OPTIMIZATION OF PROCESS PARAMETERS IN END MILLING OF 5083 ALUMINIUM ALLOY

[1]G.Ganesh, [2]D. Santha Rao, [3]B.N.V.S.Ganesh Gupta K
[1] P.G Scholar, [2] Associate Professor, [3]Assistant Professor
[1]Department of Mechanical Engineering
[1]BVC Engineering College, Odalarevu, Amalapuram, India.

Abstract: Computer Aided Manufacturing improves productivity in the modern manufacturing environment, however optimization of numerous factors involved in automated manufacturing or material removal environment is critical to produce high quality products. Recent advancements in manufacturing technology allow now a much wider selection of machining processes. In order to improve the accuracy, a long and expensive calibration process is usually performed on the CNC machine. In this thesis an attempt is made to investigate and evaluate the effect of different process parameters like cutting tool helix angle, speed, feed and depth of cut. 5083 aluminum alloy was selected as work material due to its wide range of applications in Automobile, locomotive and aerospace industries. The cutting speed in the range of 2000 rpm to 3500 rpm with a step of 500 rpm, feed of 800 mm/min to 1400 mm/min with a step of 200 mm/min, depth of cut of 0.25mm to 0.4 mm with a step of 0.05mm, Cutting tool helix angles of 25°, 45° Left hand helix and Right hand helix were chosen.

The L16 design matrix was generated by using Minitab software. The machining is carried out as per the design matrix with HSS tool using SEMITOM AL 9002 oil as a cutting fluid. The process parameters were optimized using Single variable Optimization (Taguchi) and Multi Variable Optimization (Taguchi based Grey Relational Analysis) for better output response. The Analysis Of Variance (ANOVA) also carried out to know the percentage contribution of process parameters.

Keywords: Material Removal Rate, Surface Roughness, Taguchi's L16 Orthogonal Array, and TGRA.

I. INTRODUCTION

Milling is the machining process of using rotary cutters to remove material from a work piece by advancing (or *feeding*) the cutter into the work piece at a certain direction. The cutter may also be held at an angle relative to the axis of the tool Milling covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes for machining custom parts to precise tolerances. Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine.

2. LITERATURE REVIEW

S.Ema and R.Daviest investigated the cutting performance of several end mills with right and left hand helix angles is reported. Cutting tests were performed on aluminum alloy L65 for three milling processes in which cutting force, surface roughness and concavity of a machined plane surface were measured. The cutting performance of the end mills was assessed using variance analysis. The investigation showed that end mills with left hand helix angles are generally less effective than those with right hand helix angles, except for the case where the helix angle is small. The effects of spindle speed, depth of cut and feed rate on the cutting force and the surface roughness are generally significant. There is no significant difference between down milling and up milling with regard to the cutting force, although the difference between them regarding the surface roughness was large.

3. Experimental Methodology:

A. Taguchi's Design approach

Taguchi methods are statistical methods, or sometimes called robust design methods, developed by Genichi Taguchi to improve the quality of manufactured goods. Taguchi realized that the best opportunity to eliminate variation of the final product quality is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

- System design
- Parameter (measure) design
- Tolerance design

B. Taguchi Grey Relational Analysis (TGRA):

In the grey relation analysis, experiment data, i.e., measured responses are first normalized in the range of 0 to 1. This process is called normalization or grey relation generation. Based on this data, grey relation coefficients are calculated to represent the correlation between the ideal (best) and the actual normalized experimental data. Overall, grey relation grade is then determined by averaging the grey relation coefficient corresponding to selected responses. The overall quality characteristics of the multi-

Response process depend on the calculated grey relation grade. The Taguchi based GRA is similar to GRA only, but the difference is GRA we will be performed for S/N ratios of the results of response variables.

C. Normalization:

Normalization of the signal to noise ratio is performed to prepare raw data for the analysis where the original sequence is transformed to a comparable sequence. Linear normalization is usually required since the range and unit in one data sequence may differ from the others. There are three different types of data normalization according to the requirement of Lower the Better (LB), Higher the Better (HB), or Nominal the Best (NB) criteria. If the target value of original sequence is infinite, then it has a characteristic of the "higher is better".

D. Analysis Of Variance (ANOVA):

Analysis of Variance (ANOVA) is a statistical method for determining the existence of differences among several population means. The aim of ANOVA is the detect differences among several population means, the technique requires the analysis of different forms of variance associated with the random samples under study. The Analysis of Variance is used to find out the percentage contribution of input process parameters for response variables.

4. EXPERIMENTATION:

4.1 Selection Of work material:

5083 Aluminum alloy is chosen for experimentation. It has purchased from local market in Hyderabad at a cost of 500/kg with the thickness of 22 mm. The work piece is cut to a size of 110 mm x 52 mm with respect of length and breadth. The weight of the each work piece was measured with digital balance meter. 5083 Aluminum alloy retains exceptional strength after welding. It has the highest strength of the non – heat treatable alloys.

Fig.4.1 Work pieces before machining

4.2 Selection of Milling Machine and Cutting tool:

The model of the machine used for machining is DMV320. It has Spindle speed range of 800 rpm -8000 rpm. The power of spindle motor is 7.5 kW, power supply given is 230V, 50Hz signal phase supply. SIMTON AL 9002 oil is used as cutting fluid for machining. The experiment is carried out at Ambica Industries, Kushaiguda, Hyderabad.

The control panel of a machine is used to operate the all functions by manually and part programs by means of G and M codes. The part program is generated by G and M codes based on the given structure to the work piece. Before running a program, may choose to execute the part program in single block mode to prove it out or select the optional stop or block delete or edit functions. Once a program is running, the machine control unit to adjust speed and feed based on requirement.

Fig. 4.2 Milling Machine

4.3 Cutting Tool and Specifications:

- The experiment is conducted by end milling cutters made of high speed steel (HSS).
- The experiment is carried out by the selection of four end mill tools having left hand helix and right hand helix cutters are 25º RH,25º LH,45º RH and 45º LH.

Specification of cutting tool:

- Cutter diameter = 10 mm
- shank length= 32 mm
- Shank diameter= 10mm
- flute length = 33 mm
- Helix angle = 25º and 45º (LH & RH)
- length of cut = 30 mm
- Overall tool length = 65mm
- no. of flutes = 4

Fig. 4.3 25° LH, 25° RH, 45° LH and 45° RH End Milling Tool

4.4 SELECTION OF PROCESS PARAMETERS AND THEIR LEVELS AND DESIGN OF THE MATRIX:

The process parameters are selected for the experimentation of End milling was follows:

Cutting Tool Helix Angle (°)
During milling process work is done by cutting tool helix angle having four number of flutes with an angle of 25º RH ,25º LH,45ºRH and 45º LH having left hand and right hand helix.

Cutting speed (rpm)
While most of the machining takes place during on Cutting speed. The cutting speed in the range of 2000 rpm to 3500 rpm in step of 500 rpm in each experiment.

Feed (mm/min)
It is the rate at which the work piece under process advances under the revolving milling cutter. Revolving the cutter remains stationary and feed is given to the work piece through the table. The feed in the range of 800 mm/min to 1400 mm/min with step of 200 mm/min in each experiment.

Depth of cut (mm) Depth of cut in milling operation is the measure of penetration of cutter into the work piece. Depth of cut is taken as in the range of 0.25 mm to 0.4 mm with step of 0.05 mm in each experiment.

	Levels			
Process Parameters	1	2	3	4
Helix Angle	25° RH	25°LH	45° RH	45°LH
Cutting Speed	2000 rpm	2500 rpm	3000 rpm	3500 rpm
Feed	800 mm/min	1000 mm/min	1200 mm/min	1400 mm/min
Depth of cut	0.25 mm	0.3 mm	0.35 mm	0.4mm

Table 4.1 Process parameters and their levels

5. DESIGN OF EXPERIMENT:

The L16 orthogonal array was created by using the MINITAB 17 software. The given table and its procedure is given below.

STEPS INVOLVED IN CREATING L16 ORTHOGONAL ARRAY USING MINITAB 17

1. Open the MINITAB 17 window, then an empty worksheet will be displayed.

2. Go to STAT > DOE > Taguchi > Create Taguchi Design

3. Then select 4-level design, number of factors 4 and enter factors (Cutting Tool Helix Angle, Cutting speed, Feed, Depth of cut) and their levels.

Fig5.1 Machining of 5083 Aluminum alloy with cutting fluid

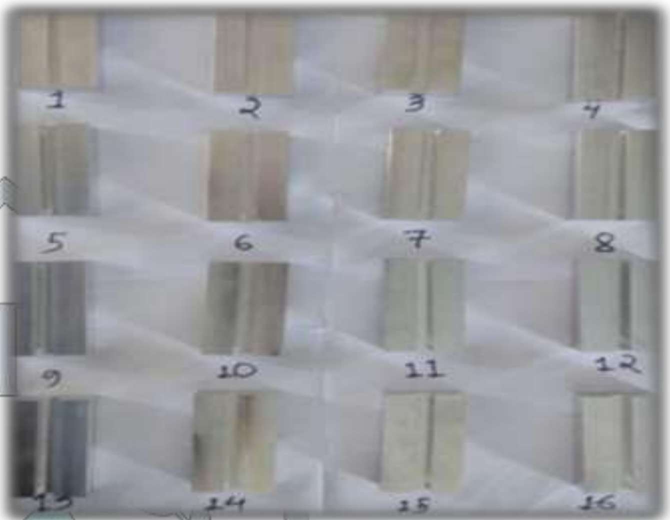


Fig 5.2 Work pieces after machining

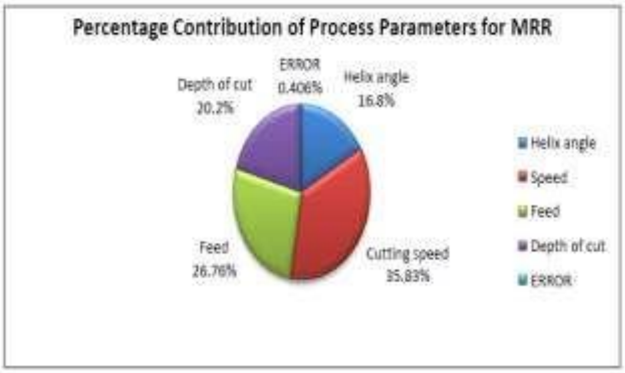
Ex No	Helix angle	Cutting speed (rpm)	Feed (mm/ min)	Depth of cut (mm)	Material removal rate (mm³/min)	S/N ratio	Surface roughnes s(µm)	S/N ratio
1	25°RH	2000	800	0.25	1850.70	65.3467	1.57	-3.91799
2	25°RH	2500	1000	0.3	2424.90	67.6939	0.88	1.11035
3	25°RH	3000	1200	0.35	3634.46	71.2088	**0.64**	3.87640
4	25°RH	3500	1400	0.4	**5394.62**	74.6392	0.76	2.38373
5	25°LH	2000	1000	0.35	3843.47	71.6945	0.90	0.91515
6	25°LH	2500	800	0.4	3569.75	71.0528	0.98	0.17548
7	25°LH	3000	1400	0.25	3905.86	71.8343	0.98	0.17548
8	25°LH	3500	1200	0.3	4050.53	72.1502	0.86	1.31003
9	45°RH	2000	1200	0.4	5346.72	74.5617	0.77	2.27019
10	45°RH	2500	1400	0.35	5349.65	74.5665	0.78	2.15811
11	45°RH	3000	800	0.3	2703.33	68.6380	0.80	1.93820
12	45°RH	3500	1000	0.25	2784.73	68.8957	1.00	0.0000
13	45°LH	2000	1400	0.3	4736.25	73.5087	0.87	1.20961
14	45°LH	2500	1200	0.25	3341.69	70.4793	0.85	1.41162
15	45°LH	3000	1000	0.4	4455.58	72.9781	0.76	2.38373
16	45°LH	3500	800	0.35	3076.74	69.7618	0.84	1.51441

Table 5.1 S/N Ratio VS MRR and SR

The experimental results were analyzed with the Analysis Of Variance (ANOVA), which is used to know the design parameters percentage contribution towards the MRR and SR.

5.2 ANOVA for Material Removal Rate:

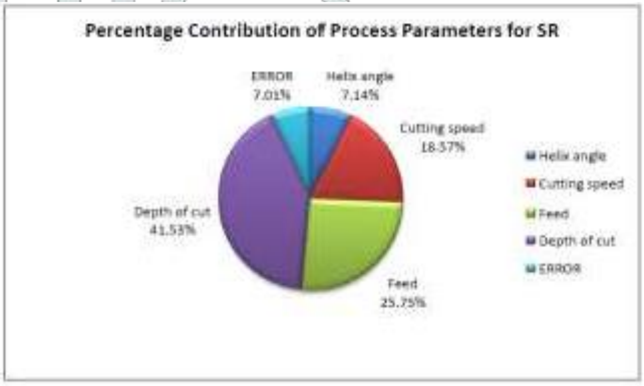
	Means					S/N ratios				
Source	DF	SS	MS	F	% of contribution	DF	SS	MS	F	% of contribution
Helix angle	3	1182757	394252	0.29	6.77	3	11.46	3.821	0.49	16.8
Cutting speed	3	1208010	69337	0.05	6.92	3	10.385	1.1285	0.50	35.83
Feed	3	8432914	3144305	4.71	48.32	3	45.13	16.377	3.87	26.76
Depth of cut	3	6460907	2153636	2.35	37.02	3	38.21	12.738	2.77	20.29
Residual Error	3	165045			0.97	3	0.355			0.406
Total	15	1744963			100	15	105.54			100



From above chart Cutting speed and feed are the most influential parameters on material removal rate with percentage contribution of 35.83%, 26.76%.

5.3 ANOVA for Surface Roughness:

	Means					S/N Ratios				
Source	DF	SS	MS	F	% of contribution	DF	SS	MS	F	% of contribution
Helix angle	3	0.05285	0.01762	0.37	8.42	3	3.038	1.013	0.31	7.14
Cutting speed	3	0.1155	0.03848	0.90	18.41	3	7.903	2.634	0.91	18.57
Feed	3	0.1550	0.05165	1.31	24.71	3	10.96	3.655	1.39	25.75
Depth of cut	3	0.2431	0.08102	2.53	38.75	3	17.67	5.889	2.84	41.53
Residual Error	3	0.06075			9.71	3	2.976			7.01
Total	15	0.62726			100	15	42.54			100



From above chart the feed and depth of cut are the most influential parameters on surface roughness with percentage contribution of 25.75%, 41.53%.

5.4 Taguchi analysis For Grey Relational Grade:

Process parameters	Level	Grey Relational Grade			
		Helix angle	Cutting speed	Feed	Depth of cut
Average Value	L1	-6.101	**-4.773**	-6.918	-6.362
	L2	-6.537	-6.714	-7.286	-7.370
	L3	**-5.970**	-7.259	**-4.543**	-6.601
	L4	-6.670	-6.533	-6.530	**-4.945**
	Delta	0.700	2.486	2.742	2.425
	Rank	4	2	1	3

Table 5.2 Grey Relation Grade (Taguchi Analysis)

Helix angle 45RH, Cutting peed of 2000 Rpm, feed at 1200 mm/min Depth of cut of 0.4 mm are the optimal parameter level for the higher Grey Relational Grade.

5.4 ANOVA FOR GREY RELATIONAL GRADE:

	S/N ratio				
Source	DF	SS	MS	F	% of contribution
Helix	3	0.009257	0.003086	0.21	5.06
Speed	3	0.04574	0.01525	1.33	25.01
Feed	3	0.06069	0.02623	1.99	33.19
Doc	3	0.03947	0.01316	1.10	21.58
Residual Error	3	0.027683			15.16
Total	15	0.18284			100

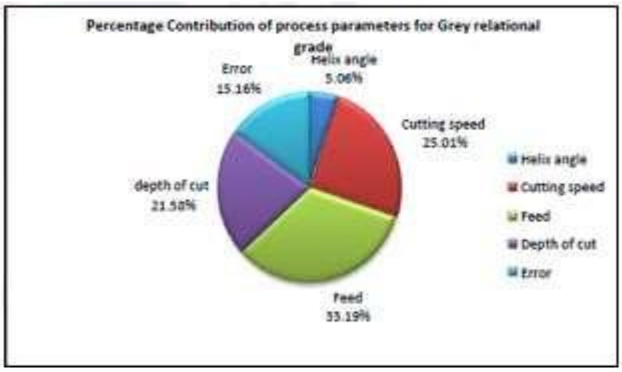


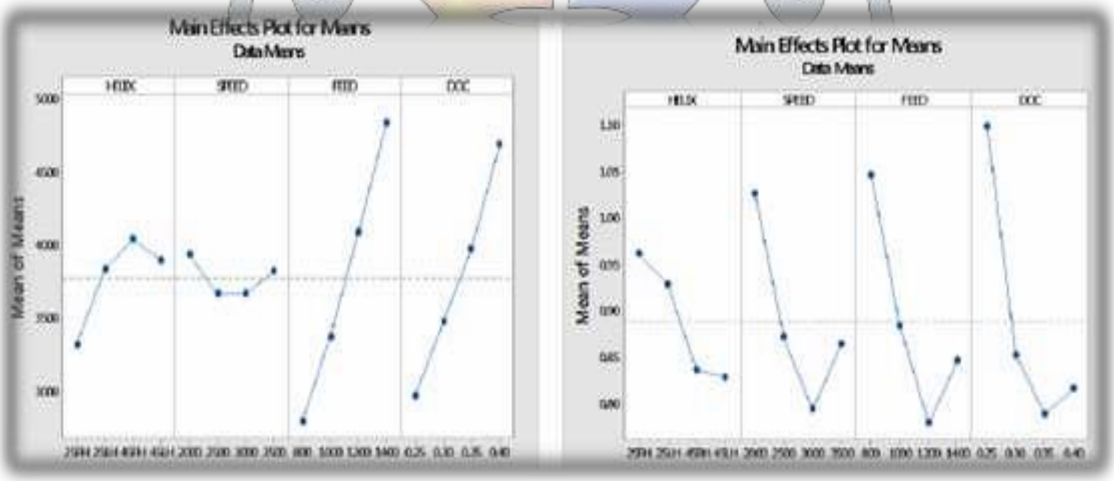
Table 5.3 Grey Relation Grade (ANOVA)

Optimization		Optimum Level	Predicted	Confirmation Test
Taguchi Analysis of Design	Material Removal Rate	Helix angleL4=45LH Cutting speedL4=3500rpm FeedL4=1400mm/min Depth of cutL4 = 0.4mm	5929.55 mm^3/min	5349.62 mm^3/min
	Surface Roughness	Helix angleL2 = 25LH Cutting speedL1 =2000rpm FeedL1 =800mm/min Depth of cutL4 =0.25mm	1.11 µm	0.95 µm
Optimization	**Predicted Grey Relational Grade**	**Optimal Level Of Parameters**	**Confirmation Test For Material Removal Rate**	**Confirmation Test For Surface Roughness**
Grey Relational Analysis	0.4979	Helix angleL3 =45RH Cutting speedL1= 2000rpm FeedL3=1200mm/min Depth of cutL4 = 0.4mm	5986.23 mm^3/min	0.89 µm

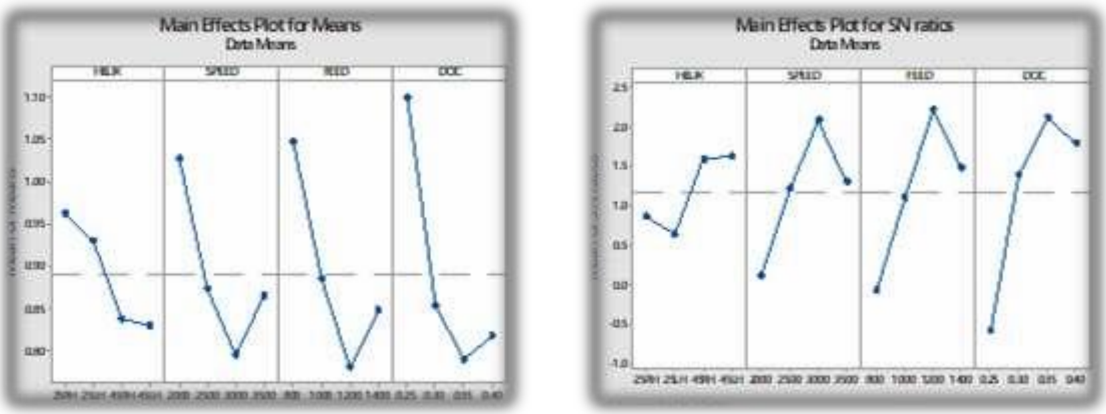
Table 5.4 Predicted results and confirmation test results obtained from Taguchi and Taguchi grey relational analysis

From the Taguchi Analysis optimal parameter level for MRR is Helix angle is 45LH, Cutting Speed is 3500rpm, Feed 1400mm/min and Depth of cut is 0.4mm and at this level the experimental value of Material removal rate is found to be 5349.62 mm^3 /min. While the optimal parameter level obtained for surface Roughness is Helix angle at 25LH, Cutting Speed is 2000 rpm, Feed 800mm/min, Depth of cut is 0.25mm and at this level the experimental value of Surface Roughness is found to be 0.95µm. From the Grey Relational Analysis, it was found that the optimal parameter level is Helix angle 45RH, Cutting speed 2000rpm, Feed 1200mm/min, Depth of cut 0.4mm. The confirmation test was carried out at this level then observed the following results: Material Removal Rate 5986.23mm^3/min, Surface Roughness 0.89µm.

6. Main effect plots for input parameters v/s output parameters:



Graph 6.1 Input Parameters V/S MRR



Graph 6.1 Input Parameters V/S SR

7. CONCLUSIONS:

The experiments were conducted to optimize the different machining parameters like Tool Helix angle, Cutting speed, feed and Depth of cut in End milling machining of 5083 Aluminium alloy. Finally it can be concluded that:

From Taguchi analysis:

- The material removal rate was found to be 5349.62mm3/min at optimal parameter levels of Cutting tool helix angle at level 4(45LH), Cutting speed at level4(3500rpm), Feed at level 4(1400mm/min), Depth of cut at level 4(0.4mm).
- The Surface Roughness was found to be 0.95µm at optimal parameter levels of Cutting tool helix angle at level 2(25LH), Cutting speed at level 1 (2000 rpm), Feed at level 1(800mm/min), Depth of cut at level 1(0.25mm).

From Grey Relational Analysis:

- The material removal rate was 5986.23mm3/min, Surface Roughness was 0.89µm at Optimal parameter level Helix angle at level 3(45RH), Cutting speed at level 1 (2000rpm), feed at level 3(1200 mm/min), Depth of cut at level 4(0.4mm).
- The response variables Material Removal rate and Surface Roughness are greatly improved by Grey Relational Analysis compared to Taguchi.

From ANOVA

- Cutting speed and Feed are the most influential parameters in increase of Material Removal Rate.
- Feed and Depth of cut are the most influential parameters in decrease of Surface Roughness.

8. REFERENCES:

[1] Thakur Paramjit Mahesh, R.Rajesh, “OPTIMAL SELECTION OF PROCESS PARAMETERS IN CNC END MILLING OF AL7075 T6.” International Conference on Advances in Manufacturing and Material Engineering, AMME 2014.

[2] J.S.Pang, M.N.M. Ansari, Omar S. Zaroog, Moaz H. Ali, S.M. Sapuan, “ Design and Optimization of parameters on the CNC Milling Machine Process of Halloy site Nanotube (HNT/A1/Ep) Hybrid composite”, Housing and Building National Research Centre, HBRC Journal, 2014.

[3] A.ArunPremnath, T.Alwarsamy, T.Abhinav,C.Adithya,Krishna Kant,“Surface Roughness Prediction By Response Surface Methodology In Milling Of Hybrid Aluminum Composites.”, International Conference on Modelling Optimisation and Computing,2012.

[4] Lohithaksha M Maiyara, Dr.R.Ramanujamb, K.Venkatesanc, Dr.J.Jeraldd, “Optimization of Machining Parameters for End Milling of 718 Super Alloy Using Taguchi Grey Analysis”, International Conference on DESIGN AND MANUFACTURING, IConDM 2013.

[5] Lakshmipathi Tammineni1 and Hari Prasada Reddy Yedula, “Investigation Of Influence Of Milling Parameters On Surface Roughness And Flatness”, International Journal of Advances in Engineering & Technology, Jan. 2014.©IJAET

[6] Deepak Kumar and Sandeep Jindal, "Optimization of Process Parameters of Gas Metal ARC Welding by Taguchi‟s Experimental Design Method", International Journal of Surface Engineering and Material Technology, Vol.1 No.1,July-Dec-14 55

[7] Mohammed T. Hayajneh, Montasser S. Tahat b, Joachim Bluhm, "A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process", Jordan Journal of Mechanical and Industrial Engineering volume 1, Number 1, Sep. 2007 ISSN 1995-6665 Pages 1 – 5.

[8] D.Sudhakaraa,G.Prasanthi,"Application of Taguchi Method for Determining Optimum Surface Roughness in Wire Electric Discharge Machining of P/M Cold Worked Tool Steel (Vanadis-\4E)"Procedia Engineering 97 (2014) 1565 –1576.

[9] Chi-Hsiang Chen,Yung-Cheng Wang, Bean-Yin Lee, “The Effect of Surface Roughness of End- Millson Optimal Cutting Performance for High-Speed Machining", Strojniški vestnik - Journal of Mechanical Engineering 59(2013)2,124-134.

[10] Mohammad Khoran,Pouyan Ghabezi And Eisa Khoran,"The Effects Of Milling Parameters On 56 Surface Roughness Of Stainless Steel X22 Cr Mo V 12 1",indian j.sci.res.1(2) : 445- 452,2014.