Optimization of Drilling Process Parameters Using Taguchi Method

B. Pavani srikavya[1], N.S.C.Chaitanya[2] , P.Raja Naveen[3]
[1]Department of Mechanical Engineering,
Vignan Institute of Informtion Technology, Viskhapatnam, PIN - 535045, India
[2,3] Department of Mechanical Engineering,Raghu
Engineering college, Viskhapatnam, PIN - 531162, India

ABSTRACT

The major parameters that affect turning operation in terms of material removal rate and surface roughness are speed, feed and depth of cut apart from other variables like material and type of tool. But these are the ones that can be varied during operation. In this work experiments were designed using Taguchi method and material removal rate(MRR) and surface roughness were optimized using ANOVA analysis in order to lessen time, improve performance and to maximize productivity. Influence of radial drilling machine variables on material removal rate and surface roughness for mild steel were investigated and optimum values of input parameters are presented.

Keywords:Taguchi method, ANOVA analysis, optimization of drilling process, S/N ratio, material removal rate, DOE.

INTRODUCTION

Machining is one of the most important material removal methods isacollection of material working processes in which power driven machine tools, such as lathes, milling machines, drilling presses are used with a sharp cutting tool to mechanically cut the material to achieve the desired geometry. The three principal machining processes are classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planning, boring, broaching and sawing.

The three primary factors in any basic drilling operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right atthe machine.

This paper is relatedto optimization of turning process parameters using Taguchi method.Taguchi method is a powerful problem solving technique for improving process performance, yield and productivity.In Taguchimethodology best result is achieved by optimization of control factors using design of experiments. Taguchi created some techniques based on DOE such as signal-to-noise ratio, orthogonal arrays, and robust designs.Mostly orthogonal array technique is used to reduce the complexity and the number of experimental runs involved in solving a problem with full factorial design.

Taguchi developed a special design of orthogonal arrays to study the entire parameters

ISBN : 978-93-87793-94-1

space with a small number of experiments only.The experimental results are then transformed into a signal-to-noise (s/N) ratio. It uses a (S/N) ratio as a measure of qualitycharacteristics deviatingform or nearing to the desired values.

Noise (N): It is a set of uncontrolled parameters which influences thefinal result response.

Signal (S): It is the output variable or response.

Signal to noise ratio (S/N):This indicates robustness of an experiment consolidates several repetitions in to one value the reflects the amount of variation present.

Orthogonal Array is defined as Taguchi has envisaged a new method of conducting the design of experiments which are based on well definedguidelines. This method uses a special set of arrays called orthogonal arrays. An orthogonal array produces a design matrix whose columns areall mutually orthogonal. Orthogonal array contains nine rows. The
maximum number of columns in the orthogonal array depends on number of levels on the experimental designs variables. Each array will containone less number of columns then the number of rows. For example an L32 orthogonal array contains maximum of 32 columns.

1. LITERATURE REVIEW

The purpose of this chapter is to provide a review of past research efforts related to optimization of turning process parameters using Taguchi method. A review of other relevant research studies is also provided. Thereview is done to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort.The review is detailed so that the present effort can be properly tailored to
add to the present body of literature as well as to justify the scope and direction of the present effort.

Yogendra thyagi et al 2012[1] applied Taguchi method for optimization of machining Mild Steel by CNC drilling machine with a HSSTool. Results obtained by taguchi method and signal-to-noise ratio match closely with (ANOVA) and found Spindle Speed of drilling machine Tool mainly affects the SR and feed ratelargely affects the MRR.

Syed et al[2] presents a detailed model for drilling process parameter. The detailed structure includes in the model, are three parameters such as such as Spindle Speed, feed and depth of cut on material removal rate in drilling of 41 Cr 4 material using HSS spiral drill andsimulated by Minitab14 based on Taguchi method, analysis of variance (ANOVA), multivariable linear regression (MVLR), has been developed to determine the optimum conditions leading to higher MRR**.**

K.Lipin et al[3] presented , a comprehensive and in-depth review on optimization of drilling parameters using Taguchi methods.Ahmed Basil Abdulwahhab et al[4] optimized process parameter such spindle speed, feed rate and tool diameter using Taguchi method and Analysis of variance (ANOVA) was employed

ISBN : 978-93-87793-94-1

to determine the most significant control factors affecting the surface roughness.

Kompan Chomsamutr and Somkiat Jongprasithporn[5]compared the cuttingparameters of turning operation the work pieces ofmedium carbon steel (AISI 1045) by finding the longest tool life by Taguchi methods and Response Surface Methodology: RSM and observed both methods showed the same results.Nisha Tamta and R S Jadoun[6] performed Parametric optimization of the drilling machining process for Surface roughness (Ra) has been performed using Taguchi method using statistical software MINITAB-1 and validated with experimental results.Kunal Sharma et al[7] conducted multi-objective optimization of drillingprocess parameters point angle, drill diameter, feed rate and spindle speed using Taguchi method in machining of AISI304 stainless steel.

2. METHODOLOGY

Designs for Taguchi analysis were done according to Taguchi method. Forthree factors and three levels L9 orthogonal array was selected. The experiments for drilling was conducted using a radial drilling machine manufactured by organisation. The radial drilling machine gives a wide variety of feeds, cutting speeds and depth of cut. It is an robust and rigid structure and used for heavy work.

The L9orthogonal array was used for design of experiment. The mild steel work piece of thickness 20 mm , length 150 mm and breadth 100mm was used. Initially the given work piece is fitted the chuck key. The high speed tool bit is positioned in the tool cutting is kept at an angle to the axis of the given piece. During this process positioned in the tool holder, speed of the drill bit is high. After this operation, the diameter of the work piece is to be reduced according to the given dimensions by drilling process. While doing work piece one end of the work piece is reduced to the required diameter. The Metal Removal Rate is measured has been done using weight balancing machining and weight after machining with respect to machining time. Roughness measured as been done using a Talysurf Equipment.

Table 2.1 Level of input parameters

S.No	Parameters	Level1	Level2	Level3
1	Speed	600	1100	1600
2	Feed Rate	0.5	1.0	1.5
3	Depthof Cut	5	7.5	10

Table 2.2 Experimental observations using Taguchi L9 matrix

S.No	Speed (Rpm)	Feed Rate (Mm/ Min)	Depth Of Cut (Mm)	MRR (Cm3/ Min)*10	Surface Roughness (Mm)

1	600	0.5	5	2.3	4.56
2	600	1.0	7.5	4.7	5.09
3	600	1.5	10	7.0	5.94
4	1100	0.5	7.5	4.3	3.29
5	1100	1.0	10	8.6	4.18
6	1100	1.5	5	12.9	5.70
7	1600	0.5	10	6.0	5.25
8	1600	1.0	5	12.0	5.95
9	1600	1.5	7.5	18.0	3.52

3. S/N RATIO CALCULATIONS

Calculation of s/n ratio of metal removal rate:
1.Calculation means:

$$(m)= \Sigma M/n$$

Where, m is mean, ΣM is sum of metal removal rate values and n is number of experiments.
2.Calculation the standard deviation (σ)

$$\Sigma = S/N \text{ ratio } (m/\sigma)$$

Where, m is mean, M is material removal rate values and σ is standard deviation.
3. Calculation of S/N ratio for surface roughness:
Calculation mean (m) = ΣRa/n
Where, m is mean, ΣR is sum of metal removal rate values and n is number of experiments

4. RESULTS AND DISCUSSION

Taguchi method stresses the importance of studying the response variation using the signal to noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of the "the larger the better".

The S/N ratio values arecalculated by taking into consideration equationwith the help of software Minitab 17. The MRR values calculated from the experiments and their corresponding S/N ratio values are listed in table

Table 4.1 SN ratio for Metal Removal Rate

MRR(gm/min)	S/N RATIOS
2.3	7.23456
4.7	13.4420
7.0	16.9020
4.3	12.6694
8.6	18.6900
12.9	21.7272
6.0	15.5630
12.0	21.5836
18.0	25.1055

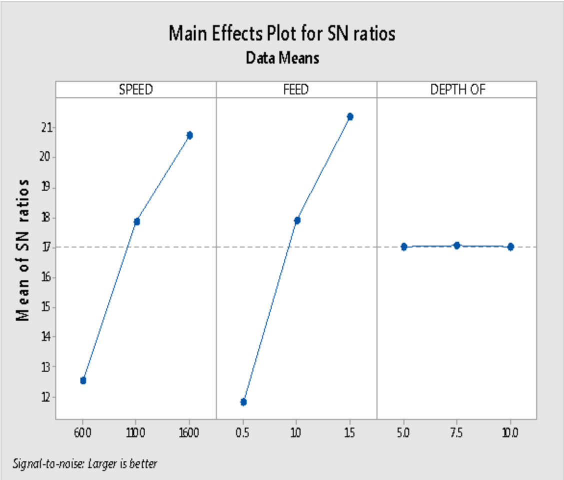

Figure 4.1 Main effects plot for SN ratios for Metal Removal Rate

Spindle Speed :- The effect of parameters spindle speed on the MRR values is shown above figure for S/N ratio. Its effect is increasing with the increase in spindle speed up to 1600 RPM. So the optimum spindle speed is level 3 i.e., 1600 RPM.

Feed Rate:- The effect of parameters feed rate on the MRR values is shown above figure for S/N ratio. Its effect is increasing with then increase in feed rate. So the optimum level is 3. i.e., 1.5 mm/min.

Depth of cut:- The effect of parameters depth of cut on the MRR values is shown above figure for S/N ratio. Its effect is increasing with the increase in depth of cut is level 2 i.e., 7.5 mm.

ANOVA for MRR:

The graphs are plotted by above experimental observations and statistical model normal probability plot, histogram plots, n versus fits plot is generally drawn. If the residual points will be scattered in the residual versus fits plot and if the residual points will follow a straight line in the normal probability line. In the graph that points are represents the number of experiments and the error are uniformly distributed on the trend line and similarly in the versus fits that are equally distributed on the mean line. So from the graphs as shown in figure. It has beencleared that our statistical model is authenticate model.

Table 4.2 Analysis of Variance for MRR

Source	DF	AdjSS	AdjMS	F-value	P-value
Speed	2	0.8225	0.4112	2.10	0.204
Error	6	1.1765	0.1961		
Total	8	1.9990			

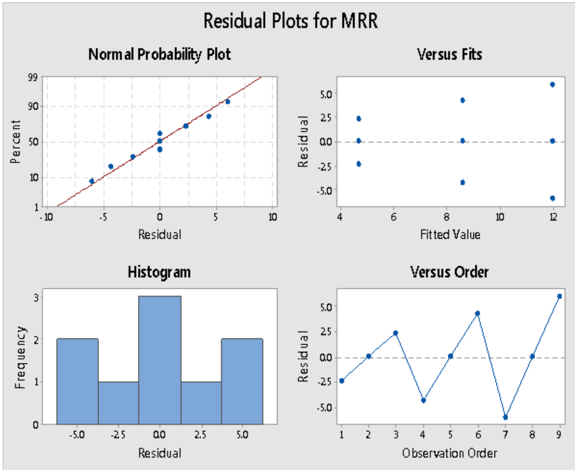

Figure 4.2 Residual plots for Material removam rate

Analysis of variance:

The table 4.2 analysis of variance for MRR represents to investigate how different parameters affect the mean and variance of a process performance characteristic. Here DF means degree of freedom and each parameter have 2 degrees of freedom and Adj SS adjustable sum of squares it was calibrated from mean values and Adj MS adjustable mean square values and F-value is a fisher is a scientist he is the author of robust designing and P-value represents the probability value it having the range of 0-1 and it was calculated from mean values.

Means:

Table 4.3 represents the mean values on metal removal rate for the corresponding factor values. Here N value represent the sample size of the input factors and St Dev means the standard deviation is effects on the each value for individual parameters.

Table 4.3 Mean values on metal removal rate

Speed	N	Mean	St dev	95%CI
600	3	0.467	0.235	(-0.159,1.092)
1100	3	0.860	0.430	(0.234,1.486)
1600	3	1.207	0.590	(0.581,1.832)

Model summary:

Table 4.4 Model summary for Metal Removal Rate

S	R-sq	R-sq(adj)	R-sq(pred)
0.442819	41.14%	2.53%	0.00%

The confirmation analysis result is showed that the Experimental observations and here set the confidence level for regression coefficient is below 95% and here we got 41.14% is obtained for Metal removal rate.

Taguchi analysis for Surface Roughness:

Taguchi method stresses the importance of studying the response variation using the signal-to-noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of the "The Smaller-the better". The S/N ratio for the larger the better is:

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration equation with the help of software Minitab 17. The Surface Roughness values calculated from the experiments and their corresponding S/N ratio values are listed in table 4.5.

Table 4.5 S/N Ratio for Surface Roughness

SR	S/N RATIOS
4.56	13.1793
5.09	14.1344
5.94	15.4757
3.29	10.3439
4.18	12.4235
5.70	15.1175
5.25	14.4032
5.95	15.4903
3.52	10.9309

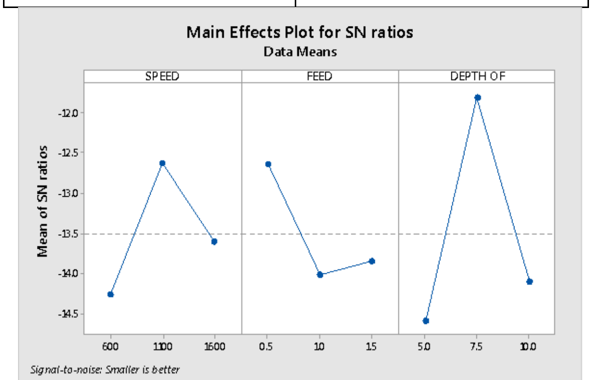

Figure 4.3: Main effect plot for SN ratios for surface roughness

Spindle Speed :- The effect of parameters spindle speed on the SR values is shown above figure for S/N ratio. Its effect is increasing with the increase in spindle speed up to 1600 RPM. So the optimum spindle speed is level 3 i.e., 1600 RPM.

Feed Rate:- The effect of parameters feed rate on the SR values is shown above figure for S/N ratio. Its effect is increasing with the increase in feed rate. So the optimum level is 3. i.e.,1.5mm/min.

Depth of Cut : The effect of parameters depth of cut on the SR values is shown above figure for S/N ratio. Its effect is increasing with the increase in depth of cut is level 2 i.e., 7.5mm.

ANOVA for Surface Roughness:

The graphs are plotted by above experimental observations and statistical model normal probability plot, histogram plots, n versus fits plot is generally drawn. If the residual points will be scattered in the residual versus fits plot and if the residual points will follow a straight line in the normal probability line. In the graph that points are represents the number of experiments and the error are uniformly distributed on the trend line and similarly in the versus fits that are equally distributed on the mean line. So from the graphs as shown in figure 4.4, it has been cleared that our statistical model is authenticate model.

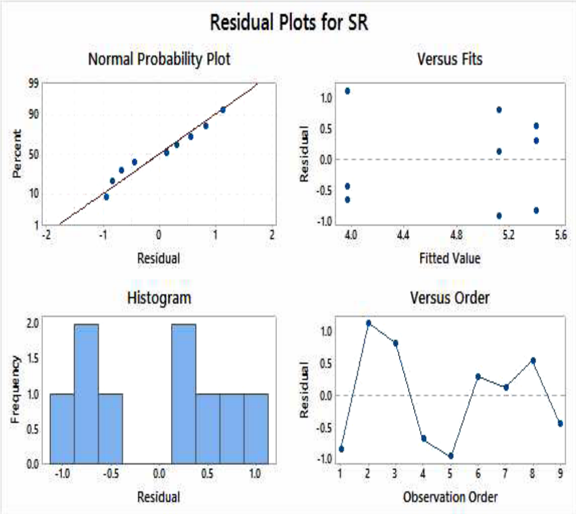

Figure 4.4 Residual plots for Surface Roughness

Analysis of variance:

The table 4.6 analysis of variance for SR represents to investigate how different parameters affect the mean and variance of a process performance characteristic. Here DF means degree of freedom and each parameter have 2 degrees of freedom and Adj SS adjustable sum of squares it was calibrated from mean values and Adj MS adjustable mean

square values and F-value is a fisher is a scientist he is the author of robust designing and P-value represents the probability value it having the range of 0-1 and it was calculated from mean values.

Table 4.6 Analysis of variance for Surface Roughness.

ISBN : 978-93-87793-94-1

Source	DF	AdjSS	AdjMS	F-value	P-value
Speed	2	3.453	1.7266	2.29	0.182
Error	6	4.526	0.7543		
Total	8	7.979			

Means:

In the table 4.7 represents the mean values on Surface Roughness for the corresponding factor values. Here N value represent the sample size of the input factors and St Dev means the standard deviation is effects on the each value for individual parameters.

Table 4.7 Means values for Surface Roughness

Speed	N	Mean	St dev	95%CI
600	3	5.405	0.742	(4.178,6.632)
1100	3	3.969	0.978	(2.742,5.196)
1600	3	5.113	0.869	(3.886,6.340)

Model summary:

Table 4.8 Model summary for Metal Removal Rate

S	R-sq	R-sq(adj)	R-sq(pred)
0.86850	43.28%	24.37%	0.00%

The confirmation analysis result is showed that the Experimental observations and here set the confidence level for regression coefficient is below 95% and here we got 43.28% is obtained for Surface Roughness.

5. CONCLUSIONS

This study deals with the optimization of multiple parameters surface roughness along with material removal rate in such of an optimal parametric combination capable of producing desired surface quality of the turned product in relatively lesser time and enhancement in productivity. The following conclusions may be drawn from the results of the experimental analysis in connection with correlated multi response optimization of drilling process.

Influence of Radial Drilling Machine variable on material removal rate and surface roughness for mild steel investigated in this machining variables included cutting speed, feed rate and depth of cut. After the calculation the minimum surface roughness and maximummetal removal rate:-

- Minimum surface roughness value is 3.29µm is obtained at the speed of 1100 rpm and depth of cut is 7.5mm and feed rate of 1.0 mm/min.
- Maximum metal removal rate of 18.0 cm3/min is obtained at the speed of 1600 rpm and depth of cut is 7.5mm and feed rate of 1.5 mm/min

Analysis was done by considering 95% confidence level and regression coefficients are found to be 0.4114 and 0.4328 for surface roughness. Moderate values of regression coefficients explain the adequacy of data and shown the variance and errors are distributed

ISBN : 978-93-87793-94-1

normally. Finally, the optimum values of input variables are presented in table 5.1

Table 5.1 Optimum values of input variables

S. No	Output	Speed	Feed Rate	Depth Of Cut	Optimum Values
1	MRR (cm^3/min)	1600	1.5	7.5	18.0
2	SR (μm)	1100	1.0	7.5	3.29

REFERENCES

[1] Tyagi, Yogendra, Vedansh Chaturvedi, and Jyoti Vimal. “Parametric Optimization of CNC Drilling Machine for Mild Steel Using Taguchi Design and Single to Noise Ratio.” *International Journal of Engineering Science and Technology* 4 (2012): 10.

[2] Syed, S A, and S D Ambekar. “Experimental Analysis of Material Removal Rate in Drilling of 41Cr4 by A Taguchi’s” 01, no. 04 (2015): 7.

[3] Lipin, K, and Dr P Govindan. “A Review on Multi Objective Optimization of Drilling Parameters Using Taguchi Methods” 4, no. 2 (n.d.): 11.

[4] Ahmed Basil Abdulwahhab, Mostafa Adel Abdullah, Atheer Rasim Mohammed (2016) from Iraq. “Optimization of drilling parameter on surface roughness using Taguchi method”.

[5] Chomsamutr, Kompan, and Somkiat Jongprasithporn. “Optimization Parameters of Tool Life Model Using the Taguchi Approach and Response Surface Methodology” 9, no. 1 (2012): 6.

[6] Tamta, Nisha, and R S Jadoun. “Parametric Optimization of Drilling Machining Process for Surface Roughness on Aluminium Alloy 6082 Using Taguchi Method” 2, no. 7 (2015): 7.

[7] Sharma, Kunal, Mr Abhishek Jatav, and Suresh Gyan Vihar Unversity. “Optimization of Machining Parameters in Drilling of Stainless Steel” 4, no. 8 (n.d.): 7.