ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 129-135 (2013)
Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

Optimization of Process Parameters for Milling Using Taguchi Methods

Pratyusha J[1], Ashok kumar.U[2], Laxminarayana .P[3]

[1]Department of Mechanical Engineering, University College of Engineering, Osmania University, Hyderabad, India, pratyushaj@gmail.com
[2]Department of Mechanical Engineering, University College of Engineering, Osmania University, Hyderabad, India, uak.oumech@gmail.com
[2]Department of Mechanical Engineering, University College of Engineering, Osmania University, Hyderabad, India, plaxou@yahoo.com

Abstract*:* The Present work deals with the effects of various milling parameters such as spindle speed, feed rate, and depth of cut on the surface roughness of finished components. The experiments were conducted on AISI 304 S.S plate material on vertical milling machine using carbide inserts and by using Taguchi's technique including L9 orthogonal array. The analysis of mean and variance technique is employed to study the significance of each machining parameter on the surface roughness.

Keywords: Carbide inserts, vertical milling machine, L9 Orthogonal Array, Taguchi Method.

INTRODUCTION

Quality and productivity play a major role in today's manufacturing market. From a customer's viewpoint, quality is very important because the extent of quality determines the degree of satisfaction of the customers. Apart from quality, there exists another important criterion called productivity which is directly related to the profits of an industry and also to its growth. Every manufacturing firm aims at producing larger number of units within short time. Productivity can be increased by having sound knowledge of all the optimization techniques for machining**.**

Due to this surface finish & dimensional accuracy becomes very important. The knowledge of cutting forces developing in the various machining processes under given cutting factors is of great importance, being a dominating criterion of material machinability, to both: the designer-manufacturer of machine tools, as well as to user. Milling like any metal cutting operation is used with an objective of optimizing surface roughness at micro level and economic performance at macro level

The experiments have been planned using Taguchi's experimental design technique. The machining parameters used are Depth of cut (dc), 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. A L9 orthogonal array, Taguchi method and analysis of variance (ANOVA) are used to formulate the experimental layout, to analyses the effect of each parameter on the machining characteristics and to predict the optimal Choice for each milling parameter such as spindle speed, feed rate and depth of cut. Analyzed the effect of this parameter surface roughness (SR). Results obtained by Taguchi method match with ANOVA and cutting speed are highly influencing parameter. The analysis of the Taguchi method reveals that, in general the spindle speed significantly affects the SR.

Optimization of cutting parameters is valuable in terms of providing high precision and efficient machining. One of the effects of cutting force in the milling operation with low diameter tool (during metal cutting) is tool deflection. Optimization of cutting parameters is essential for a manufacturing unit to respond effectively to severe competitiveness and increasing demand of quality product in the market. In cutting process, optimization of cutting parameters is considered to be a vital tool for improvement in output quality of a product as well as reducing the overall production time.

LITERATURE

Many machining processes were optimized by the researchers for improving the surface roughness quality of the product G. Akhyar et al. [1] applied Taguchi optimization method to improve the cutting parameters in lathe operation on Ti6Al4V with coated and uncoated cemented carbide tools under dry conditions and high cutting speeds for improved surface finish. L27 orthogonal array including four factors such as Cutting speed, feed rate, depth of cut and tool grades with three levels for each factor was used to identify the optimal combination. ANOVA is used to determine the cutting speed and tool grade to be significant factors affecting the surface finish.

Milon D. Selvam, A.K. Shaik Dawood,.G. Karuppusami had studied the influence of 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 carried out using Taguchi's experimental design technique. The machining parameters used are Number of passes (P), Depth of cut (dc), 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 [1]

Anil Choubey et al., had described about the Productivity and quality are interdependence each other and it's very difficult to balance both factors and find optimum results. MRR and SR also depend on the tool material and work material. In end milling, surface finish and material removal rate are two important aspects, which require attention from industry personnel because MRR and SR highly affect machining performances. In today environment industry want to manufacture low cost, high quality product in short time. CNC machine are suitable for flexible manufacturing system. In this paper, Taguchi L9 orthogonal array is employed to analyze experimental results of machining obtain from 9 experiments for finish machining individually by varying for process parameters {spindle speed(s), feed(f), depth of cut(d), width of cut(w)}. ANOVA has been performed and compared with Taguchi method.
In this investigation A L9 orthogonal array, Taguchi method and analysis of variance (ANOVA) are used to formulate the experimental layout, to analyses the effect of each parameter on the machining characteristics and to predict the optimal choice for each end milling parameter such as spindle speed, feed rate, depth of cut and width of cut, and analyzed the effect of these parameter on the material removal rate (MRR) and surface roughness (SR). Results obtained by Taguchi method match with ANOVA and cutting speed are highly influencing parameter. The analysis of the Taguchi method reveals that, in general the spindle speed significantly affects the SR, while, the feed mainly affects the MRR. Experimental results are provided to verify this approach. [2]
As the CNC machines are highly expensive, there is an economic need for efficient use of machine tools by setting optimum cutting parameters. As the actual milling operation is highly constrained and nonlinear in nature, the traditional optimization techniques are not suitable in such cases. For this reason we have used GA with a Self-Organizing Adaptive Penalty (SOAP) strategy for rapid convergence by focusing the search near the boundary of the feasible and infeasible solution space. In this work, the optimum feed rate and cutting speed for a specific depth of cut of end milling operation are determined by minimizing the machining time. The constraints are: maximum allowable cutting force, machine power, available rotational speed and required surface finish. We adopted a modified GA approach to ensure the optimum solution be always feasible and does not violate any constraint. The result shows that the approach used in this work converges rapidly and differentiate the critical and non-critical constraints to get a better understanding of the optimum condition, work carried by Nafis Ahmad, Tomohisa Tanaka and Yoshio Saito [3].

METHODOLOGY

DEFINITION OF PROBLEM

In this investigation an attempt was made to find out the optimum process parameters of MILLING on AISI 304 plates. Process parameters considered are cutting speed, depth of cut and feed rate. Each process parameter is considered at three levels (with one trial on each specimen). Trails are conducted and the response characteristics are studied, for surface finish.

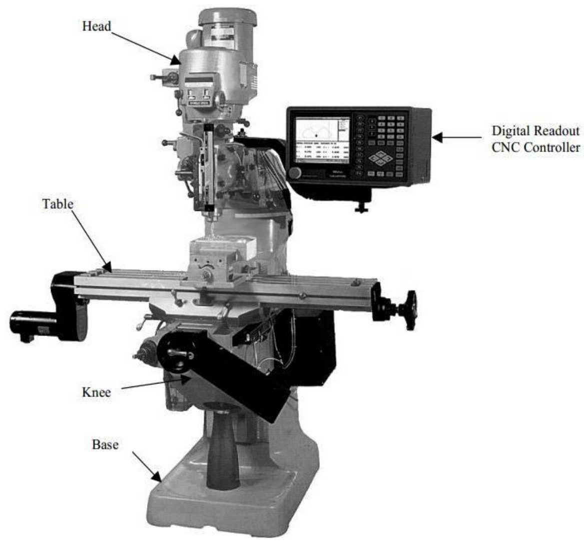


Fig 1: Vertical Milling Machine

Table 1 : Specification of Miling Machine

Bed length	850 mm
Bed Width	350 mm
Bed Height	300 mm
Spindle angle	360o
Spindle Speed	48-1500 R.P.M
Spindle power	3 HP
Feed	0.2-5mm
Accuracy	0.2 mm
Machine Weight	1 ton

Table 2: Material Properties of Mild Steel

Element	**%**
C	0.18
Mn	0.95
P	0.009
S	0.0021
Si	0.26
Ni	0.0073
Cr	0.04
Fe	balance

Table 3: Taguchi Array L9 (33) approach

Trails	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	3	2
5	2	2	1	3
6	2	3	2	1
7	3	1	2	3
8	3	2	3	1
9	3	3	1	2

Table 4: Taguchi Array L9 (33) on Milling Machine approach

Trial No	Milling parameter levels		
	A	B	C
1	1000	100	0.25
2	1000	150	0.50
3	1000	200	0.75
4	1250	100	0.75
5	1250	150	0.25
6	1250	200	0.50
7	1500	100	0.50
8	1500	150	0.75
9	1500	200	0.25

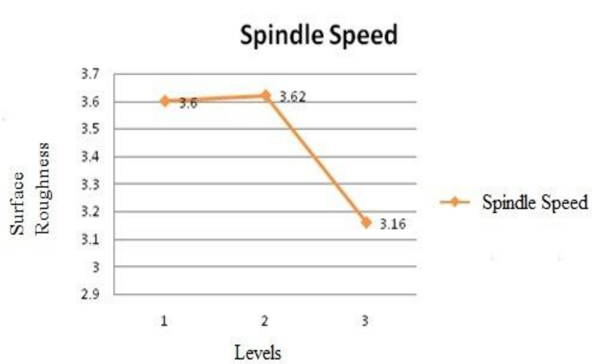
Table 5: Experimental Results for the Milling

Trail no	Spindle speed 'rpm'	Feed rate 'mm/min'	Depth of cut 'mm'	Surface roughness 'Ra'	MRR 'g/min'
1	1000	100	0.25	4.02	0.98
2	1000	150	0.50	3.86	0.93
3	1000	200	0.75	3.80	0.86
4	1250	100	0.75	3.85	0.89
5	1250	150	0.25	3.82	0.90
6	1250	200	0.50	3.21	0.83
7	1500	100	0.50	3.00	0.85
8	1500	150	0.75	3.24	0.97
9	1500	200	0.25	3.25	0.90

RESULTS AND DISCUSSIONS

Table 6: Influence of each Process Parameter on Surface Roughness

S.NO.	Parameters	L_1	L_2	L_3
1	SPINDLE SPEED	3.60	3.62	3.16
2	FEED RATE	3.45	3.64	3.31
3	DEPTH OF CUT	3.54	3.33	3.53



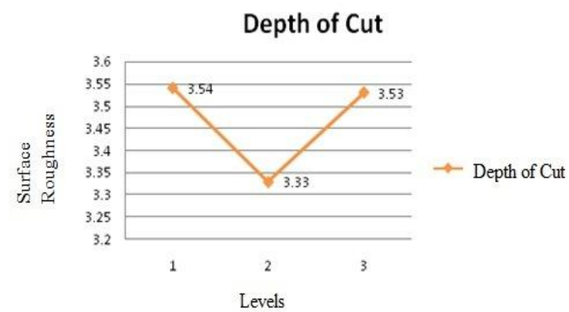


Fig 2: Influence of each Process Parameter on Surface Roughness

RESPONSE GRAPH

This graph indicates the influence of each process parameter on surface roughness. Response graph for surface roughness is shown in Fig 4.1. Quality characteristics for surface roughness is smaller the better. Hence, it can be observed from Fig 4.1 that surface roughness is smaller

i. At third level of spindle speed i.e. rpm
ii. At third level of feed rate i.e.mm
iii. At second level of depth of cut i.e.mm

However, the significant and insignificant parameter will be discriminated based on percentage contribution of each factor toward surface roughness.

ANOVA

The surface roughness values obtained is different, the experimental trial combination given in Table 3.7, Analysis of variance (ANOVA) is performed and results are given in Table 4.3. Percentage contribution of each factor is depicted in the form of bar graph in Fig 4.2. It can be observed from Fig 4.2 that Depth of cut has get major contribution towards variation in surface roughness, next best significant parameters is spindle speed and next best significant parameters is feed rate.

Hence, spindle speed and Depth of cut are significant parameter which must be maintained at the levels specified i.e. Depth of cut at level-2 and Spindle speed at level-3 other parameter can be maintained at any one of the level values specified based on cost consideration

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 129-135 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

Table 7 : Analysis of Variance (ANOVA) for Surface Roughness

Source	**DOF**	**Sequence**	**Adjustment**	**% contribution**
Spindle speed	2	0.4116	0.2058	29.53798459
Feed rate	2	0.1383	0.06915	9.924935054
Depth of cut	2	0.748	0.37378	53.64775451
Error	2	0.096	0.048	6.889325851
Total	**8**	**1.39**		**100**

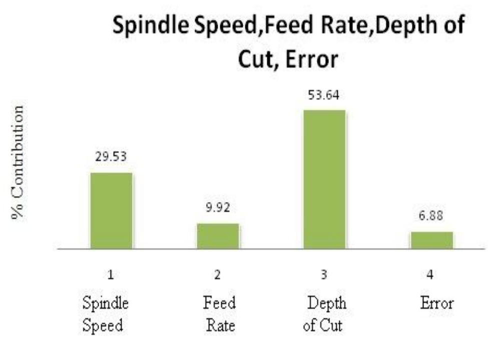


Fig 3: Percentage Contribution of each factor on Surface Roughness

OPTIMUM CONDITION

After performing ANOVA it is observed that the optimum condition for smaller surface roughness is spindle speed at level-2, depth of cut at level-1 and the values of each factor is given in Table 8.

Table 8: Optimum Condition for Surface Roughness

S.No.	Factor Name	Notations	% Contribution	Level Description
1	Spindle speed	N	29.53	(1500)3
2	Feed rate	F	9.92	(200)3
3	Depth of cut	Dc	53.64	(0.50)2

STEPS INVOLVED TO FIND THE OPTIMUM CONDITION USING ANOVA

1. Total of all the results = $\overline{T}$
2. Correction Factor (C.F.)

   C.F. = $\frac{\overline{T}^2}{n}$

   Where, T = Total number of results

   n = Number of experiments
3. Total sum of squares, S_T

   $S_T = \sum_{i=1}^{n} yi^2$ - C.F.
4. Factor sum of squares, S_A
5. Degree of freedom, f_t
6. Factor degree of freedom, f_A
7. Variance, V
8. % Contribution, P_A

SAMPLE CALCULATIONS

$y_{A1} = \frac{3.52+3.80+3.50}{3} = 3.60$

$y_{A2} = \frac{3.85+3.82+3.21}{3} = 3.62$

$y_{A3} = \frac{3.00+3.24+3.25}{3} = 3.16$

$y_{B1} = \frac{3.52+3.85+3.00}{3} = 3.45$

$y_{B2} = \frac{3.80+3.82+3.24}{3} = 3.62$

$y_{B3} = \frac{3.50+3.21+3.25}{3} = 3.32$

$y_{C1} = \frac{3.52+3.82+3.25}{3} = 3.53$

$y_{C2} = \frac{3.80+3.21+3.00}{3} = 3.33$

$y_{C3} = \frac{3.50+3.85+3.24}{3} = 3.53$

$\overline{T} = \frac{3.52+3.80+3.50+3.85+3.82+3.21+3.00+3.24+3.25}{9} = 3.49$

Degree of Freedom, f_t

$f_t = n – 1$

$f_t = 9 – 1$

$f_t = 8$

Factor Degree of Freedom, f_A

f_A = No.of Levels – 1

$f_A = 3 – 1$

$f_A = 2$

SURFACE ROUGHNESS VALUES AT OPTIMUM CONDITION

Grand Average of standard value of surface roughness $(\overline{T})$ =3.49

Expected surface roughness at optimum condition

$Y_{Optimum} = \overline{T} + [\overline{N_3} - \overline{T}] + [\overline{F_3} - \overline{T}] + [\overline{DC_2} - \overline{T}]$

= 3.49+ (3.6-3.49) + (3.31-3.49) + (3.33-3.49)

= 2.82

(STANDARD VALUE based on the significance of factors and their percentage contribution towards result)

Instead of conducting '27' experimental trial combination by varying one factor at a time i.e. full factorial experiments, with the help of Taguchi's L_9 Orthogonal array optimized condition can be obtained by analyzing the results of nine experimental trials. Interestingly the obtained optimum condition does not match with any of the experimental trial combination existing in L_9 array.

It can be observed that the surface roughness value obtained at optimum condition is less than any of the surface roughness values obtained experimentally as per L_9 Orthogonal array.

CONFORMATION TEST

Conformation test is performed at obtained optimum condition and surface roughness value is observed to be 2.82. It can be observed that the result obtained in conformation test matches with surface roughness value at optimum condition with reasonable degree of accuracy.

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 129-135 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

MATERIAL REMOVAL RATE

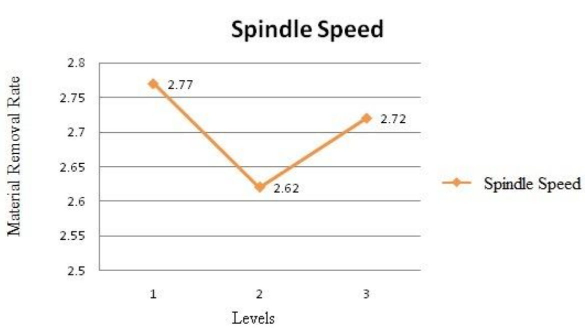
OPTIMIZATION OF PROCESS PARAMETERS FOR MATERIAL REMOVAL RATE

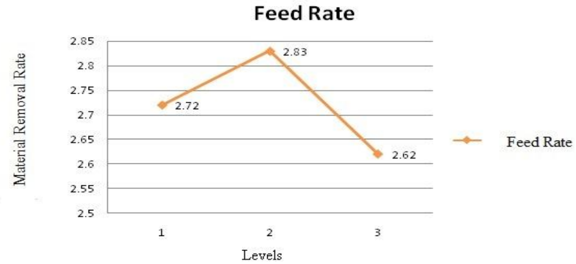
Table 9: Parameter Levels and Response of Material Removal Rate

Trial No	Milling parameter levels and response			
	A	B	C	MRR
1	1	1	1	0.98
2	1	2	2	0.93
3	1	3	3	0.86
4	2	1	3	0.89
5	2	2	1	0.90
6	2	3	2	0.83
7	3	1	2	0.85
8	3	2	3	0.97
9	3	3	1	0.90

Table 10: Influence of each Process Parameter on Material Removal Rate

Parameters	L_1	L_2	L_3
SPINDLE SPEED	2.77	2.62	2.72
FEED RATE	2.72	2.83	2.62
DEPTH OF CUT	2.78	2.61	2.72





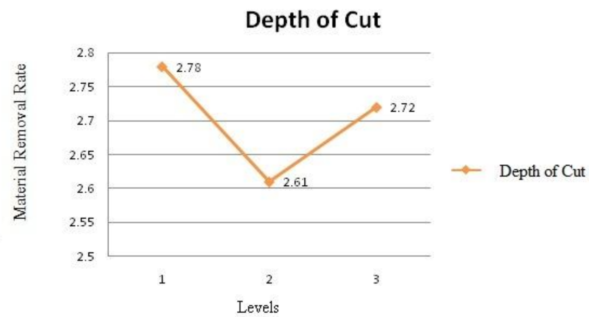


Fig 4: Influence of each Process Parameter on Material Removal Rate

RESPONSE GRAPH

This graph indicates the influence of each process parameter on material removal rate. Response graph for material removal rate is shown in Fig 4.1. Quality characteristics for material removal rate are the higher the better. Hence, it can be observed from Fig 4.1 that material removal rate is higher

i. At first level of spindle speed i.e. rpm
ii. At second level of feed rate i.e.mm
iii. At first level of depth of cut i.e.mm

However, the significant and insignificant parameter will be discriminated based on percentage contribution of each factor toward material removal rate.

ANOVA

The material removal rate values obtained is different, the experimental trial combination given in Table 3.7, Analysis of variance (ANOVA) is performed and results are given in Table 4.3. Percentage contribution of each factor is depicted in the form of bar graph in Fig 4.2. It can be observed from Fig 4.2 that feed rate has get major contribution towards variation in material removal rate, next best significant parameters is Depth of cut and next best significant parameters is spindle speed.

Hence, feed rate and Depth of cut are significant parameters which are higher percentage of contribution must be maintained at the levels specified i.e., feed rate at level-2, Depth of cut at level-1 and Spindle speed at level-1

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 129-135 (2013)
Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

Table 11: Analysis of Variance (ANOVA) for Material Removal Rate

Source	DOF	Seqss	Adjms	% contribution
Spindle speed	2	3.89E-03	0.001944	19.47
Feed rate	2	9.62E-03	0.004811	48.19
Depth of cut	2	4.96E-03	0.002478	24.81
Error	2	0.0015	0.00075	7.51
Total	**8**	2.00E-02		**100**

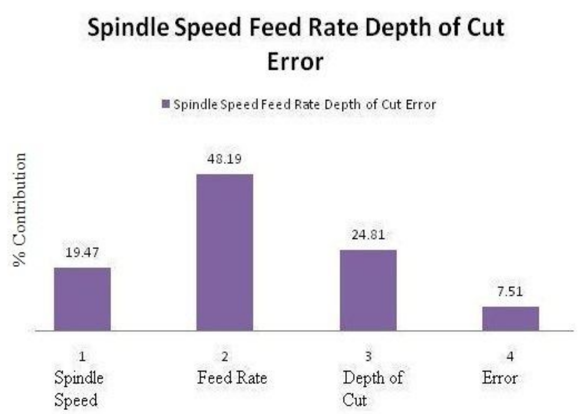


Fig 5: Percentage Contribution of each factor on Material Removal Rate

MATERIAL REMOVAL RATE VALUES AT OPTIMUM CONDITION

Grand Average of standard value of material removal rate $(\bar{T})$ =0.93
Expected material removal rate at optimum condition
Y Optimum= $\bar{T} + [\bar{N_1} - \bar{T}] + [\bar{F_2} - \bar{T}] + [\bar{DC_1} - \bar{T}]$
= 0.903+ (2.77-0.903) + (2.83-0.903) + (2.78-0.903)
= 5.97 (STANDARD VALUE based on the significance of factors and their percentage contribution towards result)

Instead of conducting '27' experimental trial combination by varying one factor at a time i.e. full factorial experiments, with the help of Taguchi's L9 Orthogonal array optimized condition can be obtained by analyzing the results of nine experimental trials. Interestingly the obtained optimum condition does not match with any of the experimental trial combination existing in L_9 array.

It can be observed that the material removal rate value obtained at optimum condition is less than any of the material removal rate values obtained experimentally as per L_9 Orthogonal array.

CONFORMATION TEST

Conformation test is performed at obtained optimum condition and material removal rate value is observed to be 5.97. It can be observed that the result obtained in conformation test matches with material removal rate value at optimum condition with reasonable degree of accuracy.

CONCLUSIONS

After conducting the experiments and analyzing the experimental results the following conclusions are made

i. Taguchi method has been successfully employed for optimizing the process parameters of Milling of mild steel plates. It has been shown that the Taguchi method provides a systematic and efficient methodology for searching the milling process parameters with optimal milling parameters.
ii. As per L9 orthogonal array, we have 3^3=27 combinations. Instead of 27 experiments, nine numbers of trials were conducted. The optimum value for surface roughness and material removal rate is not available in the nine numbers of experiments. The optimum values of surface roughness, combinations of parameters and their levels are also predicted by Taguchi method.

Results of the conformation experiment for the milling performances

i. By the experiment results it was found that the surface roughness quality characteristic is smaller the better but the experimental value is 3.00mm i.e., at parameters S_3, F_1, D_2 and for material removal rate quality characteristic is bigger the better but experimental value is i.e., 0.98 at S_1, F_1, D_1.
ii. After applying Taguchi techniques the predicted values are 2.82mm and material removal rate is 5.97mm. The values obtaining after applying Taguchi technique is more effective than the experimental values.

By ANOVA techniques, influence of each milling parameter is studied and the prediction of the surface roughness and material removal rate is done. Analysis of surface roughness and material removal rate parameters such as spindle speed, feed rate and depth of cut against variations in milling

REFERENCES

[1] Milon D. Selvam, Dr.A.K.Shaik Dawood,Dr. G. Karuppusami, "Optimization Of Machining Parameters For Face Milling Operation In A Vertical CNC Milling Machine Using Genetic Algorithm", An International Journal (ESTIJ), ISSN: 2250-3498, Vol-2, August (2012).
[2] Anil Choubey, Vedansh Chaturvedi, Jyoti Vimal, "The Implementation Of Taguchi Methodology For Optimization Of End Milling Process Parameter Of Mild Steel", International Journal of Engineering Science and Technology, ISSN : 0975-5462, Vol-2, (2007)
[3] Nafis Ahmad, Tomohisa Tanaka and Yoshio Saito, "Optimization Of Cutting Parameters For End Milling Operation By Soap Based Genetic Algorithm", ICME05-AM-08, August (2006).

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 129-135 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

[4] John D. Kechagias, Christos K. Ziogas, Menelaos K. Pappas, Ioannis E. Ntziatzias, "Parameter Optimization during Finish End Milling of Al Alloy 5083 using Robust Design", ISBN: 978-988-18210-6-5 (2011).

[5] R. JaliliSaffar, M.R. Razfar, A.H. Salimi and M.M. Khani, "Optimization of Machining Parameters to Minimize Tool Deflection in the End Milling Operation Using Genetic Algorithm", World Appl. Sci. J., 6 (1): 64-69, 2009.

[6] S.S.K. Deepak, "Applications of Different Optimization Methods for Metal Cutting Operation – A Review", Research Journal of Engineering Sciences, Vol. 1(3), 52-58, September (2012).

[7] Prof. Bharat S Patel, Mr. Hiren Pal, "Optimization of Machining Parameters For Surface Roughness In Milling Operation", International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012).

[8] PR.Periyanan, U.Natarajan, S.H.Yang, "A study on the machining parameters optimization of micro-end milling process" ,International Journal of Engineering, Science and Technology ,Vol. 3, No. 6, 2011, pp. 237-246.

[9] Mr. Dhole N.S, Prof. Naik G.R , Mr. Prabhawalkar M.S."Optimization of Milling Process Parameters Of En33 Using Taguchi Parameter Design Approach", JERS/Vol.III/ Issue I/January-March, 2012/70-74.

[10] Vikas Pare, Geeta Agnihotri& C.M. Krishna, "Optimization of Cutting Conditions in End Milling Process with the Approach of Particle Swarm Optimization", International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Volume-1, Issue-2, 2011.

[11] Shaji S. and Radhakrisnan V., Analysis of process parameters in surface grinding with graphite as lubricant based on Taguchi method, Journal of Material Processing Technology , 1–9 (2003).

[12] Singh S., Shan H.S. and Pradeep K., Parametric optimization of magnetic field assisted abrasive flow machining by the Taguchi method, Quality and Reliability Engineering International, 18,273–283 (2002).

[13] Taguchi G., parameter design: A panel discussion, In V. N. Nair, (Ed.). Techno metrics, 34, 127–161 (1973) Vol. 1(3), 52-58, September (2012).

[14] Manna A. and Bhattacharyya B., Investigation for optimal parametric combination for achieving better surface finish during turning of Al/SiC-MMC, International Journal of Advanced Manufacturing Technology, 23, 658–665 (2004)