OPTIMIZATION OF MACHINING PARAMETERS FOR FACE MILLING OPERATION IN A VERTICAL CNC MILLING MACHINE USING GENETIC ALGORITHM

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Abstract - This paper discusses the use of Taguchi technique and Genetic Algorithm (GA) for minimizing the surface roughness in machining mild steel with three zinc coated carbide tools inserted into a face miller of 25 mm diameter. The experimental study was carried out in a FANUC series CNC vertical machining center (VMC). The experiments have been planned using Taguchi's experimental design technique. The machining parameters used are Number of passes (P), Depth of cut (d_c), Spindle speed (N), and Feed rate (f). The effect of machining parameters on surface roughness is evaluated and the optimum cutting condition for minimizing the surface roughness is determined. The predicted values are confirmed by using validation experiments.

Key Words: Taguchi technique, Genetic Algorithm (GA), vertical machining center (VMC), machining parameters

I. INTRODUCTION

With the more precise demands of modern engineering products, the control of surface texture has become more important. It has been investigated that surface texture greatly influences the functioning of the machined parts. Manufacturing involves various processes to turn raw materials to finished products to be used for a variety of purposes. Whatever may be the manufacturing process used, it is not possible to produce perfectly smooth surface. Hence, the improved qualities of product and the economics of the manufacturing operation are very important consideration to produce product having the functional and visual appeal. In this work, the machining parameters such as number of passes (P), depth of cut (d_c), spindle speed (N) and feet rate (f) that affect the surface roughness in the milling operation was studied. Taguchi's orthogonal array is used to plan the experiments and Genetic Algorithm (GA) is used for the process of optimization. The confirmation test was conducted using optimum combination of cutting parameters.

II. LITERATURE SURVEY

[1] A series of experiment have been carried out in Design of Experiments to investigate the influence of cutting parameters such as cutting speed, feed rate and depth of cut on surface roughness in face milling operation. [2] Taguchi parameter design which provides a systematic procedure that can effectively and efficiently identify the optimum surface roughness in the process control of individual end milling machines. [4] A series of experiment have been carried out in Design of Experiments to investigate the influence of cutting conditions such as cutting speed, feed rate per tooth, feed velocity on tool life, tool wear and surface finish in face milling operation. [5] Investigated the machining parameters such as number of passes, depth of cut in each pass, spindle speed and feed rate to get better surface finish, dimensional accuracy and tool wear. [6] Proposed a Genetic Algorithm approach to find the optimal set of machining parameters to get better surface finish, tool life and dimensional tolerance in turning operation. [8] A series of experiment have been carried out in Taguchi's parametric design in which signal to noise ratio and Pareto analysis of variance are employed to analyze the effect of milling parameters such as cutting speed, feed rate and depth of cut on surface roughness. [9] Proposed a Grey-Taguchi parameter method to optimize the milling parameters of Aluminium alloy to get better surface finish.

A. TAGUCHI TECHNIQUE

Taguchi proposes a holistic view on quality, which relates quality to cost, not just to the manufacturer at the time of production, but to the customer and society as a whole. Taguchi defines quality as, "The quality of a product is the (minimum) loss imparted by the product to the society from the time product is shipped" .This economic loss is associated with losses due to rework, waste of resources during manufacture, warranty costs, customer complaints and dissatisfaction, time and money spent by customers on failing products, and eventual loss of market share.

Robust design is an engineering methodology for obtaining product and process conditions, which are minimally sensitive to the various causes of variation to produce high quality products with low manufacturing costs. Taguchi's parameter design is an important tool for robust design. It offers simple and systematic approach to optimize design for performance, quality and cost. Two major tools in robust design are,

- Orthogonal arrays, which accommodate many design factors simultaneously.

- Signal to Noise ratio, which measures quality with emphasis on variation.

Taguchi's approach is totally based on statistical design of experiments, and this can economically satisfy the needs of problem solving and product / process optimization. By applying this technique one can significantly reduce the time required for experimental investigation, as well as to study the influence of individual factors to determine which factor has more influence and which has less.

In this work smaller the better quality characteristic has been chosen, as the performance characteristic is surface roughness,

$$S/N = -10\log \Sigma (\sigma^2 + Ra_m^2) \longrightarrow \text{I}$$

Where,

σ - Standard deviation of surface roughness

Ra_m - Mean value of surface roughness

Equation **I** gives the relation of signal to noise

B. GENETIC ALGORITHM

An algorithm based on mechanics of natural selection and natural genetics, which are more robust and more likely to locate global optimum. It is because of this feature that GA goes through solution space starting from a group of points and not from a single point. The cutting conditions are encoded as genes by binary encoding to apply GA in optimization of machining parameters. A set of genes is combined together to form chromosomes, used to perform the basic mechanisms in GA, such as crossover and mutation. Crossover is the operation to exchange some part of two chromosomes to generate new offspring, which is important when exploring the whole search space rapidly. Mutation is applied after crossover to provide a small randomness to the new chromosomes. To evaluate each individual or chromosome, the encoded cutting conditions are decoded from the chromosomes and are used to predict machining performance measures. Fitness or objective function is a function needed in the optimization process and selection of next generation in genetic algorithm. Optimum results of cutting conditions are obtained by comparison of values of objective functions among all individuals after a number of iterations. Besides weighting factors and constraints, suitable parameters of GA are required to operate efficiently. GA optimization methodology is based on machining performance predictions models developed from a comprehensive system of theoretical analysis, experimental database and numerical methods. The GA parameters along with relevant objective functions and set of machining performance constraints are imposed on GA optimization methodology to provide optimum cutting conditions. The process of optimization is carried out GA tool in MATLAB 7.0.0.19920.

III. EXPERIMENTATION

The experiment was planned based on Taguchi's L_9 orthogonal array and performed in Mild Steel work piece of size (55 mm x 21 mm x 21 mm). The processing of the job was done by three zinc coated carbide tools inserted into a face miller of 25 mm diameter. The machining parameters considered were Number of passes (P), Depth of cut (d_c), Spindle speed (N), and Feed rate (f).

The selected machining parameters are given in the table 1 and the machining parameters assigned into a standard L_9 (3^4) orthogonal array as given in table 2. Figure 1 shows the picture of CNC vertical machining centre.

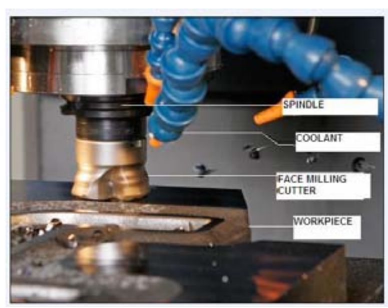
Table 1 Control factors and levels

Factor Notation	Control factors	Factor levels		
		Level 1	Level 2	Level 3
P	Number of passes	1	2	4
dc	Depth of cut (mm)	0.10	0.16	0.20
N	Spindle speed (rpm)	1000	1500	2000
f	Feed rate (mm/min)	300	400	500

Table 2 Machining parameters assigned in a L_9 (3^4) orthogonal array

Expt. no	Number of passes, P	Depth of cut, dc (mm)	Spindle speed, N (rpm)	Feed rate, f (mm/min)
1	1	0.10	1000	300
2	1	0.16	1500	400
3	1	0.20	2000	500
4	2	0.10	1500	500
5	2	0.16	2000	300
6	2	0.20	1000	400
7	4	0.10	2000	400
8	4	0.16	1000	500
9	4	0.20	1500	300

a) Machine



b) Closer view

Figure 1 CNC Vertical Milling Centre

IV. RESULTS AND DISCUSSION

A. Experimental conditions and S/N ratio

The experiments were conducted based on Taguchi's L_9 orthogonal array. The observed values of surface roughness are shown in the table 3.

Table 3 Experimental values and S/N ratio

Exp No.	CONTROL FACTORS				MEASURED PARAMETERS			Standard Deviation, σ	S/N ratio
	Number of passes, P	Depth of cut, d_c (mm)	Spindle speed, N (rpm)	Feed rate, f mm/min	Ra_1 (µm)	Ra_2 (µm)	Mean, Ra_m (µm)		
1	1	0.1	1000	300	2.00	2.28	2.140	0.197990	-6.62682
2	1	0.16	1500	400	1.59	1.76	1.675	0.120208	-4.49147
3	1	0.2	2000	500	1.35	1.55	1.450	0.141421	-3.24797
4	2	0.1	1500	500	1.32	1.24	1.280	0.056569	-2.14844
5	2	0.16	2000	300	1.30	1.26	1.280	0.028284	-2.14526
6	2	0.2	1000	400	1.64	1.84	1.740	0.141421	-4.82531
7	4	0.1	2000	400	1.16	1.10	1.130	0.042426	-1.06463
8	4	0.16	1000	500	1.62	1.71	1.665	0.063640	-4.43146
9	4	0.2	1500	300	1.84	1.45	1.645	0.275772	-4.38392

B. Response of process parameters

The average effects for each level of process parameters are shown in table 4 and table 5.

Table 4 Response based on Surface roughness

Factors / Levels	P	d_c	N	f
1	1.755	1.517	1.848	1.688
2	1.433	1.540	1.533	1.515
3	1.480	1.612	1.287	1.465
Max-Min	0.322	0.095	0.561	0.223
Rank	2	4	1	3

Table 5 Response based on S/N ratio

Factors / Levels	P	d_c	N	f
1	-4.78880	-3.31130	-5.29450	-4.38530
2	-3.09967	-3.68930	-3.67460	-3.49185
3	-3.32470	-4.15240	-2.18400	-3.27590
Max-Min	1.68833	0.84110	3.11050	1.10940
Rank	2	4	1	3

C. Response curve

Response curves are graphical representations of change in performance characteristics with the variation in machining parameter level. Figure 2 shows the response graph for four factors and three levels. From the graphical representation the peak points are chosen as the optimum levels of machining parameters, such as level two of number of pass, level one of depth of cut, level three of spindle speed, level three of feed rate.

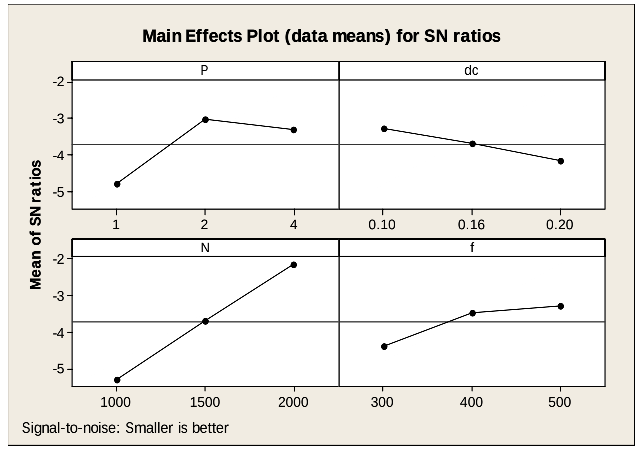


Figure 2 Response graph

a. Optimum machining parameters

From the responses the optimum set of machining parameters were found as given in the table 6.

Table 6 Optimum machining parameters

Number of passes (P)	Depth of cut (d_c), mm	Spindle speed (N), rpm	Feed rate (f), mm/min
2	0.1	2000	500

b. Confirmation experiment

The confirmation experiments have been conducted at optimum levels of machining parameters and the result was found as given in the table 7.

Table 7 Results for Taguchi technique

Experimental values			Predicted value, Ra	Error (%)
Ra_1	Ra_2	Mean, Ra_m		
0.96	0.99	0.975	0.933	4.308

The deviation between the predicted value and the confirmation test is 4.308%.

D. Genetic algorithm conditions and parameter constraints

Population size	-	100
Number of variables	-	4
Initial range	-	[1, 0.1, 1000, 300; 4, 0.2, 2000, 500]
Selection function	-	Roulette
Elite count	-	4
Crossover fraction	-	0.9
Mutation function	-	Uniform
Mutation rate	-	0.1
Migration	-	forward
Total number of iterations	-	500
Level of Display	-	Iterative

a. Graphical result of genetic algorithm

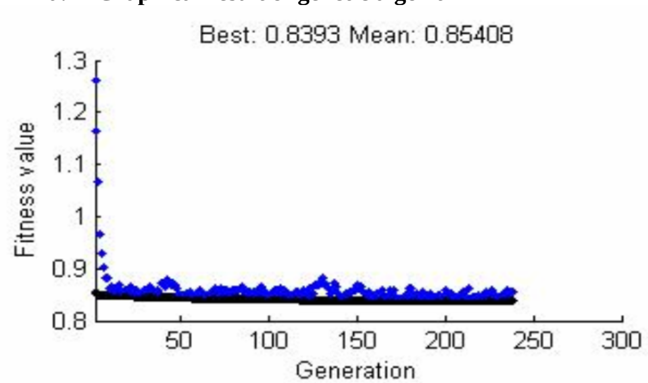


Figure 3 Plot of Generation Vs Fitness value

From the Fig. 3 Plot of Generation Vs Fitness graph best 'Ra' value is found out as 0.8393

b. Optimum machining parameters

From the mathematical computation, the optimum set of machining parameters was found. It is given in table no.8

Table 8 Optimum machining parameters

Number of passes (P)	Depth of cut (d_c), mm	Spindle speed (N), rpm	Feed rate (f), mm/min
3	0.1162	1999	497.7

c. Confirmation experiment for Genetic algorithm

The confirmation experiments have been conducted at optimum levels of machining parameters and the result was found as shown in the table no.9.

Table 9 Results for Genetic Algorithm

Experimental values			Predicted value, Ra	Error (%)
Ra_1	Ra_2	Mean, Ra_m		
0.89	0.87	0.88	0.8393	4.625

The deviation between the predicted value and the confirmation test is 4.625%.

V. CONCLUSION

The influences of number of passes, depth of cut, spindle speed and feed rate on machined surface roughness in face milling operation have been studied. The experiment has been performed on Mild Steel and obtained data has been analyzed using Taguchi technique and Genetic algorithm. It has been observed that, Taguchi's orthogonal array provides a large amount of information in a small amount of experimentation. All the four parameters are predominantly contributing to the response and all have been considered. Optimum machining parameter combination has been found through Taguchi technique and fine tuned with Genetic algorithm. Results of both techniques have been compared and optimum machining parameter combination setup has been suggested for minimum surface roughness. The surface roughness evaluated through Taguchi technique is 0.975 µm with 4.308 % error from the predicted value and for genetic algorithm it is 0.88 µm with 4.625 % error from the predicted value.

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