Vol.3, No.3

ISSN:2349-0012

INNOVATIVE RESEARCH ORGANISATION

International Journal of Advance Research in Education, Technology & Management

(Scholarly Peer Review Publishing System)

Optimization of Machining Parameters for Face Milling Operation in a vertical CNC Milling Machine

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ABSTRACT

The Taguchi method is a powerful problem solving technique for improving process performance, yield and productivity. Face milling in a CNC milling machine involves many parameter affecting the MRR. An analysis of significant process parameters of face milling process using CNC milling machine is made in this paper. The parameters considered are cutting speed, feed and depth of cut and the response considered is MRR.

Using Taguchi analysis, the effect of various process parameters at different levels on face milling is analyzed and optimal settings of the various parameters have been accomplished. The outcome of this paper is the optimized process parameters of the face milling process in CNC machine which leads to improved process performance, reduced process variability and thus maximizing MRR.

n this paper, we describe the formatting guidelines for IJARETM Journal Submission.

General Terms

Taguchi method – statistical Process control. DOE-Design of Experiments.

Keywords

Face Milling – MRR-Material Removal Rate – Taguchi method – statistical Process control.

1. INTRODUCTION

1.1 Taguchi Method

The quality engineering method that Taguchi proposed is commonly known as Taguchi method. This is form of DOE with special application principles. The work of practioner is made simple by providing a clear understanding of the variation nature and economic consequences of quality engineering in the world of manufacturing. The philosophy of Taguchi is broadly applicable and has three stages in process development [1].

1. System Design

2. Parameter Design

3. Tolerance Design.

Taguchi recommends that statistical experimental design methods can be employed to assist in quality improvements particularly during parameter and tolerance design. DOE and Taguchi methods have wide applications in analyzing manufacturing and production processes. Face milling using CNC milling machine is a very common production process to manufacture many industrial parts. The parameters/variables that affect the process are many and these directly affect the machining time involved.

A fish bone diagram showing the process variables is shown in Figure 1.

This paper summarizes the following:

i Maximizing the MRR through process control, keeping the effects of uncontrolled parameters at a minimum level

ii. Analyze and select the most significant parameters that affect quality characteristics.

iii. Select an appropriate OA (orthogonal array) and suitable levels of parameters. Collect the related experimental data.

iv. Analyze the data using DOE software and generate ANOVA table, interaction graphs and response graphs.

v. Decide on the optimal settings for the control parameters

vi. Validate the optimum setting levels in reducing the level of the Quality Characteristic (MRR)

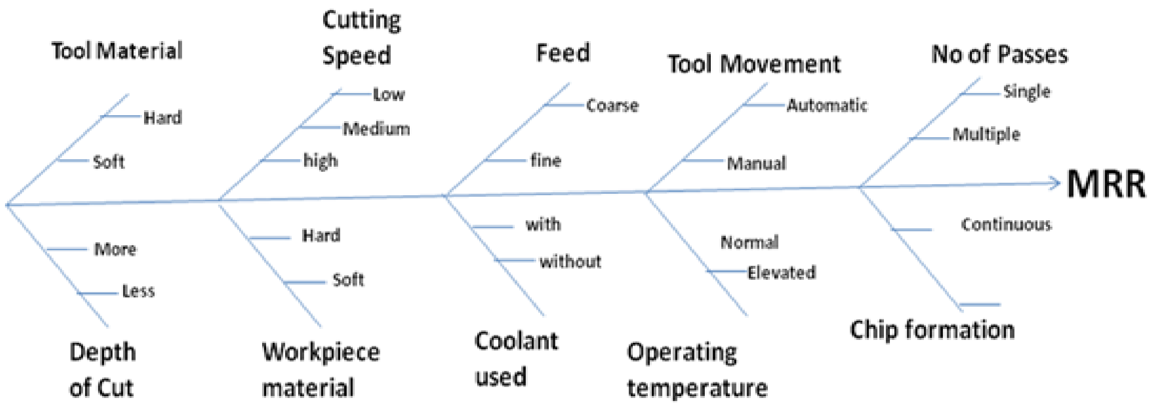

Figure 1. **Fish Bone Diagram**

1.2 Process Parameters of Face Milling Process in CNC Machines

The following process parameters are identified as significant and their levels are listed in table 1: (Based on the industry practice for CNC Face milling)

Table No. 1 Factors and Levels

Process Parameters / Levels	**Cutting Speed (rev/min.)**	**Feed rate(mm/min.)**	**Depth of cut (mm)**
Level 1	1000	50	0.5
Level 2	2500	150	2

2. EXPERIMENTAL PLANNING

The machining process is carried out in CNC machine – Fanuc series 21-M which uses Emco Win NC software.

2.1 Taguchi

The first step in Taguchi method is to select an appropriate OA (orthogonal array). The choice of a suitable OA design is critical for the success of the experimental design and this depends on the total degrees of freedom required to study the main and interaction effects, resource availability and time constraints[6]. Amongst the standard OAs, L_4 , L_8 , L_{16} L_{16} , L_{32} etc., L_8 was found most appropriate to study 3 factors at two levels as this OA covers both main effects of factors, two factors interaction and three factors interaction as well. The OA selected, process parameters and interactions assigned are given in table2.

TABLE No. 2 L_8 ARRAY

Exp./trial No..	**A**	**B**	**AXB**	**C**	**AXC**	**BXC**	**AxBXC**
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

3. TAGUCHI OPTIMISATION

3.1 Experimental procedure

The experiments are conducted against the trial conditions tabulated in table 2, with TWO replicates. The material removed during the machining process was estimated and knowing the machining time , the MRR is calculated and recorded in table 3.The quality characteristic is MRR and so “Larger is better” analysis is performed. In addition, to produce statistically more reproducible conditions for multiple run experiments S/N ratio analysis was preferred over standard analysis using average values.

Table No. 3 Experimental trial results and S/N ratios

Exp. /trial No.	**A**	**B**	**A X B**	**C**	**A X C**	**B X C**	**A X B X C**	**Replicate 1 (MRR) g/min**	**Replicate 2 (MRR) g/min**
1	1	1	1	1	1	1	1	1.558	1.261
2	1	1	1	2	2	2	2	8.833	7.76
3	1	2	2	1	1	2	2	3.539	4.63
4	1	2	2	2	2	1	1	24.32	23.27
5	2	1	2	1	2	1	2	1.582	1.59
6	2	1	2	2	1	2	1	8.280	8.18
7	2	2	1	1	2	2	1	3.158	3.68
8	2	2	1	2	1	1	2	23.009	21.18

3.2 Analysis of results

Standard software packages are used to analyze and interpret results. Average effects of factors and interactions are tabulated in Figure 2. The plots for main effects and interactions are shown in Figure 3.

The ANOVA table after pooling until the DOF of the error term is approximately half the total DOF of the experiment is shown in Figure 4 along with PIE chart in Figure 4.

The optimal conditions and performance factors were shown in Figure.5. The optimal conditions of the control factors are as under:

Cutting speed : 1000r.p.m: Feed rate: 150mm/min and Depth of cut: 2mm

4. CONFIRMATION EXPERIMENTS

Two samples were machined keeping the optimized factor levels parameters and an average MRR was taken. The result for the same is as follows:

Sampl e no	Speed (rpm)	Feed (mm/min)	DOC(mm)	MRR (gm/min)
1	1000	150	2	24.8
2	1000	150	2	26.3

This matches with the optimized MRR as per the calculations and software predictions.

5. CONCLUSION

The following are the conclusions

i) Depth of cut and feed rate are the significant factors as evidenced by the percentage contribution and interaction graphs.

ii) The optimum levels of control factors are found as under:

Cutting speed: 1000 rpm

Feed rate :150 mm/min

Depth of cut :2 mm

iii) The predicted optimum MRR level is 23.97 gms/min, reflecting higher yield level using this optimization.

iv) The optimum level of control factors as above are the levels at which the effect of noise factors on the response parameters is less.

Figure 2. Average Effects of factors a

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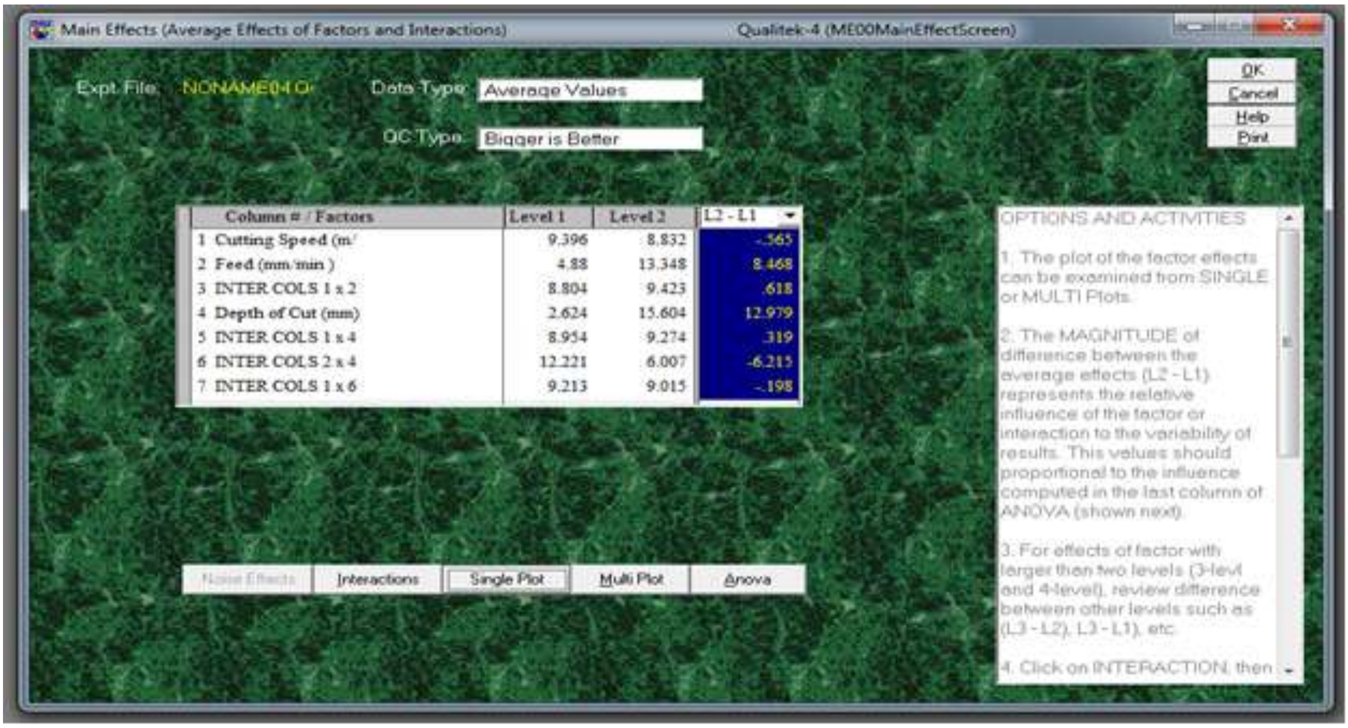


Figure3. Multiple Graphs of main effects.

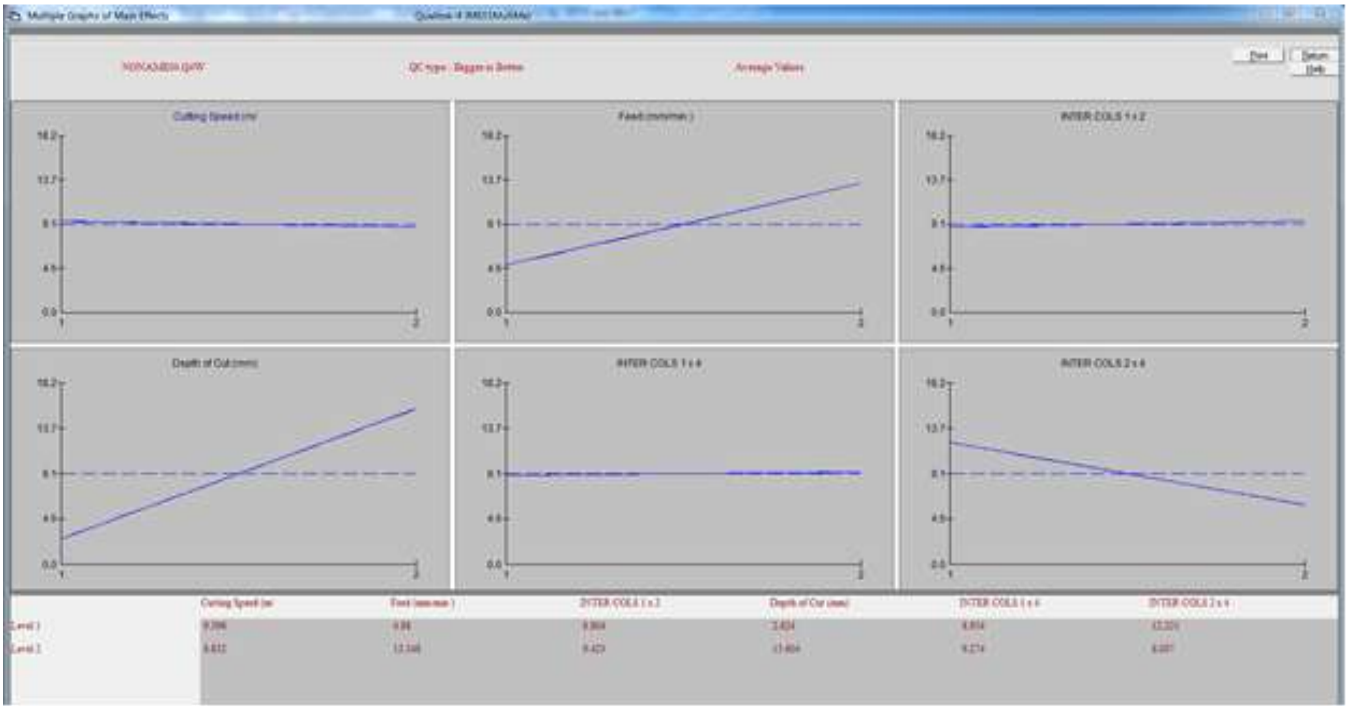
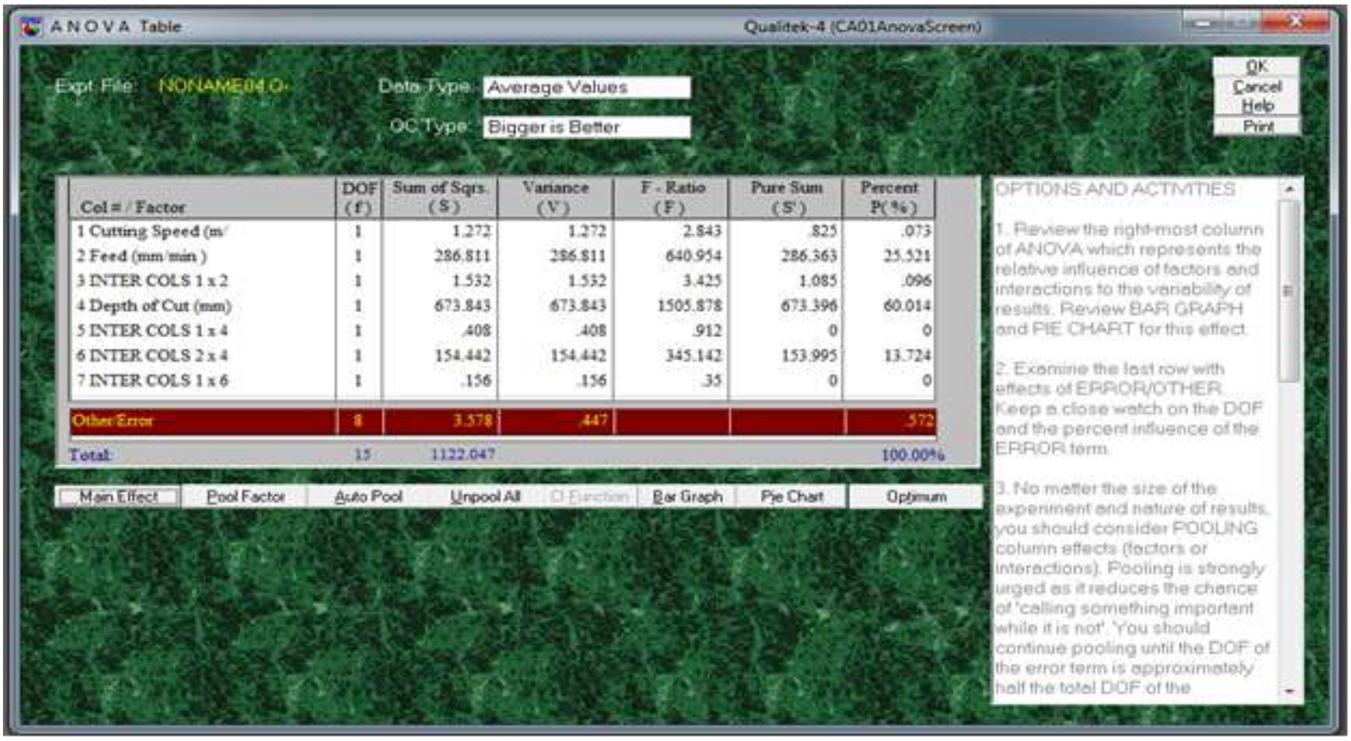
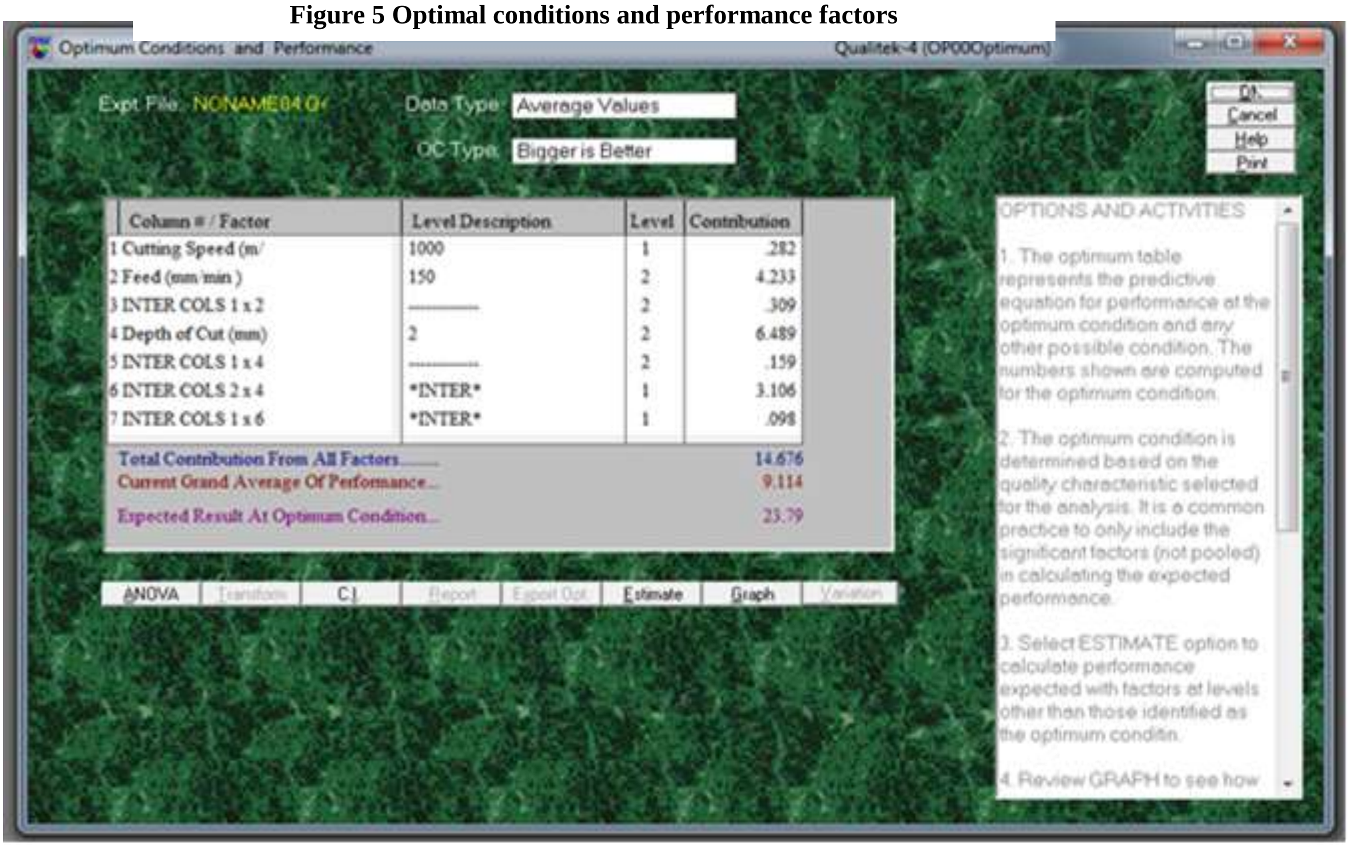


Figure 4 ANOVA Ta



Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 Cutting Speed (m/	1	1.272	1.272	2.843	.825	.073
2 Feed (mm/min)	1	286.811	286.811	640.954	286.363	25.521
3 INTER COLS 1 x 2	1	1.532	1.532	3.425	1.085	.096
4 Depth of Cut (mm)	1	673.843	673.843	1505.878	673.396	60.014
5 INTER COLS 1 x 4	1	.408	.408	.912	0	0
6 INTER COLS 2 x 4	1	154.442	154.442	345.142	153.995	13.724
7 INTER COLS 1 x 6	1	.156	.156	.35	0	0
Other/Error	8	3.578	.447			.572
Total:	15	1122.047				100.00%

Figure 5 Optimal conditions and performance factors



Column # / Factor	Level Description	Level	Contribution
1 Cutting Speed (m/	1000	1	.282
2 Feed (mm/min)	150	2	4.233
3 INTER COLS 1 x 2	------------	2	.309
4 Depth of Cut (mm)	2	2	6.489
5 INTER COLS 1 x 4	------------	2	.159
6 INTER COLS 2 x 4	*INTER*	1	3.106
7 INTER COLS 1 x 6	*INTER*	1	.098
Total Contribution From All Factors....			14.676
Current Grand Average Of Performance...			9.114
Expected Result At Optimum Condition...			23.79

6. ACKNOWLEDGMENTS

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