An Application of Taguchi Parameter Design in Predicting and Optimizing the Machining Parameters for Face Milling Operation

Krushnaraj Bodana and Bimal Kumar Mawandiya

***Abstract*—The quality of surface finish is always an application based and higher the surface finish higher is the manufacturing cost. The face milling operation is widely acceptable machining process for machining the large and flat surfaces with lower machining time. This research paper demonstrates the application of Taguchi parameter design in selecting the significant parameters for the study of face milling operation of an automobile chassis component and subsequently the optimization of the same parameters for achieving the required surface finish and cycle time in a CNC face milling operation. The Taguchi's parameter design approach is an efficient trial strategy by which different parameters affecting the process are analyzed. In this study L9 orthogonal array was selected and experiments were carried out to optimize the machining parameters based on the signal to noise ratio. Tests were conducted after implementing the optimized values of significant parameters for the validation purpose and subsequently the process capability is also calculated for verifying the statistical stability of the process.**

***Index Terms*— Cycle time, Surface finish, Taguchi parameter design**

I. INTRODUCTION

A. Background

Face milling operation is one of the basic process of material removal and the milled surfaces of the components are widely used when there is a requirement of mating between two surfaces. While mating the two surfaces, the surfaces roughness of the components plays a major role in deciding the quality of the product. [1] In this research face milling operation is carried out on chassis component of an automobile where the required (targeted) surface finish and the machining time were not attainable which resulted in the deterioration of the product quality and the production time loss. Therefore, the machine operator normally uses "Trial and Error" approach for selecting machining parameters. Hence, in this research Taguchi design method was adopted for providing the robust solution.

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B. Literature Review of Taguchi Design

Taguchi design method was developed by Dr. Genichi Taguchi and it is a set of methodologies through which the characteristic variability of the manufacturing processes can be taken into consideration during the design stage itself [2]. The uniqueness of Taguchi design methodology is that it can check the process for multiple number of factors at once. Additionally it also considers the influence of the noise factors apart from the controlled factors. Julie Z. Zhang et al. [3] have studied the turning operation for optimizing the surface roughness in an end milling operation using Taguchi design and concluded that Taguchi design is efficient methodology for the optimization of machining parameters. Sujan Debnath et al. [4] have carried out experiments on mild steel using a TiCN + Al2O3 + TiN coated carbide tool insert in the CNC turning process. By using the Taguchi design methodology they have measured the effect of various cutting fluids and the cutting parameters on the quality of surface finish and concluded that the cutting speed, depth of cut and the flow rate of the cutting fluid are the significant factors which are influencing the surface roughness. M. Nalbant et al. [5] have shown that the effect of insert radius and the feed rate as controlled parameters which are influencing the surface roughness in turning process of AISI 1030 carbon steel by using Taguchi design. J.A. Ghani et al. [6] have experimented on harden steel to optimize the end milling parameters and also analysed the effect of the interaction of the parameters using Taguchi design. W.H. Yang and Y.S. Tarng have used Taguchi method for optimizing the cutting parameters in turning of S45C steel with tungsten carbide tool and along with the used of ANOVA for identifying the significant factors which affects the operation [7]. Tsann-Rong Lin has carried out the experimental design for optimizing the cutting parameters of face milling operation with TiN coated tools [8]. Eyup Bagci and Şeref Aykut have identified the optimum surface finish in CNC face milling operation of cobalt based alloy by optimising the milling parameters such as feed rate, cutting speed and depth of cut [9].

II. METHODOLOGY

The Taguchi method widely used because it can be performed using lower number of experiments with the advantage of getting an overview of how the parameters are influencing the performance of the process. [2]

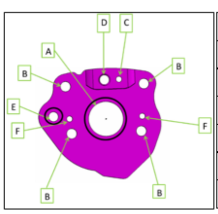
Following steps are carried out for applying the Taguchi parameter design approach:

- Determine the quality parameters to be optimized.
- Select the significant controlled parameters and their different levels for the study.
- Select suitable orthogonal array.
- Conduct the required number of experiments.
- Analyze the result obtained from the experiment and determine the optimized level of controlled parameters.
- Predict the performance of optimized parameters
- Conduct a confirmation run to get the actual output

The main purpose of this research paper is to apply Taguchi parameter design for predicting the major factors which affecting the face milling operation and to optimize the same for surface roughness and machining time.

III. The Machining Process

Machining process considered in this study is a stage of the assembly line of a particular component. Therefore, prime objective was to attain the required machining time for maintaining the single piece flow pattern in the entire assembly line while achieving the targeted surface finish. Fig. 1 shows the geometry of the component which is to be machined where the face milling operation is one of the required operation.



S.NO.	REFERENCE	DESCRIPTION	NOMINAL
1	A	Diameter	Ø36
2	B	Diameter	M10
3	C	Diameter	M6
4	D	Diameter	Ø10
5	E	Diameter	Ø10
6	F	Diameter	M6

Fig. 1. Geometric details of part to be machined

The required data such as machining parameters, machining time and the operation sequence are collected as shown in Table I to understand the existing condition. From Table I, it is evident that the face milling operation is taking relatively more time. Moreover, Face milling operation gets complete in two stages to attain the required surface finish. Therefore, face milling time need to be reduced to achieve the single piece flow pattern in the assembly line. Hence, this research paper deals with the optimization of face milling parameters.

There are two purposes of face milling operation i) to cut the initial thickness of spindle plates of 10 mm and to maintain the required camber angle configuration after machining on both LH and RH sides as shown in Fig. 2. Here, uniqueness of face milling operation is that its cutting depth varies with the overall length of the component before the machining operation. This overall length is termed as "track width" as indicated in Fig. 2. and ii) to obtained the required surface finish of face of the spindle plate. Fig. 3 shows the spindle plate before and after the machining operation.

TABLE I
MACHING OPERATIONS DETAILS

Sr. No	Machining operation	Machining parameters		Machining time (sec)
		Speed (rpm)	Feed (mm/ min)	
1	Face Milling operation	1000	500-500	52
2	Drilling of dia. ø5 mm (3 No.)	4000	600	12
3	Drilling of dia. ø8.5 mm (4 No.)	3747	675	19
4	Drilling of dia. ø10 mm (2 No.)	3185	478	20
5	Rear Milling operation	2000	50-150-150-150	42
6	Chamfering operation	2700	531	39
7	Tapping of M6	1.5	637	16
8	Tapping of M10	1	1060	19
9	Total tool changing time			24
		Total		243

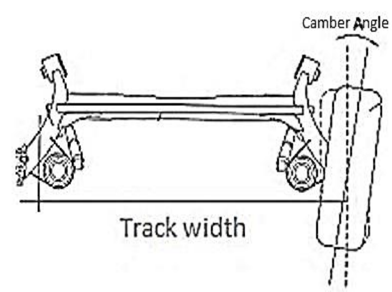


Fig. 2. Required machining configuration for suspension component under study

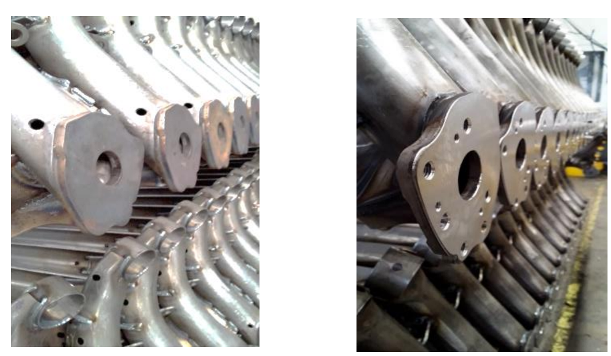


Fig. 3. Before and after machining view of spindle plate

IV THE EXPERIMENT

This section provides details about how the face milling operation was optimized using Taguchi design. Based on the methodology suggested earlier first step was to select the quality parameters which are to be optimized. Therefore, surface roughness and machining time were selected as concern parameters which are to be optimized. Then after observing the face milling operation carefully for finding out the governing parameters which influencing the quality of face milling operation and subsequently analyzing the process, it was found that there are there major parameters: speed, feed and track width which were influencing the process significantly. Therefore, the parameters speed, feed and track width are selected as a controlling factors.

Three different level for each controlling parameters were defined. These levels of each parameters are shown in Table II which are selected in such a manner that it will not affect the overall machining time of the component.

TABLE II
LEVELS OF CONTROLLED PARAMETERS

Feed(mm/min)	Speed(rpm)	Track width(mm)
350	500	1229
550	750	1230.5
750	1000	1231.5

The L9 orthogonal array was selected for the analysis and based on that experiments were performed for different combination of levels of controlled parameters. The required response surface finish and cutting time were measured with the use of digital roughness tester and stop watch, respectively.

- Machine : Bosch make Two way horizontal machining centre
- Material : SS4012A
- Hardness: 125 BHN
- Total area to be machined: 14306.75 mm^2
- Surface roughness measure method: Digital roughness tester shown in Fig. 4

Fig. 4. Digital Surface Roughness Tester

The output (result) of the experiment is shown in Table III.

TABLE III
EXPERIMENTAL RESULTS FOR L9 ARRAY

Feed (mm/min)	Seed (rpm)	Track width (mm)	Ra (µm)	Time (sec)
350	500	1229	0.402	30.41
350	750	1230.5	0.568	30.2
350	1000	1231.5	0.629	30.36
550	500	1230.5	0.384	22.62
550	750	1231.5	0.398	22.61
550	1000	1229	0.327	22.62
750	500	1231.5	1.126	18.56
750	750	1229	0.986	18.58
750	1000	1231.5	0.742	18.56

The statistical software MINITAB was used for the calculation of S/N ratio and to observe how the response is varying with the change in the machining parameters. This relation is shown in Fig. 5. Finally, the optimum values of these parameters were selected based on the relation of signal to noise ratio which is shown in Table IV and the final value of the response was predicted.

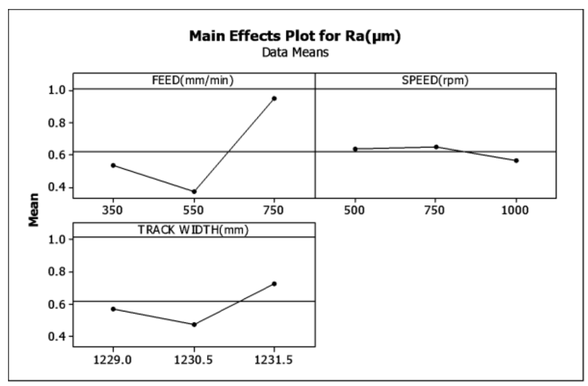


Fig. 5. Effects of main factors on response

TABLE IV
RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

Response Table for Signal to Noise Ratios			
Smaller is better			
Level	FEED	SPEED	TRACK WIDTH
1	5.6185	5.066	5.9157
2	8.6749	4.3459	5.2728
3	0.5612	5.4427	3.6662
Delta	8.1137	1.0967	2.2495
Rank	1	3	2

Based on the recommendation, the parameters were implemented and the actual response was measured and it was found that the actual value (0.332 µm) and the predicted value (0.297 µm) of response were almost equal and it is well within the limit (0.40 µm). Therefore, the milling parameters; feed- 550 mm/min, speed - 1000 rpm and the trackwidth-1229.0 were selected for the final process.

Confirmation runs were conducted based on the suggested parameters and the results were satisfied as the output of the confirmation runs provides the value of process capability index C_{pk} around 1.04 (shown in Fig. 6) which is satisfactory value.

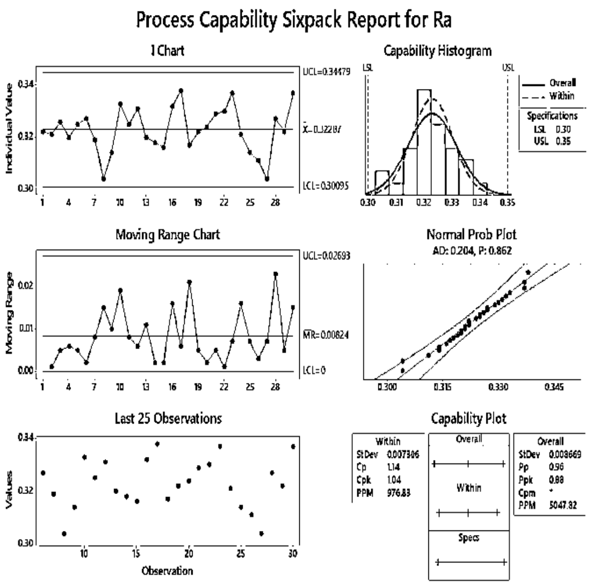


Fig. 6. Confirmation Runs

After these modification, cycle time was measured and the improvement in the cycle time is shown in Table V.

V. CONCLUSION

In this experimental study, the face milling operation was optimized by varying machining parameters using Taguchi design concept. Feed, speed and track width of the face milling operation were the significant controlling factors which affects the quality of surface finish operation and the machining time. After implementation of the optimized value of controlling parameters as obtained by Taguchi design, the machining time of face milling operation is reduced from 52 seconds to 22 seconds without compromising the quality of surface finish. It is also observed that the Taguchi parameter design method is easy to understand and also easy to implement for optimizing the controlled factors.

TABLE V
MACHINING OPERATION DETAILS AFTER MODIFICATION

Sr. No	Machining operation	Optimized Machining parameters		New machining time (sec)
		Speed (rpm)	Feed (mm/ min)	
1	Face Milling operation	1000	550	22
2	Drilling of dia. ø5 mm (3 No.)	4000	600	12
3	Drilling of dia. ø8.5 mm (4 No.)	3747	675	19
4	Drilling of dia. ø10 mm (2 No.)	3185	478	19
5	Rear Milling operation	2000	50-150	23
6	Chamfering operation	2700	531	0
7	Tapping of M6	1.5	637	16
8	Tapping of M10	1	1060	19
9	Total tool changing time			12
		Total		142

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