it is shown that, the Taguchi method is best suitable to solve surface quality problems on SAE 1541.

Keywords- FaceMilling, optimisation, Surface Roughness Taguchi Method,L9 OrthogonalArray,Cuttingspeed,feed,depth of cut,coolant flow rate,ANOVA

I. INTRODUCTION

With more demands of modern engineering products,the control of surface roughness has become more important.In manufacturing industries,manufacturing focuses on productivity and quality of the product.To increase production computer numerical control (CNC) and vertical machining centres (VMC) machining tools are implemented during past decades[1].

Face milling is an operation for producing plane or flat surfaces using face milling cutters. Surface roughness is one of the most important parameter to determine the quality of product. Several factors like cutting speed, feed, depth of cut, type of coolant, coolant pressure, tool geometry, work piece material influence surface roughness[2].

a) Surface roughness and measurement

Surface roughness of a machined product could affect several of the product's functional attributes, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, and resisting fatigue[3]. There are several ways to describe surface rough- ness. One of them is average roughness which is often quoted as Ra symbol. Ra is defined as the arithmetic value of the departure of the profile from the center-line along sampling [4].

There are many methods of measuring surface roughness, such as using specimen blocks by eye or fingertip, microscopes, stylus type instruments, profile tracing instruments, etc. The tools measuring surface roughness withprobes, measure, and control in appropriate length and circumferences.The probe comes in and out holes while traveling on the surface. The probe is made up of diamond nip which very high in cost [5].

II.EXPERIMENTAL DETAILS

In this work,Taguchi method used for Design of experiments (DOE).Analysis of Variance is adapted for performance analysis.Finally,with the use of Regression Analysis,mathematical model for Ra is Generated and it is validated by confirmation test.

a) Design of Experiment

Taguchi and Konishi had developed Taguchi techniques [6]. These techniques have been utilized widely in engineering analysis to optimize the performance characteristics within the combination of design parameters. Taguchi technique is also power tool for the design of high quality systems. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance, and computational cost [7].In this study we have consider 4 factors which affect majorly on quality characteristic such as (A) Cutting Speed , (B) Feed ,(C) Depth of Cut and (D) Coolant Flow Rate. The design of experiment was carried out by Taguchi methodology using Minitab 14 software. In this technique the main objective is to optimize the surface roughness that is influenced by four input process parameters.

b) Taguchi Method

Characteristics of Taguchi Technique are as follows:

a)simple, efficient and systematic method to optimize product/process to improve the performance or reduce the cost.

b)Help arrive at the best parameters for the optimal conditions with the least number of analytical investigations.

c)It is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipments and facilities.

d)Therefore, the Taguchi method has great potential in the area of low cost experimentation. Thus it becomes an attractive and widely accepted tool to engineers and
scientists [8].

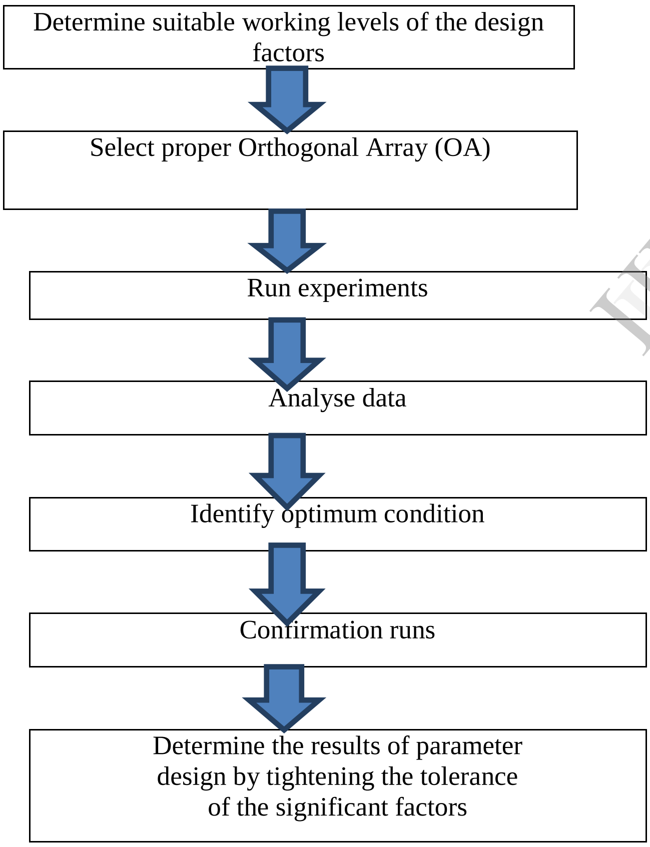

Fig1.Flow chart of Taguchi method

1. Characteristic Nominal is better

S/N = -10 log (ŷ/s2y)…………………(i)

2. Characteristic Smaller is better

S/N = -10 log ((l/n) (Σy2)).............(ii)

3. Characteristic Larger is better

S/N = -10 log ((1/n) (Σ (1/y2)).........(iii)

Where; is the average of data observation, s^2y is the variance of y, n the number of observations and y is the observed data. The characteristic used in this experiment was the S/N ratio smaller is better, where the low surface roughness is desirable [9].

In the Taguchi method, the term ‘signal’ represents the desirable value (mean) for the output characteristic and the term ‘noise’ represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: lower is better (LB), nominal is best (NB), or larger is better (LB).Smaller is better S/N ratio used here because the quality characteristic is Surface Roughness Ra.Smaller-the-better quality characteristic was implemented and introduced in this study.

c) Workpiece Material

In this study,workpiece material is SAE 1541,a type of low alloy steel. It is also called as medium carbon steels is type of Mnalloy[10]. Percentage of each element is given below:

Table 1: Chemical composition of work-piece component

C	Mn	Si	Cr	Al	Cu	HRC
0.399	1.52	0.205	0.103	0.25	0.15	52-59

d) Working Machine

For the experiments,Hyundai WIA F500DI model Vertical Machining Centre (VMC) is used.

Fig 2.Working Machine Hyundai WIA F500DI

High performance HYNDAI WIA f 500D CNC Milling machine (working space, X, Y and Z movements being 600×460×570 mm) variable spindle speeds, optimum 8000 rpm; main spindle power,14.7 kw.having table size 700×500mm was employed to perform experiments.

e) Surface Roughness Tester

Mititoyo surface tester of model SJ-400 was used to measure surface roughness in experimental work.The roughness tester having measuring force 075mN-4mN and Diamond tip 5μm stylus having accuracy ±0.03μm.The probe comes in and out holes while traveling on the surface. The probe is made up of diamond nip which very high in cost

Fig 3.Surface roughness testerMititoyo SJ-400

III.EXPERIMENTAL CONDITIONS

A series of experiments were carried out on Hyundai WIA F500DI (VMC) (Sanjeev Auto). From OVAT analysis four input controlling parameters selected having three levels.

Table 2:Summary details of parameters and their levels

Sr. No	Process Parameters	Level I	Level II	Level III
1	Cutting Speed (RPM)	1200	1400	1600
2	Feed (mm/min)	150	180	210
3	Depth of Cut (mm)	0.2	0.3	0.4
4	Coolant Flow Rate (lit/min)	20	40	60

Table 3: Experimental design matrix of L9 Orthogonal Array by Minitab 14

Exp No	A Speed (RPM)	B Feed (mm/ min)	C Depth Of Cut (mm)	D Coolant Flow Rate (Lit/min)
1	1200	150	0.2	20
2	1200	180	0.3	40
3	1200	210	0.4	60
4	1400	150	0.3	60
5	1400	180	0.4	20
6	1400	210	0.2	40
7	1600	150	0.4	40
8	1600	180	0.2	60
9	1600	210	0.3	20
10	1200	150	0.2	20
11	1200	180	0.3	40
12	1200	210	0.4	60
13	1400	150	0.3	60
14	1400	180	0.4	20
15	1400	210	0.2	40
16	1600	150	0.4	40
17	1600	180	0.2	60
18	1600	210	0.3	20

IV.RESULTS AND ANALYSIS

A table is got after actual experimentation, showing Ra values and S/N ratios for each trials.Table is given below:

Table 4:Summary Report for different trial conducted during Experimentation

Exp No	Speed	Feed	DOC	CF	Ra	S/N Ratio
1	1200	150	0.2	20	0.69	3.223
2	1200	180	0.3	40	1.07	-0.5876
3	1200	210	0.4	60	1.48	-3.4052
4	1400	150	0.3	60	0.75	2.4987
5	1400	180	0.4	20	1.01	-0.0864
6	1400	210	0.2	40	1.14	-1.138
7	1600	150	0.4	40	0.61	4.2934
8	1600	180	0.2	60	0.63	4.0131
9	1600	210	0.3	20	0.88	1.1103
10	1200	150	0.2	20	0.88	1.1103
11	1200	180	0.3	40	1.06	-0.5061

12	1200	210	0.4	60	1.47	-3.3463
13	1400	150	0.3	60	0.84	1.5144
14	1400	180	0.4	20	0.86	1.31
15	1400	210	0.2	40	1.01	-0.0864
16	1600	150	0.4	40	0.59	4.5829
17	1600	180	0.2	60	0.61	4.2934
18	1600	210	0.3	20	0.91	0.8191

a) S/N Ratio Analysis-

Table 5: Response Table for Signal to Noise Ratios - Smaller is better (Ra)

Level	Speed	Feed	DOC	CF
1	-0.6278	2.8180	1.8488	1.1859
2	0.6302	1.3866	0.7980	1.0816
3	3.1830	-1.0192	0.5386	0.9180
Delta	3.8109	3.8372	1.3102	0.2679
Rank	2	1	3	4

Table 6: Response Tables for Means

Level	Speed	Feed	DOC	CF
1	1.1083	0.7267	0.8267	0.8717
2	0.9350	0.8733	0.9183	0.9133
3	0.7050	1.1483	1.0033	0.9633
Delta	0.4033	0.4217	0.1767	0.0917
Rank	2	1	3	4

The level of a factor with the highest S/N ratio was the optimum level for responses measured. From the Table 7 and Figure 4 it is clear that, the optimum value levels for better surface finish (Ra) are at a cutting speed (1600 rpm), feed (150 mm/min),depth of cut (0.2mm) and coolant flow rate (20 lit/min). The response table includes ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values[8]; rank one to the highest Delta value, rank two to the Second highest, and so on[11].

From both ANOVA and response tables it is clear that the most significant factor is feed (B), followed by cutting speed (A), depth of cut (C) and coolant flow rate (D). Figure 4 shows graphically the effect of the four control factors on surface roughness (Ra).

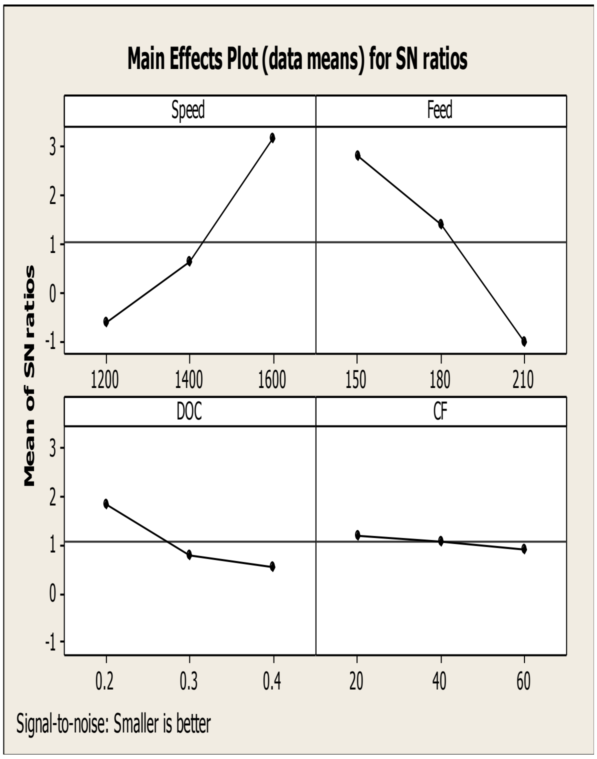

Fig 4. Effects of process parameters on S/N Ratios

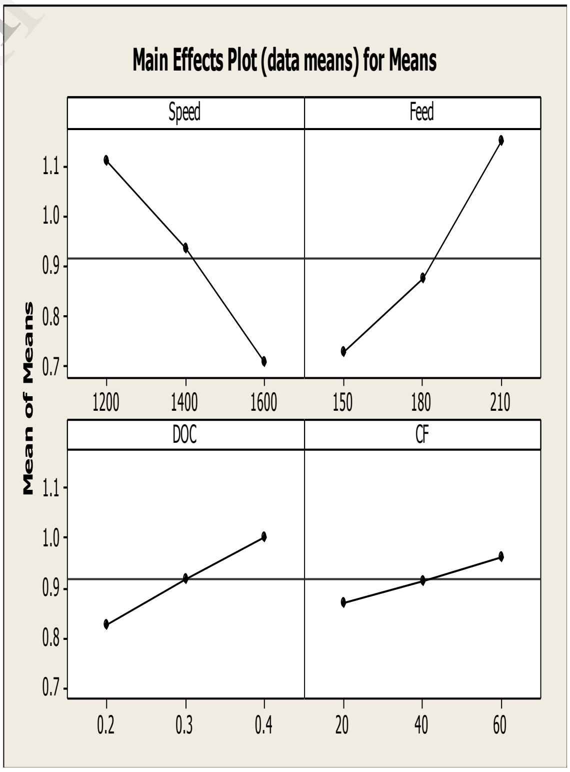

Fig 5.Effects of process parameters on Means

b) Analysis of Variance (ANOVA)

The purpose of ANOVA is to investigate which process parameters significantly affect the quality characteristic. The analysis of the experimental data is carried out using the software MINITAB 14specially used for design of experiment applications. In order to find out statistical Significance of various factors like cutting speed (A), feed (B), depth of cut (C) and coolant flow rate (D) and their interactions on surface roughness (Ra), analysis of variance (ANOVA) is performed on experimental data[10]. Table 8 shows the result of the ANOVA with the surface roughness. The last column of the table indicates p-value for the individual control factors. It is known that smaller the p-value, greater the significance of the factor. The ANOVA table for S/N ratio (Table 7) indicate that, the cutting speed (p=0.000), feed (p= 0.000), depth of cut (p=0.019) and coolant flow rate (p=0.0737) in this order, are significant control factors affecting surface roughness.[11] It means, feed is the most influencing factor and the coolant flow rate has less influence on the performance output compared to cutting speed and depth of cut.

Table 7: Analysis of Variance for S/N Ratio, using adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	44.248	44.248	22.124	45.54	0.000
Feed	2	46.023	46.023	23.011	47.36	0.000
DOC	2	6.136	6.136	3.068	6.31	0.019
CF	2	0.307	0.307	0.153	0.32	0.737
Error	9	4.373	4.373	0.486		
Total	17	101.087				

S = 0.697035   R-Sq = 95.67%

R-Sq(adj) = 91.83%

Table 8:Analysis of Variance for Ra, using Sequential SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	0.49124	0.49124	0.24562	51.71	0.000
Feed	2	0.54988	0.54988	0.27494	57.88	0.000
DOC	2	0.09368	0.09368	0.04684	9.86	0.005
CF	2	0.02528	0.02528	0.01264	2.66	0.124
Error	9	0.04275	0.04275	0.00475		
Total	17	1.20283				

S = 0.0689202   R-Sq = 96.45%

R-Sq(adj) = 93.29

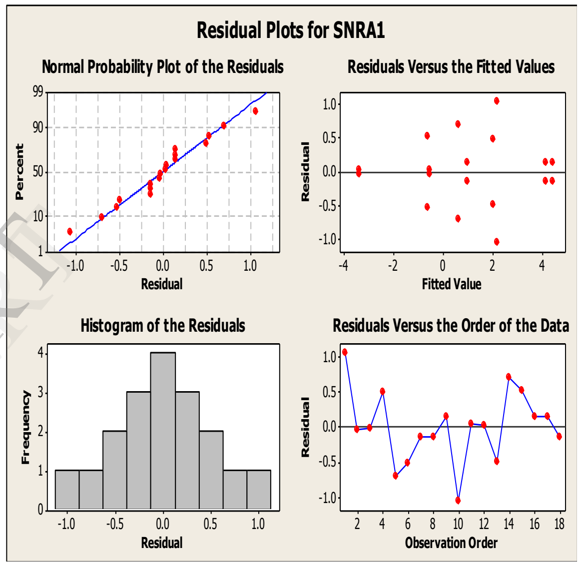

Fig 6.Residual plots for S/N ratio of Ra

4.3 Regression Analysis

Mathematical models for process parameters such as cutting speed, feed, depth of cut and coolant flow rate were obtained from regression analysis using MINITAB 14 statistical software to predict surface Roughness

4.4 Taguchi predicted values

From graphs,obtained after resultsit is clear that at high S/N ratio low Ra value can be obtained.After selecting cutting speed at 1600 rpm,feed at 150 mm/min, depth of cut at 0.2 mm and coolant flow rate at 20 lit/min,predicted value by Taguchi as follows:

Table 9: Predicted values by Taguchi method

S/N Ratio	Mean	StDev	Log(StDev)
5.85034	0.38166	0.1013	-2.16048

4.5 Confirmation Test

At cutting speed at 1600 rpm, feed at 150 mm/min, DOC at 0.2 mm and coolant flow rate at 20 lit/min trials were taken for confirmation.By this validation of mathematical model for Ra value made by Regression Analysis is validated.In this Experimental results in Table 4 and predicted values were compared and it is observed that % Error is varying in between 0.95% to 4.77%.Hence it is concluded that model is valid.

Table 10: Confirmation Tests for predicted values by Taguchi method

Sr No	Predicted Ra mean Value	Trials		Ra mean value	% Error
		1	2		
1	0.3816	0.386	0.392	0.389	2.01%

The results are shown in above table and it is observed that the average Ra i.e. 0.3894 μm and average S/N Ratio 5.8398 which falls within predicted 80% Confidence Interval.

V.CONCLUSIONS

Certain conclusions are drawn out from the study are as follows:

1) It is observed that,cutting speed,feed and depth of cut has significant effecton surface roughness.
2) Coolant flow rate is the least significant parameter on surface roughness.
3) Feed is the most significant parameter on surface roughness.
4) The result of present investigation is valid within specified range of process parameters.
5) Also the prediction made by Regression Analysis is in good agreement with Confirmation results.

6) For better surface finish i.e low roughness value (Ra), higher cutting speed, lower feed rate, lower depth of cut and low coolant flow rate is essential for work piece of SAE 1541.
7) The optimal levels of face milling process parameters are found to be:

Table10:optimised levels of parameters for face milling operation

Parameter	Value
Cutting Speed (RPM)	1600
Feed (mm/min)	150
Depth of cut (mm)	0.2
Coolant flow rate (lit/min)	20

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