Optimisation of CNC End Milling Parameters for Aluminium Alloy LM-24 by using Taguchi Technique

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Abstract- In today's competitive environment, the companies all around the world are trying to increase their profits without increasing the sales price of their products. The reduction in production time and optimization of process parameters plays an important role for enhancement of productivity. After iron, aluminium is now the second most widely used metal in the world. CNC milling is one of the fastest cutting processes for aluminium. But optimization of CNC milling process parameters is to be done through an experimentation work. Therefore in this particular thesis work machining of Aluminium LM24 is done in which optimization of CNC milling process parameters is attempted for analysis. The tool used for machining is Solid Carbide Square end mill K 10 tool. The main response Variables taken are Material Removal Rate(MRR) and Surface finish that mainly depends upon parameters such as Speed, Feed Rate and Depth of Cut. As the depth of cut increases the MRR increases, surface roughness of the workpiece is also increases. Whereas by increasing the Speed, Material Removal Rate and Surface Finishing improve simultaneously.

Keywords – Optimization, CNC, Milling , MRR.

I. Introduction

Machining [6] is the manufacturing process in which unwanted material is being removed from the workpiece to get finished product. Many manufacturing Process like Turning, Milling, Drilling, Boring, Are commonly used for the machining the unwanted material to get the desired product. In today's context the organizations want more material removal rate but without compromising surface finish. The machining Parameters for CNC End Milling used in the current study are Spindle Speed, Feed Rate and Depth of Cut. Reponses like Surface roughness and material removal rate are considered during the Study. They have great impact on the mechanical properties such as corrosion resistance, fatigue and creep. It also impacts on the functionality of the machine such as friction, wear, heat transmission etc.

The Technique Used for the optimization of CNC End Milling process Parameters like Spindle Speed, Feed Rate and Depth of Cut for the Aluminium Alloy LM24 AL - Si8Cu3Fe is done by Taguchi Method..

Milling is the process of cutting away material by feeding a workpiece past a rotating multiple tooth cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. The machine for holding the workpiece, rotating the cutter, and feeding it is known as the Milling machine.

II. LITERATURE REVIEW

Zhou et al. [1] (1995) investigated on tool life criteria in raw turning. A new tool-life criterion depending on a pattern-recognition technique was proposed and neural network and wavelet techniques were used to realize the new criterion. The experimental results showed that this criterion was applicable to tool condition monitoring in a wide range of cutting conditions.

Aggarwal Aman et.al [2] (2005) had reviewed the literature on optimizing machining parameters in turning processes. Various conventional techniques employed for machining optimization include geometric programming, geometric plus linear programming, goal programming, sequential unconstrained minimization technique, dynamic programming etc. The latest techniques for optimization include fuzzy logic, scatter search technique, genetic algorithm, Taguchi technique and response surface methodology.

Singh Hari et.al [3] (2006) Optimizing multi-machining characteristics through Taguchi's approach and utility concept .A simplified model based on Taguchi's approach and utility concept is used to determine the optimal settings of the process parameters for a multi-characteristic product. The model is used to predict optimal settings of turning process parameters to yield the optimum quality characteristics of En24 steel turned parts using TiC coated carbide inserts. The optimal values obtained using the multi-characteristic optimization model has been validated by confirmation experiments. The model can be extended to any number of quality characteristics provided proper utility scales for the characteristics are available from the realistic data.

Hayajneh Mohammed T. et.al [4] (2007) carried out a study of the Effects of Machining parameters on the Surface Roughness in the End-Milling Process for the Aluminium . A set of experiments designed to begin the characterization of surface quality for the end-milling process have been performed. The objective of this study is to develop a better understanding of the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness and to build a multiple regression model.

Lu H.-S. et.al [5] (2008) focused on the optimal cutting parameters design of rough cutting processes in side milling for SKD61 tool steels. The fuzzy logics can be a proper basis to perform the optimization procedure with complicated multiple performance characteristics. The improvement of tool life and metal removal rate from the initial cutting parameters to the optimal cutting parameters are 54% and 9.7%. Hence, this reveals that the proposed approach in this study can effectively improve the cutting performance.

III. RESULT

The results for MRR for each of the 27 treatment conditions with repetition are given in Table 1. This Table shows the variation of signal to noise ratio and material removal rate for different possible combinations of speed feed and depth of cut.

Table 1: Results for MRR

S.NO	Spindle Speed (Rpm)	Feed Rate (Mm/Min)	Depth Of Cut (Mm)	MRR mm^3 / min	S/N Ratio
1	1100	450	0.3	2222.2	66.94
2	1100	450	0.6	3694.4	71.35
3	1100	450	0.9	7619.0	77.64
4	1100	550	0.3	2222.2	66.94
5	1100	550	0.6	3492.1	70.86
6	1100	550	0.9	8755.6	78.85
7	1100	650	0.3	3333.3	70.46
8	1100	650	0.6	5500.0	74.81
9	1100	650	0.9	9155.6	79.23
10	1400	450	0.3	2857.1	69.12
11	1400	450	0.6	4444.4	72.96
12	1400	450	0.9	8518.3	78.61
13	1400	550	0.3	4177.8	72.42
14	1400	550	0.6	5460.3	74.74
15	1400	550	0.9	10666.7	80.56
16	1400	650	0.3	4777.8	73.58
17	1400	650	0.6	6944.4	76.83
18	1400	650	0.9	10555.6	80.47
19	1700	450	0.3	2317.5	67.30
20	1700	450	0.6	5714.3	75.14
21	1700	450	0.9	7301.6	77.27
22	1700	550	0.3	3111.1	69.86
23	1700	550	0.6	6577.8	76.36
24	1700	550	0.9	9155.6	79.23
25	1700	650	0.3	4444.4	72.96
26	1700	650	0.6	8888.9	78.98
27	1700	650	0.9	9777.8	79.80

The Analysis of Variance (ANOVA) for the mean MRR at 95% confidence interval is given in Table 2.Table 3 shows the ranks of various factors in terms their relative significance. Main effects plot for the MRR are shown in Figure 1 which shows the variation of MRR with the input parameters. The interactions plots are shown in the Figure 2 which shows all interaction are significant for the MRR.

Table 2 Analysis of Variance for Means

Source	DoF	Seq SS	Adj SS	Adj MS	F	P	
Spindle Speed	2	10472903	10472903	5236452	816.27	.000	Significant
Feed Rate	2	19416315	19416315	9708157	1513.33	.000	Significant
Depth of Cut	2	152150863	152150863	76075432	11858.78	.000	Significant
Spindle Speed * Feed Rate	4	1674761	1674761	418690	65.27	.000	Significant
Spindle Speed * Depth of Cut	4	7660109	7660109	1915027	298.52	.000	Significant
Feed Rate* Depth of Cut	4	2431253	2431253	607813	94.75	.000	Significant
Residual Error	8	51321	51321	6415			
Total	26	193857525					

Table 3: Response table for means of MRR

Level	Spindle Speed	Feed Rate	Depth of Cut
1	5110	4965	3274
2	**6489**	5958	5635
3	6365	**7042**	**9056**
Delta	1379	2077	5782
Rank	3	2	1

Table 4 shows the ANOVA results for S/N ratio of MRR at 99% confidence interval. Main effects plot and interaction plot of S/N ratio for MRR are shown in the figure 3 and 4 respectively.

Firstly data has been checked for its normality by probability plot (see first plot of figure 5). As data points are distributed all along the normal line and having negligible outliers, so data can be concluded as normally distributed. The second plot doesn't show any trend while plotting residual versus fitted values of data which implies Taguchi Array chosen is well fitted with given data set. Third plot is frequency histogram showing data distribution and at last residue versus order plot highlights the random data points which signifies non-significance of experimental order as far as first response (MRR) is concerned.

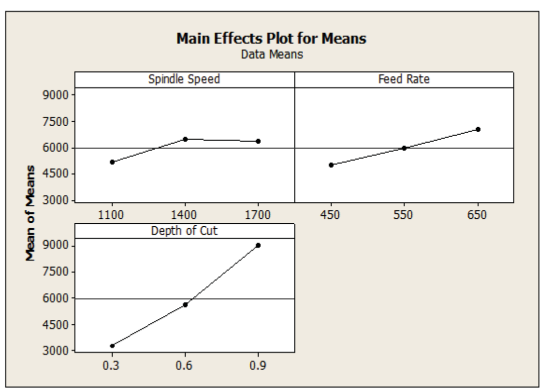

Figure 1: Main effects plot of MRR for Means

The 3-D surface plots as a function of two factors at a time, maintaining all other factors at fixed levels not only provides understanding of both the main and the interaction effects of these two factors, but also helps to identify the optimum level of each variable for maximum response. See figure 6 containing surface plot and its corresponding 2-D contour plot of MRR versus Spindle Speed &Depth of Cut at a holding value of feed rate.

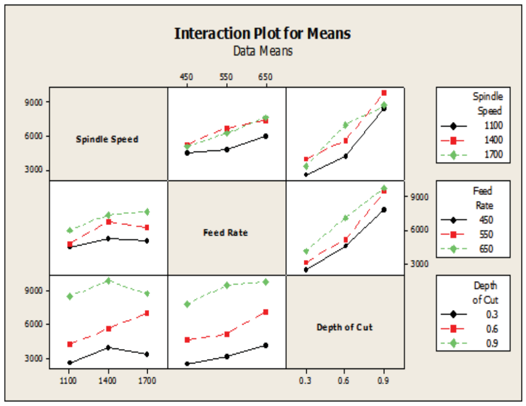

Figure 2: Interaction plot for MRR

Table 4 Analysis of Variance for S/N Ratio

Source	DoF	Seq SS	Adj SS	Adj MS	F	P	
Spindle Speed	2	33.078	33.078	16.539	98.33	.000	Significant
Feed Rate	2	52.999	52.999	26.499	157.54	.000	Significant
Depth of Cut	2	374.576	374.576	187.288	1113.47	.000	Significant
Spindle Speed * Feed Rate	4	4.411	4.411	1.103	6.56	.012	Significant
Spindle Speed * Depth of Cut	4	19.972	19.972	4.918	29.24	.000	Significant
Feed Rate* Depth of Cut	4	8.112	8.112	2.028	12.06	.002	Significant
Residual Error	8	1.346	1.346	0.168			
Total	26	494.194					

Table 5: Response table for S/N ratio of MRR

Level	Spindle Speed	Feed Rate	Depth of Cut
1	73.01	72.92	69.95
2	**75.48**	74.42	74.97
3	75.21	**76.35**	**79.07**
Delta	2.47	3.42	9.12
Rank	3	2	1

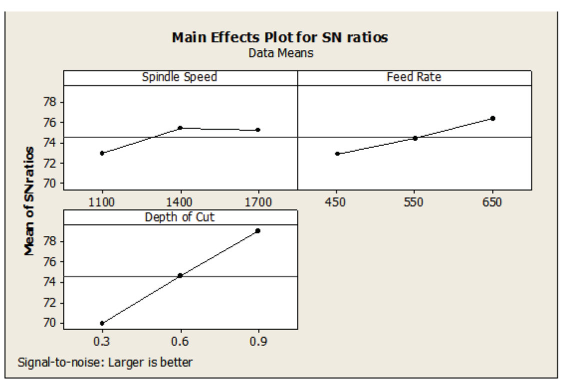

Figure 3: Main effects plot of MRR for S/N Ratio

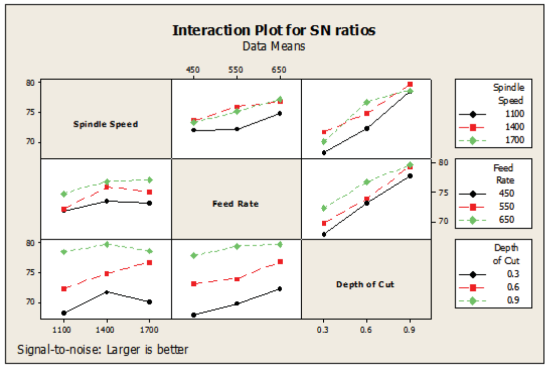

Figure 4: Interaction plot for MRR

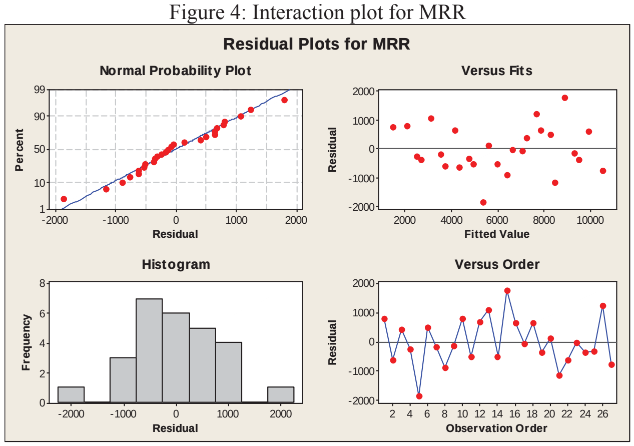

Figure 5 Data Normality Testing for MRR

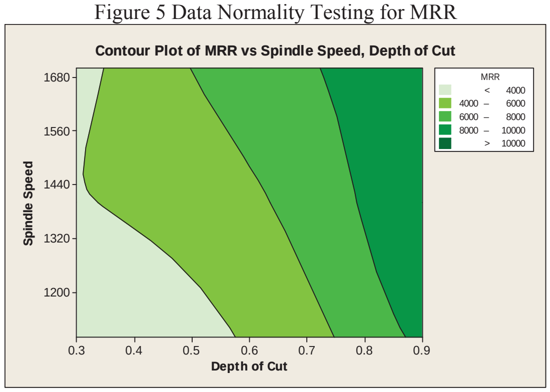

Figure 6 Contour Plot For MRR v/s Spindle Speed ,Depth of Cut.

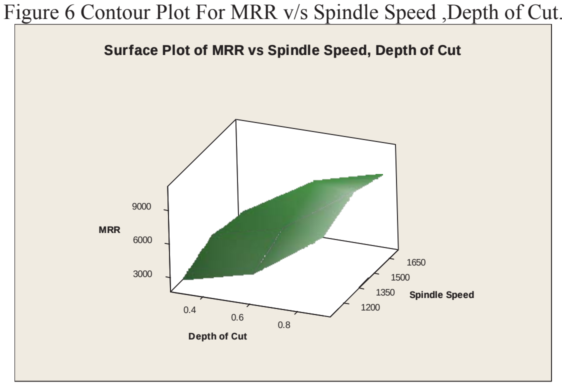

Figure 7 Surface Plot Of MRR Vs Spindle Speed, Depth of Cut

Contour plots are basically orthographic views of 3-D plot and consists of colored regions of input variables bearing different value of output response. On the same pretext figure 7 demonstrates the surface plot and contour plot of MRR Vs Spindle Speed & Feed at holding value of Depth of Cut.

Figure 8 and 9 has been generated as surface and contour plot for MRR Vs Feed and Dept of Cut at holding value of Spindle Speed.

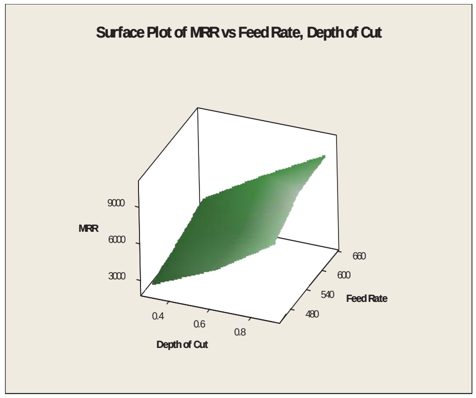

Figure 8 Surface Plot Of MRR Vs Feed Rate , Depth of Cut

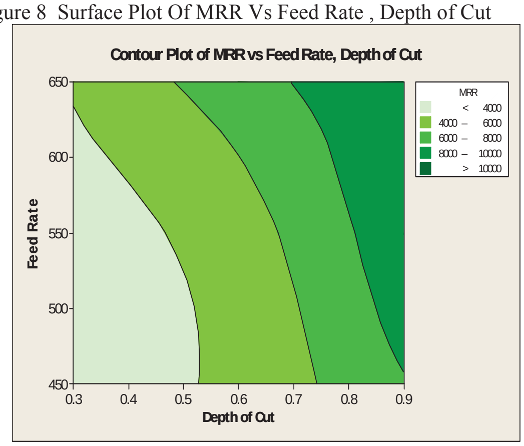

Figure 9 Contour Plot Of MRR Vs Feed Rate ,Depth of Cut

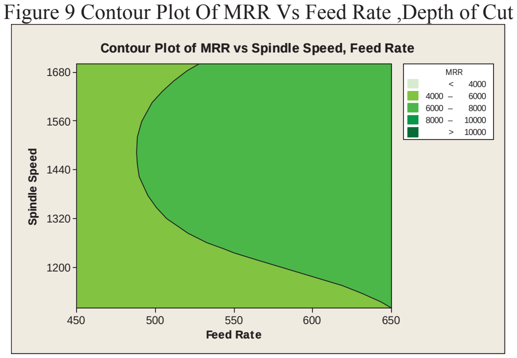

Figure 10 Surface Plot Of MRR Vs Spindle Speed , Feed Rate

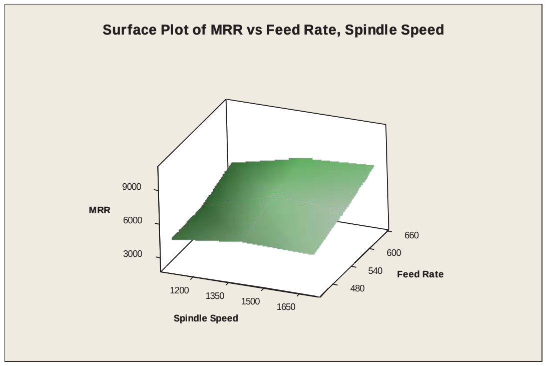

Figure 11 Surface Plot Of MRR Vs Feed Rate , Spindle Speed

Table 6 Estimated Regression Coefficients for MRR using data in uncoded units

Term	Coef
Constant	-8433
Cutting Speed (m/min)	2.0916
Feed rate (mm/rev)	10.383
Depth of cut (mm)	9637.5

Further machining is done on the optimized parameters i.e. Level 2 of Spindle Speed, Level 3 of Feed Rate and Level 3 of Depth of cut. The following Results are obtained.

Table 7 Validation of Result

S.NO	Spindle Speed (Rpm)	Feed Rate (Mm/Min)	Depth Of Cut (Mm)	MRR mm^3 / min
1	1400	650	0.9	9996.8
2	1400	650	0.9	9999.4
3	1400	650	0.9	9994.5

V.CONCLUSION

The important conclusions drawn from the present research are summarized as follows

1. The Material removal rate and surface roughness could be effectively predicted by using spindle speed, feed rate, and depth of cut as the input variables.
2. Considering the individual parameters, Depth of cut and feed rate had been found to be the most influencing parameter, followed by Spindle Speed. For MRR
3. The average actual Material removal rate value had been obtained as 9996.8 mm3/min and the corresponding predicted MRR value is 9926.3 mm3/min.
4. The average actual roughness Ra value had been obtained as 1.25 µm and the corresponding predicted surface roughness value is 1.22 µm.

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