Application of Taguchi Method for Optimization of Process Parameters of Aluminum Alloy A-356

Tumul Ozha[1] Pooja Tiwari[2]
[1]M. Tech Student [2]Professor
[1,2]Department of Mechanical Engineering
[1,2]SRIT, Jabalpur(M.P.), India

Abstract— Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The material selected for this experiment is A-356.In our work we have taken three Parameters (Feed Rate, Spindle Speed and Depth of Cut) to Optimize the Aluminum Work piece. S/N ratio and ANOVA analysis were also performed to obtain significant factors influencing Surface Roughness. L9 orthogonal array is employed by considering three factors speed, feed and depth of cut. For each factor three different levels are selected. Signal to noise ratio (S/N) and analysis of variance were employed to find the maximum material removal rate (MRR). The experimental results showed that that the optimal combination of parameters for material removal rate are at spindle speed of 600 rpm, feed rate of 2.2mm/rev, depth of cut 2.0 mm. Optimum results are finally verified with the help of confirmation experiment.

Keywords: Turning Operation, Taguchi method, ANOVA, L-9 Orthogonal array, A-356, MRR

I. INTRODUCTION

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape. Turning is used to produce rotational, typically axis-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. In the process named as turning material is removed from the outer diameter. In this process the work piece is rotating held in the chuck and tool advances which is being held in the tool post advances into it parallel to the axis of work piece and perpendicular to the work piece. The movement of the tool parallel to the axis of w/p is termed as feed and the movement of the tool perpendicular to the w/p is termed as depth of cut. The effect of the combination of these parameters removes the material from the outer surface of the w/p. Turning, generally used to decrease the radial dimensions of the work piece, to indicate dimension, and to give satisfactory surface finish to the work piece. Many a times the turning process on the work piece is done in such a way that the neighboring segments have different radial dimensions.

For optimization of turning process some input and output parameters are considered. In which some are theoretical and some are analytical. From all methods we pick one of the most preferred methods are TAGUCHI method. Machining efficiency is improved by reducing the machining time with high speed machining. The material removal rate (MRR) is an important characteristic in turning operation and high MRR is always desirable. Hence, there is a need to optimize the process parameters in a systematic way to achieve the output characteristics/responses by using experimental methods and statistical models.

II. TAGUCHI METHOD

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize design for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. Taguchi approach to design the experiments easy to adopt and apply for users with limited knowledge of statics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters determined by handbook. Taguchi method is especially suitable for industrial use but can also be used for scientific research. In Taguchi's approach, an optimum design is determined using experimental design principles, and performance consistency is achieved by carrying out trial conditions under the influence of noise factors. Dr. Taguchi employed design of experiments (DOE), which is one of the most important and efficient tools of total quality management (TQM) for designing high quality systems at reduced cost Optimization of a single response results the non-optimum values for remaining responses.

III. OBJECTIVES OF EXPERIMENTS

- To determine the evaluation criterion and decide how each criterion is to be weighed and combined for the overall evaluation.
- To examine all influencing factors and those to be included in the study
- To resolve the factor levels
- To resolve the noise factors and the repetition conditions.

A. *Design for Experiments*

- The factors and levels employed are completed. The experiments are then designed, and the method of carrying them out is established. In designing the experiment, an orthogonal array is implemented as follows:
- Convenient orthogonal array is selected.
- The components decided and their interaction with each other are assigned to columns.

- Each attempt condition is mentioned.
- The order and repetition of attempt conditions is described.
- Handling the experiments.

B. *Outcome Analysis*

- Design factors are Optimized
- Control of individual factors
- Performance at optimum conditions
- Relative influence of individual factors
- Handling a confirmation experiment
- Running the experiments at the optimum condition is the final step in the study.

IV. LITERATURE REVIEW

1) Dr. V. N. Bartaria (2017) conducted a study to optimize the Cutting Parameters for Turning A-356 Alloy using Taguchi Method. The material selected for the experiment is A-356. Experiments were conducted using Taguchi optimization technique. Optimum results are finally verified with the help of confirmation experiment.
2) N Ramesh et al (2016) conducted a study to optimize the process parameters i.e, Cutting Speed, and Depth of Cut maximizing material removal rate (MRR) and minimizing Surface Roughness (Ra) of AA 6061 using PSO. Taguchi method has been employed with an orthogonal array L9 was used to conduct the experiments. Carbide cutting tool was used.
3) Surlimani et al (2016) investigates the machining of EN36B steel to find optimal parameters for CNC turning process. The Taguchi's L9 Orthogonal array is used. The cutting parameters are Speed, Feed and Depth of cut. The Analysis of Variance (ANOVA) and Signal-to-Noise ratio are used to study the performance characteristics in turning operation.
4) Shivam Goyal et al., (2016) conducted an experiment. Work piece used was AISI 2010 mild steel. Cutting tool as WNM G32 RP carbide insert with a nose radius 0.8. Cutting parameters are cutting speed, depth of cut, feed rate. Taguchi methodology was employed.
5) Sujit Kumar Jha (2014) conducted an experiment on turning of Mild Steel using tin coated carbide tool with depth of cut, spindle speed and feed rate as cutting parameters. He investigated that feed is the most relevant factor for mrr using Taguchi method.
6) Ali Abdallah et al (2014) has investigated on turning of Aluminum alloy i.e. AL 6061 using Taguchi method with depth of cut, spindle speed and feed rate as cutting parameters using uncoated inserts for tool.
7) Vishal Francis et al., (2013) conducted an experiment using mild steel 0.18%C. Tool used was mild steel. Cutting parameters were feed rate, depth of cut and spindle speed. The methodology used was Taguchi. The highest optimal parameter for surface roughness and mrr are feed rate and spindle speed respectively.
8) Kamal Hassan (2012) conducted an experiment using medium Brass alloy (C34000) as work piece. The process parameters are cutting speed, feed and depth of cut. This study investigates the effects of process parameters on Material Removal Rate (MRR) in turning of C34000. Optimization of MRR is solved by using Taguchi method. The optimization of MRR is done using twenty-seven experimental runs based on L'27 orthogonal array of the Taguchi method.

The optimum levels of process parameters for simultaneous optimization of MRR have been identified. Optimal results were verified through confirmation experiments. Parameters making significant effect on material removal rate feed rate, and interaction between feed rate& cutting speed were found to be significant to Material removal rate for reducing the variation.

9) D. Philip Selvaraj et al. (2010) investigated that in turning of AISI-304 austenitic steel using TiCS and TiCN coated tungsten carbide cutting tool and the cutting parameters are cutting speed, feed rate and depth of cut, feed rate followed by cutting speed are the optimal parameter for surface roughness.
10) Sidda Reddy et al. (2009) has investigated on turning of Aluminum alloy using carbide cutting tool. The cutting parameters focused on this work are cutting speed, feed, depth of cut and the response is surface roughness. Adaptive Neuro Fuzzy Inference System (ANFIS) and Response Surface Methodology (RSM) are applied to predict the surface roughness.
11) Dr. S S Mahapatra (2006) conducted an experiment using Taguchi method and Genetic Algorithm. The cutting parameters taken were depth of cut, spindle speed and feed rate. Work piece was of material S45C. The highest optimal parameter influencing surface roughness is cutting velocity followed by feed rate. Also cutting velocity and feed rate is having high influence on tool life.

V. EXPERIMENTATION

The experimentation included turning of Aluminum alloy A-356 specimen on lathe which was done in an orderly manner that can be briefed under following main headings:

1) Deciding the control parameter to be analyzed.
2) Deciding the levels for the parameters.
3) Orthogonal array is selected. Here the selected OA is L9.
4) Conducting actual experiment as per the L9 Orthogonal Array.
5) Analysis of data which is obtained from the experiment
6) Result derived after the analysis phase and then the conclusion.

We used an Aluminum alloy A-356 rod having a diameter of 3.8cm and weighted 1.62 kg on which further tests were done to check its mechanical properties.

VI. WORKPIECE MATERIAL

A356.0 ALUMINIUM ALLOY is the material selected for the experiment. It is a cast alloy.(7Si - 0.3Mg).

A. *Chemical Composition of the material*

Max. 0.35 Mn
Max. 0.25 Cu
0.20 to 0.45Mg,
Max.0.6 Fe
Max.0.25 Ti
6.5 to 7.5 Si,

Max.0.35 Zn
Max. 0.15 others (total)
Max.0.05 other (each)
Rest is Al.

B. Mechanical Properties

Tensile stress 230 (N/mm^2)
0.2%. Proof Stress 185(N/mm^2)
Impact - Brinell hardness 75 Elongation 2(%)
Endurance Limit 56
Modulus of Elasticity 71
Shear strength 120

C. Applications of Aluminum A-356

Typical applications are airframe castings, machine parts, truck chassis parts, aircraft and missile components, and structural parts requiring high strength aircraft pump parts, cylinder blocks (water cooled), aircraft fittings and control parts. Other applications of A-356 are where good cast-ability is required and appreciable resistance to corrosion is required. Engine controls and aircraft structures, installations using nuclear energy.

1) Lathe Machine and Cutting Tools Used

PL-4 Bench Lathe Close grained ground alloyed Casted Iron bed with hardness of 190 -220 BH. Tool material-HSS Steel, which has a hot hardness value of about 600° C, possesses good strength and shock resistant properties.

PARAMETERS	UNIT	LEVEL -1	LEVEL -2	LEVEL -3
SPEED (A)	RPM	250	450	600
DEPTH OF CUT (B)	mm	0.6	1.6	2.0
FEED (C)	mm/rev.	2.2	2.8	3.0

Table 1: Control parameter and their values

VII. CONDUCTED EXPERIMENT

The experimentation included turning of Aluminum alloy A-356 specimen on lathe which was done in an orderly manner that can be briefed under following main headings:

1) Deciding the control parameter to be analyzed.
2) Conducting actual experiment as per the L9 Orthogonal Array.
3) Analysis of results and conclusion.

We used an Aluminum alloy A-356 rod having a diameter of 3.8cm and weighted 1.62kg on which further tests were done to check its mechanical properties.

After setting the parameters in the required format we have started doing the main experiments on the basis of Taguchi's L9 format and the length of each specimen turned is about 1.5 cm and the other parameters kept varying according to the table of Taguchi's L9 setting at different parameters that are termed as

S. No.	Speed(A) rpm	Depth(B)mm	Feed(C) mm/rev
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2: L9 Orthogonal Array

The combination of different parameters is decide as per given in the table and considerable MRR is measured each time during each experiment. The numerical value of material removal rate MRR is calculated which is given in the table-

Trial No.	Levels			
	Speed, A (RPM)	Depth of cut, B (mm)	Feed, C (mm/rev.)	MRR (mm3/Sec.)
1	250	0.8	2.2	0.5879
2	250	1.6	2.8	0.6836
3	250	2.0	3.0	0.8967
4	450	0.8	2.8	1.0901
5	450	1.6	3.0	1.2244
6	450	2.0	2.2	2.0223
7	600	0.8	3.0	1.6037
8	600	1.6	2.2	2.4691
9	600	2.0	2.8	2.2171

Table 3: Experiments performed

A. Analytical Analysis of Variance (ANOVA):

The analysis of variance (ANOVA) is another optimizing tool mentioned in the factorial design method to further optimize above parameters as discussed in section.

ANOVA is a statically based, objective decision making tool for detecting any differences in average performance of groups of items tested. An ANOVA table consists of sum of squares(SS), corresponding degree of freedom, the F-ratio corresponding to the ratios of two mean squares, and the contribution proportions from each of the control factors. These contributions proportions can be used to assess the importance of each factor for interested multiple performance characteristics (MPCs).

B. Analysis of Material Removal Rate(MRR)

After selecting the factors to be considered for the result analysis:

Degree of freedom (DOF) Variance Sum of Squares are calculated We apply these elements and on the basis of these elements we have formulated a table that shows the values of all these elements for different parameters that we have selected in our study in an order of:

Factors	DOF	Adj SS	Adj MS	F RATIO	P%
SPEED (A)	2	2.83398	1.41699	90.50	11%
DEPTH OF CUT (B)	2	0.57942	0.28971	18.50	51%
FEED (C)	2	0.34336	0.17168	10.97	84%
ERROR	2	0.03131	0.01566		
TOTAL	8	3.78808			

Table 4: Variance of Means

The above table is used to show the variance of means for the different parameters that we have selected for our experiment and the contribution P% shows that which factor is mainly required as the driving force for the whole experiment.

S/N ratio for MRR.

$$n = -10\log\left(1/n\sum_{i-1}^{n} 1/MRR^{\wedge}2\right)$$

Signal-to-noise ratio is also called as SNR or S/N, is defined as the ratio of signal power to the noise power corrupting the signal. The Signal to Noise Ratio (SNR) is the defining factor when it comes to quality of measurement. A high SNR guarantees clear acquisitions with low distortions and amount caused by noise. The better your S/N, the better the signal stands out, the better the character of your signals, and the better your ability to get the results you desire.

MRR	MRR^2	$1/MRR^2$	S/N Ratio (n)
0.5879	0.3456	2.8933	-4.6139
0.6836	0.4673	2.1399	-3.3040
0.8967	0.8041	1.2437	-0.9471
1.0901	1.1883	0.8415	0.7493
1.2244	1.4992	0.6670	1.7585
2.0223	4.0897	0.2445	6.1169
1.6037	2.5719	0.3888	4.1025
2.4691	6.0965	0.1640	7.8508
2.2171	4.9155	0.2034	6.9157

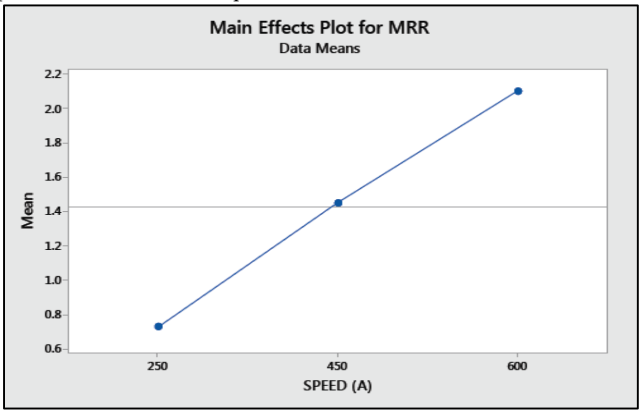
Table 5: Calculation of S/N ratio

SPEED (A)	DOC (B)	FEED (C)	MRR (mm3/sec)	S/N RATIO (n)
1	1	1	0.5879	-4.6139
1	2	2	0.6836	-3.3040
1	3	3	0.8967	-0.9471
2	1	2	1.0901	0.7493
2	2	3	1.2244	1.7585
2	3	1	2.0223	6.1169
3	1	3	1.6037	4.1025
3	2	1	2.4691	7.8508
3	3	2	2.2171	6.9157

Table 6: Response table

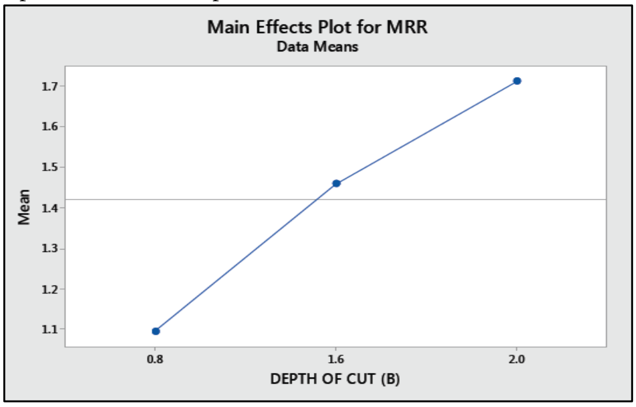
C. Graphs of Mean Values

The different graphs for the various parameters are drawn and these graphs are used to find out the combination of parameters that are required to achieve a maximum MRR.



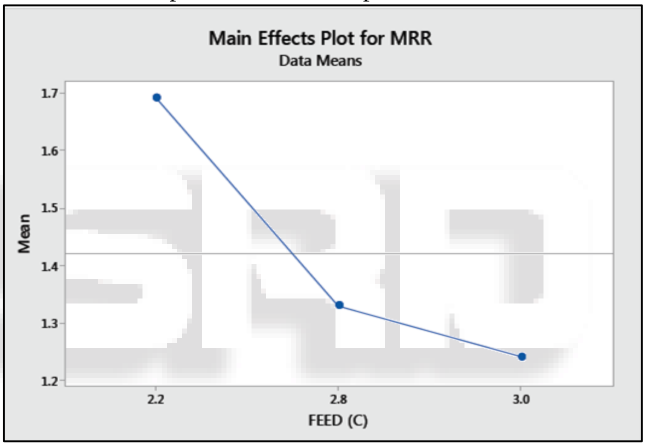
Graph 1: Mean vs. Speed

From the above graph we can conclude that the maximum value of material removal rate occurs at the level 3 of the experiment i.e. the optimum value is A3.



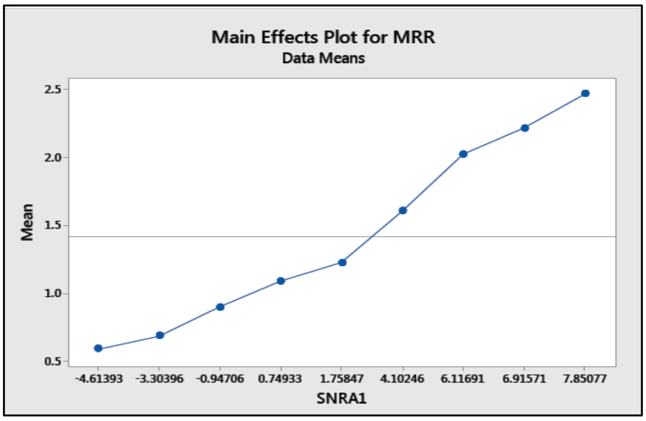
Graph 2: Mean vs. Depth of Cut

The above plot shows the variation of different levels of experiment on X-axis and the mean values of the parameter B (depth of cut) on the Y-axis. The graph shows that maximum value of material removal rate occurs at the level 3 of the experiment i.e. the optimum value is B3.



Graph 3: Mean vs. Feed

From the graph we have conclude that the optimum value of the maximum MRR occurs at level 1 i.e. C1.



Graph 4: Mean vs. S/N Ratio

VIII. RESULT AND DISCUSSION

The optimal values of individual parameters and the corresponding setting of the parameters are given in the table below-

Performance Characteristics	Optimal parameter level	Predicted parameter level
Material removal rate	A3, B3, C1	2.4691

Table 7: Result table

A. Confirmation Test:

The confirmation experiment is the final step in the first iteration of the design of the experiment process. The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. The confirmation experiment is performed by conducting a test with a specific combination of the factors and levels previously evaluated. In this study, after determining the optimum conditions and predicting the response under these conditions, a new experiment was designed and conducted with the optimum levels of the turning parameters. The final step is to predict and verify the improvement of the performance characteristic. The results of experimental confirmation using optimal turning parameters and comparison of the predicted material removal rate with the actual material removal rate using the optimal turning parameters are shown in Table-

Performance Characteristics	Optimal parameter level	Predicted parameter level
Material removal rate	A3, B3, C2	2.65846

Table 8: Confirmation table.

IX. Conclusion

The above investigation and graphs gave us the results which yields the maximum MRR at a specific combination. By using these combinations of parameters of machining using the selected parameters of the machining we can optimize the material removal rate to a value. The metal considered by us in this experiment is Aluminum alloy A-356 which is cast alloy and ductile material to machine.

Parameters	Units	Optimum levels	Optimum values
SPEED (A)	RPM	3	600
DOC (B)	mm	3	2.0
FEED (C)	mm/rev.	1	2.2

Table 9: Selected parameter and their values at optimum levels

References

[1] Sujit Kumar Jha, (2014). “Optimization of Process Parameters for optimal Mrr During Turning Steel Bar using Taguchi Method and Anova”, International Journal of Mechanical Engineering and Robotics Research, Vol. 3, No. 3, July.

[2] Ali Abdallah, Bhuvenesh Rajamony, Abdulnasser Embark, (2014). “Optimization of cutting parameters for surface roughness in CNC turning machining with aluminum alloy 6061 material”, ISOR Journal of engineering.

[3] Kamal Hassana, Anish Kumar and M.P. Garg, (2012). “Experimental investigation of Material removal rate in CNC turning using Taguchi method”, International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 2, pp.1581-1590.

[4] N. Ramesh, D. Lokanadham, N. Tejeswara Rao, (2016). “Optimization of MRR and surface roughness for turning of AA6061 using Taguchi method and PSO”, International Research Journal of Engineering and Technology, Volume: 03, Issue: 11.

[5] Sidda Reddy B, Suresh Kumar J and Vijaya Kumar Reddy K (2009). “Prediction of Surface Roughness in Turning Using Adaptive Neuro-Fuzzy Inference System”, Jordan Journal and Industrial Engineering, Vol. 3, No. 4.

[6] P. Surulimani, A. Karthikraja, V. Sivaganesan, J.Gowthama, M. Yojiith (2016). “Optimization of CNC Turning Parameters on EN36B Steel Using Taguchi Method”. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 2.

[7] Dr. S.S. Mahapatra Amar Patnaik Prabina Ku. Patnaik, (2006). “Parametric Analysis and Optimization of Cutting Parameters for Turning Operations based on Taguchi Method”, Proceedings of the International Conference on Global Manufacturing and Innovation.

[8] Selvaraj D. Philip, Chandarmohan P., (2010). “Optimization of surface roughness of AISI 304 austenitic stainless steel in dry turning operation using Taguchi design method”, Journal of Engineering Science and Technology Vol. 5, No. 3, pp. 293–301.

[9] Shivam Goyal, Varanpal Singh Kandra, Prakhar Yadav (2016). “Experimental Study of Turning Operation and Optimization of Mrr and Surface Roughness using Taguchi Method” International Journal of Innovative Research in Advanced Engineering, Issue 03, Volume 3.

[10] Vishal Francis, Ravi. S. Singh, Nikita Singh, Ali. R. Rizvi and Santosh Kumar (20130. Application of Taguchi Method and ANOVA in Optimization of Cutting Parameters for Material Removal Rate and Surface Roughness in Turning Operation. International Journal of Mechanical Engineering and Technology, Volume 4, pp. 47-53, May -June 2013.

