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OPTIMIZATION OF CNC FACE MILLING PROCESS PARAMETERS USING TAGUCHI METHOD

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ABTRACT: *In any machining operation, quality and productivity are the two most important parameters. It is therefore essential to optimize quality and productivity simultaneously. This project work highlights the optimization of CNC face milling process parameters to provide good surface finish and high material removal rate. The surface finish of the machined surface has been identified as quality attribute where as MRR has been treated as performance index directly related to productivity. Attempt has been made to optimize quality and productivity in a manner that these multi-criterions could be fulfilled simultaneously up to the expected level. This has invited a multi-objective optimization problem which has been solved by Taguchi method. Orthogonal arrays of Taguchi, the signal-to-noise ratio, the analysis of variance (ANOVA) are employed to find the optimal levels and to analyse the effect of milling parameters on surface roughness. Confirmation tests with the optimal levels of cutting parameters are carried out in order to illustrate the effectiveness of Taguchi optimization method.*

Keywords*:* *CNC milling, Taguchi method, S/N ratio, ANOVA*

1. INTRODUCTION

Milling is the process of machining flat, curved, or irregular surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. The milling machine consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the work piece. CNC machine tools provide great improvements in productivity as it increases the quality of the machined products and also it requires less operator time. Milling is a common machining operation and it is widely used in variety of manufacturing industries including automobile manufacturing companies and other high end equipment manufacturing companies. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy with very low processing time [1]. A single setting of process parameters may be optimal for a particular for single quality parameter but the same setting may not be optimal for other quality parameters. So, it is essential to optimize the process parameters simultaneously. So, multi-response optimization, weighted signal-to-noise ratio (WSN), grey relational analysis (GRA), utility concept and technique for order preference by similarity to ideal solution (TOPSIS) method have been utilized and their performance is evaluated [2]. The Taguchi of off-line quality control encompasses all stages of product/process development. However, the key element for achieving high quality and low cost is parameter design. Through parameter design optimal levels of process parameters can be determined. Thus the objective of this work is to obtain optimal settings of machining process parameters – cutting speed, feed, and depth of cut. The design of the experiment via the Taguchi method uses a set of orthogonal arrays for performing of the few experiments. That is, the Taguchi method involves the determination of a large number of experimental situations, described as orthogonal arrays, to reduce errors and enhance the efficiency and reproducibility of the experiments. Orthogonal arrays are a set of tables of numbers, which can be used to efficiently accomplish optimal experimental designs by considering a number of experimental situations **[3].**

An experimental design methodology adopting the Taguchi approach was employed in the optimization of experimental parameters, such as catalyst type, catalyst concentration, oil to alcohol molar ratio and reaction time, for the production of Mahua oil methyl ester, with the orthogonal array design used to screen the effects on the production of mahua oil methyl esters. The diversity of factors was studied by crossing the orthogonal array of the control parameters [4]. Taguchi method: Taguchi's philosophy, developed by Dr. Genichi Taguchi, a Japanese quality management consultant, is an efficient tool available for the design of high quality manufacturing system..The greatest advantage of this method is to save the effort in conducting experiments: to save the experimental time, to reduce the cost, and to find out the significant factors. Orthogonal array (OA) contributes a set of well- balanced experiments and Taguchi's signal –to-noise ratio S/N, which are logarithmic functions of desired output and serve as objective function in the optimization process [5] For a multi-response process, while applying the optimal setting of control factors, it can be observed that an increase and (or) improvement of one response may cause change in another response value, beyond the acceptable tolerance limit. This may cause severe quality loss. Thus for solving a multi-criteria optimization problem, it is convenient to convert all the objectives into an equivalent single objective function. [6]. This equivalent objective function, which is the representative of all the quality characteristics of the products is to be optimized finally.

Analysis of methodology:

In Taguchi optimization technique, the measured features of quality characteristics of the product i.e., Material removal rate and surface roughness are first normalized ranging between zero and one.

The normalized data corresponding to lower –the –better (LB) criterion can be expressed as $x_i(\mathrm{k}) = \frac{\max y_i(k) - y_i\,(k)}{\max y_i(k) - \min y_i(k)}$

Forhigher-the-better (HB) criterion, the normalized data can be expressed as

$$x_i(\mathrm{k}) = \frac{\mathrm{y_i}(k) - \min y_i\,(k)}{\max y_i(k) - \min y_i\,(k)}$$

Calculation of weighted quality characteristic parameter:

Weighted parameter 'y' is found by giving equal weightage to both the parameters.

Y= 0.5*MRR+0.5*S.R

Finding S/N Ratios:

Data sequence for MRR, which is the higher-the-better performance characteristic, is

$$SN(Higher - the - Better) = -10 \log\left(\frac{1}{\mathrm{t}}\sum_{i=1}^{t}\frac{1}{y_{i^2}}\right)$$

Data sequence for SR, which is the lower-the-better performance characteristic, is

$$SN(Lower - the - Better) = -10 \log\left(\frac{1}{t}\sum_{i=1}^{t} y_i\,2\right)$$

Where y is the weighted average, y^2 is variance of y and n is the number of observations.

Calculation of ANOVA:

Analysis of variance is calculated for the data by sum of squares.

2. EXPERIMENTATION

The Mild steel which is low in carbon is used in this study. A carbide cutting tool has been used in this work. Roughness measurement has been done using a portable microprocessor based stylus-type profilometer, Talysurf (Taylor Hobson, Surtronic 3+ UK) shown in Figure 2. It is equipped with a diamond stylus having a tip radius 5 µm. The measuring stroke always starts from the extreme outward position. The profilometer has been set to a cut-off length of 0.8 mm, filter 2CR, and traverse speed 1 mm/sec and 4 mm traverse length. Roughness measurements, in the transverse direction, on the work pieces have been repeated four times and average of four measurements of surface roughness parameter values has been recorded. MRR is calculated as the proportion of the change of weight of the work piece before and after machining to the product of machining period and density of the material.

$$MRR = \frac{Wbm - Wam}{\rho t}$$

Where: W_{bm}= weight of work piece before machining
W_{am}= weight of work piece after machining
t= machining period
ρ = density of mild steel work piece= 7800kg/m^3

Experiments have been carried out using Taguchi's L9 Orthogonal Array (OA) experimental design which consists of 9 combinations of spindle speed (800, 900 and 1000 rpm), feed rate (350,450 and 550 mm/rev) and depth of cut (DOC) (0.2, 0.25 and 0.3mm). According to the design catalogue (Peace G., S., 1993) prepared by Taguchi, L9 Orthogonal Array design of experiment has been found suitable in the present work.

2.1. Experimental setup:

Check the vertical milling machine and make it ready for performing the machining operation and then prepare mild steel work piece of size 50mmx50mmx60mm in shaping machine and performing the CNC face milling operation on CNC vertical milling machine. Calculating the weight of each work piece by the high precision digital balance meter before machining. Creating CNC part programs for tool paths with specific commands using various combinations of process control parameters like spindle speed, feed and depth of cut and performing face milling operation. After machining operationcalculatethe weight of each machined work piece by digital balance meter. Measure the surface roughness value and surface profile of the work pieces with the help of a portable stylus type profilometer, Talysurf.

2.2. Design of Experiments:

Three process control parameters (each varied at three different levels) have been considered as shown in table-1. The parametric interaction has been assumed to be negligible. Experiments have been conducted as per Taguchi's L_9 OA design of experiment.

Table 1: process control parameters and their limits

Process parameter	Level 1	Level 2	Level 3
Speed(rpm)	800	900	1000
Feed(mm/rev)	350	450	550
Depth of cut(mm)	0.2	0.25	0.3

3. RESULTS AND DISCUSSION

From the L9 orthogonal design of experiments the Material removal rate is calculated and is shown in the table 2. The material removal rate and Surface roughness values for the various process parameter combinations are shown in the table 3. The normalized values of the Material removal rate and Surface roughness are shown in the table 4.

Analysis of variance (ANOVA) is performed for the given the set of experimental values to evaluate the effect of process of parameters on the material removal rate and surface roughness. It is clearly shown from the table 6, that speed and depth of cut have significant effect on optimization of selected properties such as material removal rate and surface roughness. Next feed rate has moderate effect on the above properties.

Table 2: Material Removal Rate (MRR)

Work Piece	Initial Weight (W_I) in grams	Final Weight (W_f) in grams	Time taken for machining in sec	Material Removal Rate (MRR) in mm^3/min
1	1156.2	1124	586	422.683
2	1156.2	1125.8	404	5826352
3	1161.3	1126.5	280	956.044
4	1162.7	1129.8	418	605.4472
5	1158.2	1122.3	333	829.2908
6	1156.5	1129.4	379	550.0304
7	1159.6	1128.5	421	568.2441
8	1162.2	1126.1	458	606.3151
9	1039.1	1031.5	296	665.2807

Table 3: MRR & SR values for the various process parameters

Trial	Speed	Feed	Depth of cut	Material removal rate (MRR)	Surface roughness (SR)
1	800	350	0.2	422.6831	3.053
2	800	450	0.25	582.6352	3.016
3	800	550	0.3	956.044	3.0865
4	900	350	0.25	605.4472	2.551
5	900	450	0.3	829.2908	1.6915
6	900	550	0.2	550.0304	1.5095
7	1000	350	0.3	568.2441	1.0155
8	1000	450	0.2	606.3151	1.577
9	1000	550	0.25	665.3151	2.166

Table 4: Normalized MRR and Surface roughness values

Normalized MRR	Normalized SR
0	0.015934
0.299895	0.034042
1	0
0.342665	0.258571
0.76235	0.673588
0.238764	0.761468
0.2772913	1
0.344292	0.728875
0.454847	0.444471

Table 5: Tabulated S/N ratios

Trial	S/N Ratio
1	-41.9739
2	-15.5473
3	-6.0206
4	-10.4397
5	-2.87789
6	-6.01859
7	-3.92463
8	-5.40725
9	-6.94233

Table 6: Analysis of variance (ANOVA)

Source	DOF	Sum of squares	Mean square	F-Ratio	Rank
Speed	2	0.180113	0.900565	2.4112	1
Feed	2	0.053621	0.0268105	0.7178	3
Depth of Cut	2	0.17225	0.086125	2.3060	2
Residual	3	0.004847	0.0016157	0.0432	
Total	11	0.41083	0.0373482		

From the following graphs, it can be observed that the optimum process parameters for getting better material removal rate and surface finish are Speed: 1000 rpm, Feed: 550 mm/rev and Depth of cut: 0.3 mm.

Fig 1. Speed vs S/N ratio

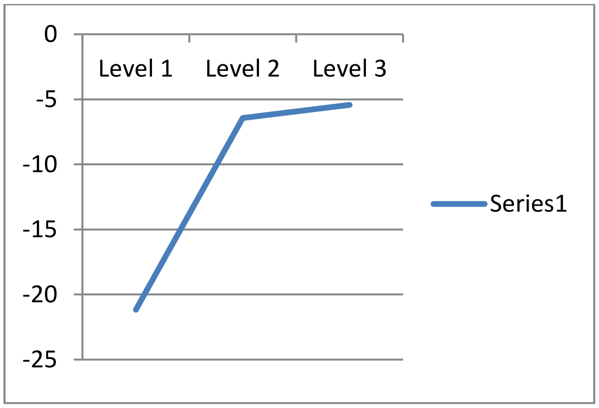


Fig 2. Feed vs S/N ratio

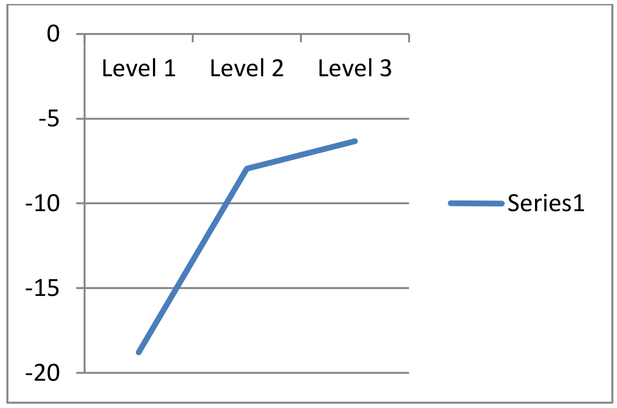
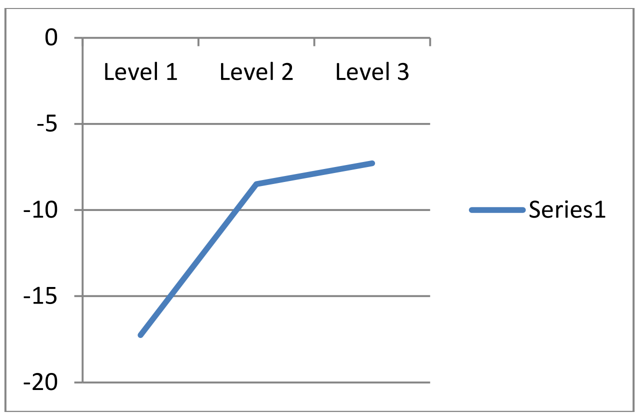


Fig 3. Depth of cut vs S/N ratio



4. CONCLUSION

The objective of this work is to obtain optimal setting of milling process parameters- cutting speed, feed, depth of cut for optimizing machining characteristics. Taguchi approach has been used to accomplish the objective. The experiments were conducted on CNC milling machine according to Taguchi L9 orthogonal array.

It is concluded that speed and depth of cut have significant effect on optimization of selected properties such as material removal rate and surface roughness. Next feed rate has moderate effect on the above properties. From the following graphs, it can be observed that the optimum process parameters for getting better material removal rate and surface finish are Speed: 1000 rpm, Feed: 550 mm/rev and Depth of cut: 0.3 mm.

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