Optimization of Turning Parameters of AL-Alloy 6082 using Taguchi Method

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Abstract
Every manufacturing industry aims at producing a large number of products within lesser time.This experiment shows the optimization of cutting parameters for surface roughness & material removal rate in the turning process to obtain the optimal setting for the process parameters and analysis of variance is used to analysis the influence of cutting parameters while turning. Orthogonal array is also beenused and prepared to obtain the optimal levels and to analyse the effect of each turning parameters. The S/N ratio is been calculated to structure the ANOVA table and study the performance characteristics in turning process. ANOVA analysis gives the contribution percentage of every process parameter. The number of experiments are to be obtained using full factorial design for optimal result.

1. Introduction

The turning operation is a machining operation performed on metals that is used widely in various industries working on metal cutting. The machining parameters selected for a turning operation is an important procedure in order to achieve high performance. Surface roughness is a term considered as a product quality index that is used to measure the surface finish of a product. As better as the surface finish, we can get the improved strength properties. The best parameter to judge the quality of turned product is surface roughness which is very important for a product. Surface roughness gives product a longer life, strength properties & affects the functional properties like friction, heat transmission, light reflection properties, etc. Production cost of an individual product is also get affected by surface roughness. As we try to minimize the surface roughness, we can accomplish towards the optimal parameters by optimizing some of the cutting parameters.

1.1. Taguchi Method

The Taguchi method is used for producing high quality product at minimum cost. This method is a conventional method. This method designs the experiment in an efficient & effective manner and analyse the process influencing parameter in lesser time. It is a modified method in design and analysis compared to traditional design and is widely used in making quality improvements. This is performed or done to find the suitable combination of parameters with the varying responses. Taguchi method is a powerful tool to design optimization for quality. It is used to find the optimal cutting parameters such as cutting speed, feed rate, depth of cut and nose radius, etc. as the overall cost can be reduced. This experiment gives some background of optimization technique applied to various turning processes for improving surface roughness.The Taguchi method is widely used to find an optimum setting of manufacturing process parameters. The objective of parameter design is to optimize the settings of the process parameter values for improving the performance characteristics and to identify the product parameter values.

1.2. S/N Ratio Analysis

Signal-to-noise ratio (abbreviated SNR or S/N ratio) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is the ratio of signal power to the noise power, often expressed in decibels. The Taguchi method uses a loss function to determine the quality characteristics. Loss function values are also converted to a signal-to-noise (S/N) ratio (η). In general, there are three different quality characteristics in S/N ratio analysis, namely “Nominal is the best”, “Larger is the better” and “Smaller is the better”. For each level of process parameters, signal-to-noise ratio is calculated based on S/N analysis. The optimal level of the process parameters is the level having highest S/N ratio.

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2.Litrature Review

A review study of literature on surface roughness modeling on turning is presented in this section.

Rajpoot, et al. [1] used RSM to find the effect of cutting speed, feed and depth of cut on surface roughness and MRR while turning of AA6061. He does to find out the effect of every factor individually on surface roughness face centered design based on RSM. At three different points, the surface roughness is measured. In Design Expert 8.0.4.1 software, the results of 20 experimented samples were examined methodically to get the surface roughness & MRR. ANOVA was performed to analyze the regression model which was developed for evaluating surface roughness for an accuracy of 95%. Both surface roughness and MRR are found to be significant factors amongst the three cutting parameters.

BalaRaju, et al. [2] studied the effect of cutting speed, feed and depth of cut while turning mild steel and aluminumby using HSS tool which was done to get better surface finish and to decrease power requirement. 2k factorial techniques were used to carry out the experiments. ANOVA was used to carry out the effect of cutting parameters and multiple regression analysis was used to develop cutting forces Feed was found to be significant factor effecting on both surface roughness and cutting force.

Hakim et al. [3] analyzed the effect of machining parameter on cutting force component in hard turning of AISI T15 high speed steel. The cutting force during the turning of the alloy steel was remarkably affected by the type of the chip produced.

Lawal et al. [4] evaluated the effect of cutting fluids on cutting force components in turning of AISI 4340 steel using Taguchi method. The results showed that cutting speed and cutting fluid were significant factors on cutting force measurements.

Borse [5] he was focused on optimizing turning parameters based on the Taguchi method to minimize the surface roughness and maximize the metal removal rate by using SAE 52100 steel with carbide inserts. Results of this study indicate that the feed rate is mostly influencing the surface roughness of the machined surface.

Deore et al. [6] used Taguchi method for optimization of machining parameters for minimum cutting forces. Turning operation was done on lathe machine on EN 19 steel. Through ANNOVA it is found out that Depth of cut is the significant factor for thrust force, and feed rate is the significant factor for feed force. Multiple regression equation was established to estimate the value of performance level for any parameter level.

Lodhi, et al. [7] experimented to optimize the surface roughness & material removal rate during machining of AISI 1018 alloy with Titanium coated carbide inserts. Spindle speed, feed rate & depth of cut were the input parameters. The experiment was performed in CNC Lathe machine using L9 orthogonal array. Surface roughness & material removal rate were obtained at the lowest and highest level respectively. ANOVA was used to obtain the most significantly effecting factor which was spindle speed for surface roughness & material removal rate with 75.295% & 78.173% respectively.

Mohan, et al. [8] examined the cutting speed, feed rate & depth of cut to get the minimum surface roughness. The work piece material used in the experiment was AISI 52100 steel alloy& cutting tool was Carbide inserts with nose radius 0.80. L9 orthogonal array was used for machining. Feed rate was found to be most significantly effected on surface roughness by ANOVA analysis.

Paramasivam et al. [9] studied the optimization of cutting speed, feed rate & depth of cut on surface roughness & material removal rate for EN24 steel based on regression analysis. Spindle speed is the significant factor over surface roughness & material removal rate.

Narayana Reddy et al. [10] analyses the machining parameters for 20MnCr5 steel in CNC horizontal lathe. The study of performance characterstics were by S/N ratio & ANOVA. L9 orthogonal array was used to design the experiment. Cutting speed, feed rate, depth of cut & hardness of tool were input parameters on output parameters like surface roughness & material removal rate.

Koura, et al. [11] inspected the cutting speed, feed rate & depth of cut on surface roughness during turning of mild steel by Carbide inserts using Artificial Neural Network. Total 27 were performed in dry condition using full factorial design. 19 out of 27 experiments were used for training and rest 8 for validation. The error calculated was 5.4%. in conclusion, they found the increase in feed rate increases surface roughness & increase in cutting speed decreases surface roughness.

Nithyanandhan et al. [12] have investigated the effects of process parameters on surface finish and material removal rate (MRR) to obtain the optimal setting of process parameters. And the analysis of Variance (ANOVA) is also used to analyse the influence of cutting parameters during machining. In this work, AISI 304 stainless steel work pieces are turned on conventional lathe by using tungsten carbide tool. The results revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR.

Shunmugesh et al. [13] studied the machining process in turning of 11sMn30 alloy using carbide tip insert in dry condition. The optimal settings for the cutting parameters were obtained. The three level cutting parameters were cutting speed, feed rate and depth of cut. The turning experiment was conducted using L27 orthogonal array in CNC turning centre stallion 200. The roughness values Ra and Rz were measured in Mitutoyu SJ210 surface roughness tester. The statistical analysis was done by MINITAB 17. It was found that the feed rate is the most significant factor to affect surface roughness other than cutting speed and depth of cut.

Shunmugesh et al. [14] they have made attempt to search for a set of optimal process parameter value that leads to minimize the value of machining performance. This study aimed at optimizing machining performance and the input parameters for 11sMn30. The input parameters considered for the study were speed, feed and depth of cut. The Taguchi analysis is used for optimizing the machining parameter.

Sharma et al. [15] have analyzed that Taguchi optimization technique pair with grey relational analysis has been adopted for evaluating parametric complex to carry out acceptable surface roughness lower is better, material removal rate higher is better of the AISI 8620 steel during turning on a CNC Lathe Trainer. After identify the optimal process parameters setting for turning operation, ANOVA is also applied for finding the most significant factor during turning operation. In this study it is concluded that the feed rate is the most significant factor for the surface roughness and material removal rate together, as the P-value is less than 0.05. Cutting speed and depth of cut is found to be insignificant from the ANOVA study.

Shivade et al. [16] have analysed that the application of single characteristics optimization approaches for turning processes. These approaches utilized in many fields to optimize the single and multi-performance characteristics efficiently. Turning is one of the most basic machining processes in traditional manufacturing process.

Quazi, et al. [17] utilized Taguchi method to optimize the surface roughness in turning EN8, EM31 and mild steels. The three levels turning parameters considered were cutting speed and feed rate. The tool grades considered were TN60, TP0500 and TT8020. The experiments were carried on Supercut 5 turning machine. The roughness was measured by Wyko NT9100 Optical Profiling System. The Taguchi method was designed and analysed by MINITAB statistical 16. L9 orthogonal array was used for analysis of all the materials along with three cutting tools. It was observed that feed rate has highest effect on surface roughness for all the three alloys.

Ranganath et al. [18] investigated the effect of the cutting speed, feed rate and depth of cut on surface roughness and material removal rate (MRR), in conventional turning of Aluminium (6061) in dry condition. The feed and speed are identified as the most influential process parameters on surface roughness. The optimum MRR was obtained when setting the cutting speed and feed rate at high values, but the optimum surface roughness was reached when the feed rate and depth of cut were set as low as possible. Low surface finish was obtained at high cutting speed.

Shivade et al. [19] the experiment was conducted to determine the optimum cutting parameters setting for minimizing surface roughness when turning of EN8 steel material. The L9 orthogonal array design is used for design the experiments. The analysis of variance (ANOVA) employed to analysis the influence of performance parameters during turning.

Sharma et al. [20] applied Taguchi orthogonal design to optimize the setting of cutting parameters in surface roughness. The experiments were conducted in CNC machine taking the cutting parameters as cutting speed, feed and depth of cut using coated carbide single point cutting tool. The material taken for experiment was mild steel 1018. For three levels three factors L27 orthogonal array was used. ANOVA and signal to noise ratio were examined using MINITAB 16 software. It was found that there were 3.2% error between predicted value and experimental value. This experiment showed that feed has immense effect on surface roughness in turning mild steel 1018 with coated carbide single point cutting tool.

Patel et al. [21] investigated the Effect of Process Parameters on MRR and Surface Roughness in Turning Operation on Conventional Lathe Machine for Aluminum 6082 Grade Material Using Taguchi Method. The most significant parameters for material removal rate were speed, depth of cut and least significant factor for MRR was nose radius. For surface roughness speed, nose radius was the most significant parameters and least significant factor for surface roughness is depth of cut.

Alagarsamy et al. [22] have studied the use of Taguchi's technique for minimizing required surface roughness and maximizing the material removal rate in machining Aluminium Alloy 7075 using TNMG 115 100 tungsten carbide tool. The experimental results revealed that the feed is the most significant parameter for surface roughness followed by speed and depth of cut. They also analyzed that the most significant parameter for MRR is speed and followed by feed and depth of cut.

Selvaraj et al. [23] optimized cutting parameters using Taguchi method in dry turning of stainless steel. The result showed that feed rate was the significant factor to control the cutting force components.

Suresh et al. [24] depicted that Taguchi design is an effective way in finding optimal process parameters for achieving low surface roughness, high VMRR and low interface temperature.

Shreemoykumarnayak et al. [25] the investigation was carried out the effect of machining parameters during dry turning of AISI 304 austenitic stainless steel. For this study HMT heavy duty lathe machine was used. They have adopted L27 orthogonal array with three machining parameters like cutting speed, feed rate and depth of cut and three importance characteristics of machinability such as material removal rate, cutting force and surface roughness were measured. For the optimization of machining parameters, Grey relational analysis was used.

Neerajsaraswat et al. [26] they determined the optimal cutting parameters for EN9 steel in turning operation. The analysis of variance (ANOVA) and signal to noise ratio (S/N ratio) were used to study the performance characteristics in turning operation. The cutting speed, feed rate and depth of cut were selected as a input parameters to optimize the surface roughness.

Nayak et al. [27] investigated the influence of different machining parameters such as cutting speed, feed and depth of cut on material removal rate, cutting force and surface roughness during dry turning of AISI 304 austenitic stainless steel. L27 orthogonal array design of experiments was adopted. To optimize the machining parameters GRA was used.

Alrashdan et al. [28]proposed multi-criteria optimization approach to optimize the cost and electrical energy consumption during the end milling machining process of AISI D2 steel. The machining parameters feed, speed, and depth of cut were considered. Regression analysis was used to model the surface roughness and energy consumption. The genetic algorithm was used to optimize the cost function.

Sahuet al. [29] have conducted an experiment to optimize the cutting parameters such as cutting speed, depth of cut, and feed in dry turning of AISI D2 steel to achieve less tool wear, optimum work piece surface temperature and maximum material removal rate. The results showed that depth of cut and cutting speed are the most important parameter influencing the tool wear.

Warhade et al. [30] paper investigated the effect of cutting parameters namely; cutting speed, depth of cut and feed rate on minimize required machining time and maximizing metal removal rate during machining of Aluminium Alloy 6063 using VBM0.2 tool. Experiments were conducted based on the established Taguchi's technique L27 orthogonal array and MINITAB-16 statistical software is used to generate the array.

Francis et al. [31] optimized the cutting parameters of mild steel (0.18% C) in turning to obtain the factors effecting the surface roughness and MRR. To study the influence of cutting parameters they applied ANOVA and Signal to Noise ratio. The cutting parameters like spindle speed, feed and depth of cut were taken into consideration. A total of 27 experiments were done which were designed according to Taguchi method. The experiments were performed by using HSS cutting tool in dry condition. For MRR the most significant factor was spindle speed whereas feed was the most significant factor forsurface roughness.

3.Material and Method

3.1Workpiece Material

The main properties of Aluminium are lightweight, strength, recyclability, corrosion resistance, durability, ductility, formability and conductivity, which make them valuable material. Due to this unique combination of properties, the variety of applications of Aluminium**(**AA6082)is preferred for our experimental process.Material plays an important role in the machining process. Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength amongst the 6000 series aluminium alloys. Aluminium Alloy 6082 is known as a structural alloy.AA6082 is the alloy most commonly used for machining. As a relatively new alloy, the higher strength of 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy. It is difficult to produce thin walled, complicated extrusion shapes in alloy 6082. The extruded surface finish is not as smooth as other similar strength alloys in the 6000 series.AA6082 has some applications where it is used like trusses, bridges, cranes, transport applications, beer barrels, milk churns, highly stressed applications, etc.

3.2Tool Material

The turning tools used for this experiment are based on the basis of different tool materials i.e. High Speed Steel tool (HSS), Carbide tool and Cobalt tool with 5% carbon contents. This is done to find the suitable tool amongst these three tools which can give the best surface finish.

3.3 Selection of Factors & Parameters

There are three cutting parameters which are planned using 3 level full factorial experimental designs. This is done to find the optimal conditions by turning process are -

- Spindle Speed (rpm)
- Flank Angle (°)
- Depth of Cut (mm)

The factors that can get affect by the cutting parameters considered

- Surface Roughness (μm)
- Material Removal Rate (mm3/sec)
- Machining Time (sec)

Table 1: Chemical Composition of AA6082

Elements	Composition %
Silicon	0.70-1.30
Magnesium	0.60-1.20
Manganese	0.40-1.00
Iron	0.0-0.50
Chromium	0.0-0.25
Zinc	0.0-0.20
Others	0.0-0.15
Titanium	0.0-0.10
Copper	0.0-0.10
Aluminium	Balance

Table 2: Physical Properties of AA6082

Property	Value
Density	2.70 g/cm3
Melting Point	555°C
Thermal Expansion	24x10-6/K
Modular of Elasticity	70 GPa
Thermal Conductivity	180 w/m.K
Electrical Resistivity	0.038x10-6 Ω.m

Table 3: Machining Parameters & Levels

Parameters	Level 1	Level 2	Level 3
Spindle Speed	900	615	407
Flank Angle	12	8	4
Depth of Cut	1.1	0.9	0.7

3.4Experimental Setup

The turning machines are, of course, every kind of lathes. Lathes used in manufacturing can be classified as engine, turret, automatics, and numerical control etc. The lathe machine on which my experiment will conduct is provided by Production Lab, SET, Sharda University. Specifications of the lathe are given by table 4.

Fig. 1: Lathe of SET

Table 4: Specification of Lathe

Specification	Value
Length of Bed	1050 mm
Height of Center	165 mm
Width of Bed	238 mm
Max Swing over Bed	330 mm
Max Swing over Slide	180 mm
Spindle bore	40 mm

Spindle Nose	8TPI
Spindle Speed	35-825 RPM
Cross Slide Travel	225 mm
Lead Screw	4 TPI
Tail Stock Sleeve	MT-3
Power Required	1 HP

3.5 Methodology

For getting accurate results, various types of analysis methods such as Taguchi methods, Regression Analysis etc. are used then ANOVA is performed for analysis. His method focuses on the effective application of engineering strategies rather than advanced statistical techniques. In this experiment, Taguchi is used to evaluate the effect of input parameters on the responses of the turning of AA6082. For analysis, MINITAB 17 is used in the experimental work. The performance and percentilecontribution of individual parameters to be done by Surface Roughness, MRR and Machining Time is measured with the help of S/N ratio & ANOVA.

The general steps involved for performing this experiment are as follows-

- Define the process objective& a target value for a performance measure of the process. The target of a process may also be a minimum or maximum. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure that can be easily controlled. The number of levels that the parameters should be varied must be specified.
- Create Orthogonal Arrays (OA) for the parameter design indicating the number of conditions for each experiment.
- Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
- Complete data analysis to determine the effect of different parameters on the performance measure.

1. ANOVA is used in the analysis of comparative experiments those in which only the difference in outcomes is of interest.
2. The statistical significance of the experiment is determined by a ratio of two variances which is independent of several possible alterations to the experimental observations. Multiplying all observations by a constant does not alter significance. So, ANOVA statistical significance results are independent of constant bias and scaling errors as well as the units used in expressing observations.

3.6 Calculation

Each work piece is cut in size of 28mm diameter and 100mm length which is performed on Lathe turning centre. Turning setup is made prepared and data is feed in the NC machine. Weighing device is the instrument used for measuring initial and final weight of the work piece will be noted. Machining time is noted by stopwatch.

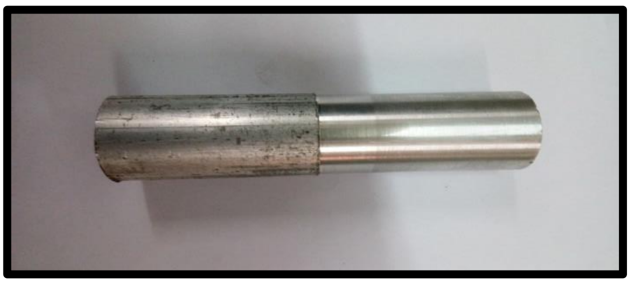

Fig. 2: AA6082 Workpiece

Material removal rate will be calculated by using relation.

$$MRR = (Wi – Wf) / \rho \times T \text{ mm3/sec}$$

Where, Wi–initial weight of the work piece (gm)
Wf– final weight of the work piece (gm)
T – Machining time (sec)
ρ – Density of material (kg/m3)

Loss function is to determine the quality characteristics used by Taguchi method. Loss function values are also converted to a signal-to-noise (S/N) ratio η. The term "signal" represents the desirable value (mean) for output characteristic and the term "noise" represents the undesirable value for the output characteristic. There are three categories of the performance characteristic in the analysis of the S/N ratio, i.e., lower-the-better, nominal-the-better and higher-the-better. The S/N ratio for each level of process parameters is based on the S/N analysis performed on MINITAB 17. The optimal level of the process parameters is the level having highest S/N ratio.

Signal to Noise Ratio: Smaller is better

$$S/N \text{ Ratio} =-10 \log (\sum Y2/n)$$

Signal to Noise Ratio: Larger is better

$$S/N \text{ Ratio} =-10 \log (\sum(1/Y2)/n)$$

Signal to Noise Ratio: Normal is better

$$S/N \text{ Ratio} =10 \log (\sum \bar{Y}2/S2)$$

Where, Y - Observed data at ith trial
n -Number of trials

Table 5: Experimental Result for HSS tool

Sr. No.	Spindle Speed (rpm)	Flank Angle (º)	Depth of Cut (mm)	SR (µm)	MRR (103mm3/sec)	MT (sec)
1	900	12	1.1	0.208	3.737	22
2	900	8	0.9	0.995	2.929	22
3	900	4	0.7	0.924	1.697	22
4	615	12	0.9	0.458	2.289	20
5	615	8	0.7	0.916	1.873	21
6	615	4	1.1	0.089	2.984	21
7	407	12	0.7	0.198	0.654	18
8	407	8	1.1	0.957	1.878	20
9	407	4	0.9	0.835	0.500	20

Table 6: Experimental Result for Carbide tool

Sr. No.	Spindle Speed (rpm)	Flank Angle (º)	Depth of Cut (mm)	SR (µm)	MRR (103 mm3/sec)	MT (sec)
1	900	12	1.1	0.614	3.292	22
2	900	8	0.9	1.608	2.838	22
3	900	4	0.7	1.029	2.141	22
4	615	12	0.9	0.603	3.513	21
5	615	8	0.7	1.362	2.116	21
6	615	4	1.1	2.438	1.513	21
7	407	12	0.7	0.495	0.712	30
8	407	8	1.1	1.044	1.104	30
9	407	4	0.9	1.319	1.667	30

Table 7: Experimental Result for Cobalt tool

Sr. No.	Spindle Speed (rpm)	Flank Angle (º)	Depth of Cut (mm)	SR (µm)	MRR (103 mm3/sec)	MT (sec)
1	900	12	1.1	1.181	2.456	22
2	900	8	0.9	1.457	3.838	22
3	900	4	0.7	1.880	2.940	22
4	615	12	0.9	1.616	1.767	21
5	615	8	0.7	1.627	2.106	21
6	615	4	1.1	2.195	3.323	21
7	407	12	0.7	1.808	1.500	20
8	407	8	1.1	1.553	1.312	30
9	407	4	0.9	2.299	1.156	30

4.Result and Analysis

Minitab 17 software is used in the experimental work for the analysis. This software inputs and analyzes the experimental data & gives the calculated results of signal-to-noise ratio. The objective of this experiment is to minimize machining time and maximize the MRR in turning optimization. The effect of different process parameters on MRR and machining time are calculated and plotted the graphs from one level to another. In this experiment, three different tools are used so, the analysis is done on the basis of tool material.

Fig. 2: AA6082 Workpiece after Turning

4.1High Speed Steel tool

4.1.1Analysis of Signal-to-Noise Ratio

Larger-the-better performance characteristic is selected to obtain material removal rate and Smaller-the better performance characteristic is selected to obtain machining time for different tool materials.

Table 8: Response table for MRR

Level	Spindle Speed	Flank Angle	Depth of Cut
1	-1.412	2.690	2.119
2	7.380	6.753	3.502
3	8.459	4.985	8.807
Delta	9.871	4.063	6.688
Rank	**1**	**3**	**2**

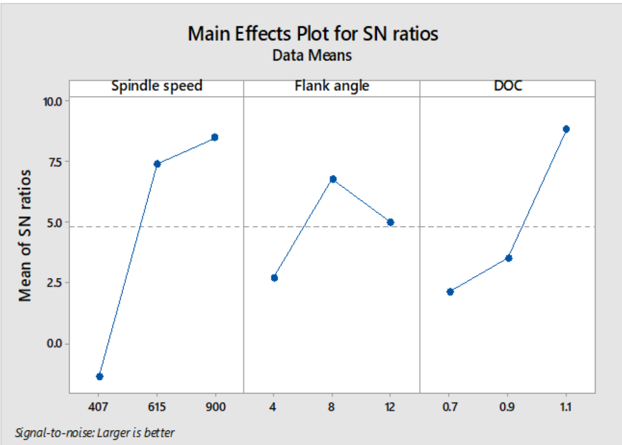

Fig. 4: Main effect plot for MRR

From the Response Table 8 and Fig.4, it is clear that spindle speed is the most influencing factor followed by depth of cut and flank angle for MRR. The optimum for MRR is spindle speed of 900 rpm, depth of cut of 1.1 mm and flank angle of 8°.

From the Response Table 9 and Fig.5, it is clear that spindle speed is the most influencing factor followed by flank angle and depth of cut for Machining time. The optimum for Machining time is spindle speed of 900 rpm, flank angle of 8° and depth of cut of 0.9 mm.

Table 9: Response table for Machining time

Level	Spindle Speed	Flank Angle	Depth of Cut
1	-2.334	-4.749	-2.167
2	-6.512	-2.605	0.206
3	-1.784	-8.486	-8.670
Delta	4.727	11.092	8.877
Rank	**3**	**1**	**2**

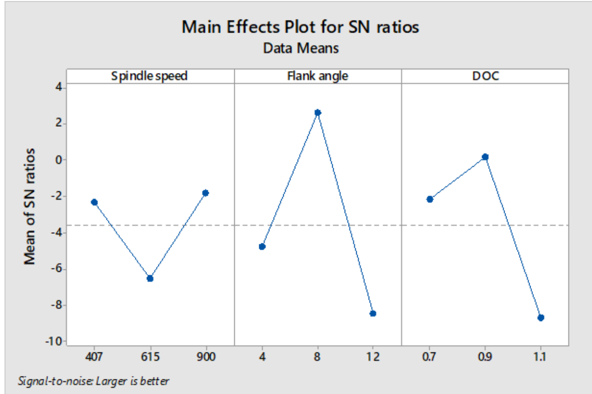

Fig. 5: Main effect plot for Machining time

4.2 Analysis of Variance (ANOVA)

Taguchi method cannot determine the effect of individual parameters on the whole process so ANOVA is used to determine the percentage contribution of an individual parameter provided in MINITAB 17.

Table 10: ANOVA result for MRR

Source	DF	SS	MS	F	P%
Spindle Speed	2	9.212	4.606	1.33	43.00
Flank Angle	2	38.649	19.324	5.57	15.20
Depth of Cut	2	12.411	6.205	1.79	35.90
Error	2	6.936	3.468		
Total	8	67.208			

S = 1.862 R-Sq = 89.7% R-Sq(adj) = 58.7%

Table 11: ANOVA result for Machining time

Source	DF	SS	MS	F	P%
Spindle Speed	2	13.562	6.781	7.19	12.20
Flank Angle	2	0.669	0.334	0.33	73.80
Depth of Cut	2	2.250	1.125	1.19	43.60
Error	2	1.885	0.542		
Total	8	18.366			

S = 0.9709 R-Sq = 89.7% R-Sq(adj) = 58.9%

Table 10 & 11 shows the ANOVA result for MRR and machining time. It is observed that the spindle speed(43.00%) is most influences the MRR followed by depth of cut (35.90%) and least significant of flank angle (15.20%). In case of machining time, flank angle(73.80%) is the most significant parameter followed by depth of cut (43.60%) and least significant of spindle speed (12.20%).

4.3Carbide tool

4.3.1Analysis of Signal-to-Noise Ratio

Table 12: Response table for MRR

Level	Spindle Speed	Flank Angle	Depth of Cut
1	-0.298	3.617	0.578
2	2.623	3.575	2.573
3	2.302	-2.564	1.475
Delta	2.922	6.182	1.995
Rank	**2**	**1**	**3**

From the Response Table 12 and Fig.6, it is clear that flank angle is the most influencing factor followed by spindle speedand depth of cutfor MRR. The optimum for MRR is spindle speed of 615 rpm, depth of cut of 0.9mm and flank angle of 4°.

From the Response Table 13 and Fig.7, it is clear that spindle speed is the most influencing factor followed by depth of cut and flank angle for Machining time. The optimum for Machining time is spindle speed of 615 rpm, flank angle of 4° and depth of cut of 0.7 mm.

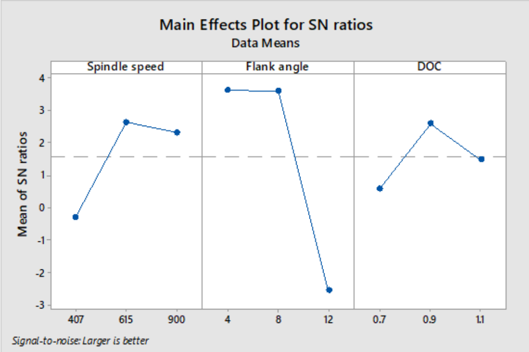

Fig. 6: Main effect plot for MRR

Table 13: Response table for Machining time

Level	Spindle Speed	Flank Angle	Depth of Cut
1	-24.78	-22.89	-22.88
2	-21.76	-22.90	-22.92
3	-22.16	-22.92	-22.90
Delta	3.02	0.02	0.04
Rank	**1**	**3**	**2**

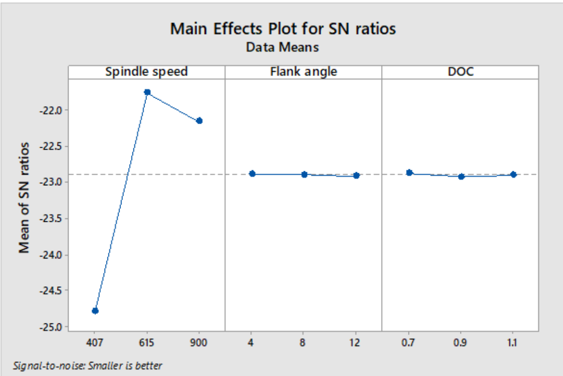

Fig. 7: Main effect plot for Machining time

Table 14: ANOVA result for MRR

Source	DF	SS	MS	F	P%
Spindle Speed	2	15.411	7.706	3.06	24.60
Flank Angle	2	5.994	2.997	1.19	45.60
Depth of Cut	2	75.918	37.959	15.08	6.20
Error	2	5.034	2.517		
Total	8	102.357			

S = 1.587 R-Sq = 95.1% R-Sq(adj) = 80.3%

Table 15: ANOVA result for Machining time

Source	DF	SS	MS	F	P%
Spindle Speed	2	16.177	8.0886	418.45	62.70
Flank Angle	2	0.001	0.0005	138.04	7.46
Depth of Cut	2	0.002	0.0012	349.93	9.84
Error	2	0.001	0.001		
Total	8	16.180			

S = 0.001923 R-Sq = 100.0% R-Sq(adj) = 90.0%

Table 14 & 15 shows the ANOVA result for MRR and machining time. It is observed that the flank angle (45.60%) is most influences the MRR followed by spindle speed (24.60%) and least significant of depth of cut (6.20%). In case of machining time, spindle speed (62.70%) is the most significant parameter followed by depth of cut (9.84%) and least significant of flank angle (7.46%).

4.4 Cobalt tool

4.4.1Analysis of Signal-to-Noise Ratio

Table 16: Response table for MRR

Level	Spindle Speed	Flank Angle	Depth of Cut
1	3.526	6.187	5.489
2	6.004	4.643	4.508
3	5.417	4.116	4.949
Delta	2.478	2.071	0.981
Rank	**1**	**2**	**3**

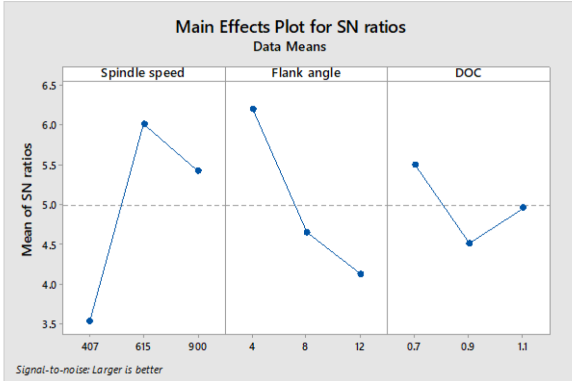

Fig. 8: Main effect plot for MRR

Table 17: Response table for Machining time

Level	Spindle Speed	Flank Angle	Depth of Cut
1	-23.63	-22.94	-21.75
2	-21.77	-22.92	-22.92
3	-22.18	-21.73	-22.92
Delta	1.87	1.21	1.17
Rank	**1**	**2**	**3**

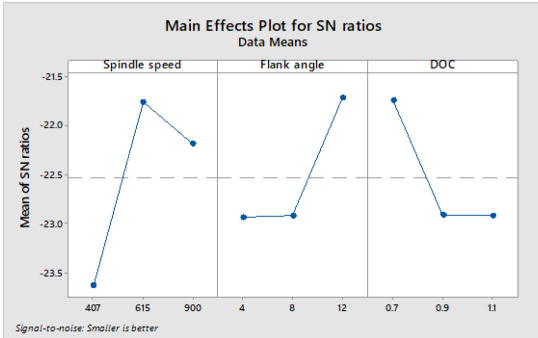

Fig. 8: Main effect plot for Machining time

4.5 Analysis of Variance (ANOVA)

Table 18: ANOVA result for MRR

Source	DF	SS	MS	F	P%
Spindle Speed	2	1.448	0.724	0.23	81.60
Flank Angle	2	6.950	3.475	1.08	48.00
Depth of Cut	2	10.061	5.030	1.57	38.90
Error	2	6.416	3.208		
Total	8	24.876			

S = 1.791 R-Sq = 74.2% R-Sq(adj) = 60.9%

From the Response Table 16 and Fig.8, it is clear that spindle speed is the most influencing factor followed by flank angleand depth of cut for MRR. The optimum for MRR is spindle speed of 615 rpm, depth of cut of 0.7mm and flank angle of 4°.

From the Response Table 16 and Fig.8, it is clear that spindle speed is the most influencing factor followed by flank angle and depth of cut for Machining time. The optimum for Machining time is spindle speed of 615 rpm, flank angle of 12° and depth of cut of 0.7 mm.

Table 18 & 19 shows the ANOVA result for MRR and machining time. It is observed that the spindle speed (81.60%) is most influences the MRR followed by flank angle (48%) and least significant of depth of cut (38.90%). In case of machining time, spindle speed (37.90%) is the most significant parameter followed by flank angle (12.20%) and least significant of depth of cut (5.70%).

Table 19: ANOVA result for Machining time

Source	DF	SS	MS	F	P%
Spindle Speed	2	1.570	0.785	1.64	37.90
Flank Angle	2	6.868	3.434	7.17	12.20
Depth of Cut	2	15.977	7.988	16.68	5.70
Error	2	0.957	0.478		
Total	8	25.374			

S = 0.6920 R-Sq = 96.20% R-Sq(adj) = 84.90%

5.Conclusions

5.1For HSS tool

Optimum conditions for optimizing MRR during turning of AA6082 are spindle speed of 900 rpm, flank angle of 8° and depth of cut of 1.1 mm.

From response table and ANOVA analysis for S/N ratio of MRR, we found spindle speed (43%) is the most significant factor followed by depth of cut (35.90%) and flank angle (15.20%) influencing MRR.

Optimum conditions for optimizing Machining Time are spindle speed of 900 rpm, flank angle of 8° and depth of cut of 0.9 mm. From response table and ANOVA analysis for S/N ratio of Machining Time, we found flank angle (73.80%) is the most significant factor followed by depth of cut (43.60%) and spindle speed(12.20%).

The union of parameters of all 9 specimens gives desired values of parameters are spindle speed 900 rpm, flank angle8° and depth of cut 0.9 mm.

5.2For Carbide tool

The optimum conditions for optimizing MRR during turning of AA6082 are spindle speed of 615 rpm, flank angle of 4° and depth of cut of 0.9 mm.

From response table and ANOVA analysis for S/N ratio of MRR, we found flank angle (45.60%) is the most significant factor followed by spindle speed (24.60%) and depth of cut (6.20%) influencing MRR. The optimum conditions for optimizing Machining Time are spindle speed of 615 rpm, flank angle of 4° and depth of cut of 0.7 mm.

From response table and ANOVA analysis for S/N ratio of Machining Time, we found spindle speed (62.70%) is the most significant factor followed by depth of cut (9.84%) and flank angle (7.46%). The union of parameters of all 9 specimen gives desired values of parameters are spindle speed 615 rpm, flank angle 4° and depth of cut 0.7 mm.

5.3 For Cobalt tool

The optimum conditions for optimizing MRR during turning of AA6082 are spindle speed of 615 rpm, flank angle of 4° and depth of cut of 0.7 mm.

From response table and ANOVA analysis for S/N ratio of MRR, we found spindle speed (81.60%) is the most significant factor followed by flank angle (48%) and depth of cut (38.90%) influencing MRR.

The optimum conditions for optimizing Machining Time are spindle speed of 615 rpm, flank angle of 12° and depth of cut of 0.7 mm.

From response table and ANOVA analysis for S/N ratio of Machining Time, we found spindle speed (37.90%) is the most significant factor followed by flank angle (12.20%) and depth of cut (5.70%). The union of parameters of all 9 specimen gives desired values of parameters are spindle speed 615 rpm, flank angle 4° and depth of cut 0.7 mm.

References

[1.] BS Rajpoot, DR Moond, S Shrivastava. Investigating the Effect of Cutting Parameters on Average Surface Roughness and Material Removal Rate during Turning of Metal Matrix Composite Using Response Surface Methodology, International Journal on Recent and Innovation Trends in Computing and Communication, 3, 2015, 241-247.

[2.] JB Raju, JA Kumar, PD Saran, CSKP Rao. Application of Taguchi Technique for Identifying Optimum Surface Roughness in CNC end Milling Process, International Journal of Engineering Trends and Technology, 2, 2015, 103-110.

[3.] MA El Hakim, MA Shalaby, SC Veldhuis, GK Dosbaeva. Effect of secondary hardening on cutting forces, cutting temperature, and tool wear in hard turning of high alloy tool steels, Measurement, 65, 2015, 233–238.

[4.] SA Lawal, IA Choudhury, Y Nukman. Experimental Evaluation and Optimization of Flank Wear During Turning of AISI 4340 Steel with Coated Carbide Inserts Using Different Cutting Fluids, Journal of IEI: Series C, 96, 2015, 21–28, 2015.

[5.] SC Borse. Optimization of turning parameters in dry turning of SAE52100 steel, International Journal of Mechanical Engineering and Technology, 5(12), 2014, 1-8.

[6.] DR Deore, R Radha. Optimization of Machining parameters in turning operation of EN19 steel, International journal of research in mechanical engineering, 2(6),2014, 1-7

[7.] BK Lodhi, Rshukla. Experimental Analysis on Turning parameters for Surface roughness and MRR, Journal of Emerging Technologies and Innovative Research, 1, 2014, 554-557

[8.] R Mohan, CJ Paul, G Mathew. Optimization of Surface Roughness of Bearing Steel during CNC Hard Turning Process. International Journal of Engineering Trends and Technology, 17, 2014, 173-175

[9.] V Paramasivam, B Moinudeen, P Premkumar. Optimization of turning process parameters for EN-24 steel using Taguchi method and Regression Anlaysis, Global Journal Of Engineering Science and Researches, 2014, 31-38

[10.] AN Reddy, R Gantisatyaprakash. Optimization of Machining Parameters of 20MnCr5 Steel in Turning Operation using Taguchi technique, International Journal of Modern Engineering Research, 4, 2014, 50-60

[11.] MM Koura, TH Sayed, AS El-Akkad. Modeling and Prediction of Surface Roughness, International Journal of Engineering Research & Technology, 3, 2014, 694-699.

[12.] T Nithyanandhan. Optimization of Cutting Forces, Tool Wear and Surface Finish in Machining of AISI 304 Stainless Steel Material Using Taguchi's Method, International Journal of Innovative Science, Engineering & Technology, 1(4), 2014, 488-493, June 2014.

[13.] K Shunmugesh, K Panneerselvam, M Pramod, A George. Optimization of CNC Turning Parameters with Carbide Tool for Surface Roughness Analysis Using Taguchi Analysis, Research Journal of Engineering Sciences, 3,2014, 1–7

[14.] SK Sharma. Optimization of Process Parameters in Turning of AISI 8620 Steel Using Taguchi and Grey Taguchi Analysis, International Journal of Engineering Research and Applications, 4(3(6)), 2014, 51-57.

[15.] AS Shivade. Optimization of Machining Parameters for Turning using Taguchi Approach, International Journal of Recent Technology and Engineering, 3(1), 2014, 145-149.

[16.] T Quazi, P Gajanan. Optimization of Turning Parameters Such as Speed Rate, Feed Rate, Depth of Cut for Surface Roughness by Taguchi Method, Asian Journal of Engineering and Technology Innovation, 2 ,2014, 5–24.

[17.] MS Ranganath, Vipin, RS Mishra. Optimization of Surface Roughness and Material Removal Rate on Conventional Dry Turning of AA6061, International Journalof Advance Research and Innovation, 1, 2014, 62-71.

[18.] AS Shivade, S Bhagat, S Jagdale, A Nikam, P Londhe. Optimization of Machining Parameters for Turning using Taguchi Approach, International Journal of Recent Technology and Engineering, 3(1), 2014, 145-149.

[19.] SK Sharma, S Kumar. Optimization of Surface Roughness in CNC Turning of Mild Steel 1018 using Taguchi method, International Journal of Engineering Research & Technology, 3, 2014,. 2928-2932.

[20.] TM Patel, VA Deshpande. Experimental Investigation of Effect of Process Parameters on MRR and Surface Roughness In Turning Operation on Conventional Lathe Machine For Aluminum 6082 Grade Material Using Taguchi Method. Journal of Engineering Research and Applications, 4(1), 2014, 177-185.

[21.] SV Alagarsamy, N Rajakumar N. Analysis of Influence of Turning Process Parameters on MRR & Surface Roughness of AA7075 Using Taguchi's Method and RSM, InternationalJournal of Applied Research and Studies, 3(4), 2014, 1-8.

[22.] DP Selvaraj, P Chandramohan, M Mohanraji. Optimization of surface roughness, cutting force and tool wear of nitrogen alloyed duplex stainless steel in a dry turning process using Taguchi method, Measurement, 49, 2014, 205–221.

[23.] RK Suresh, P Venkataramaiah, G Krishnaiah. Experimental Investigation for finding optimum surface roughness, VMRR and Interface temperature during turning of AISI 8620 alloy Steel using CNMG Insert, International Journal of Current Engineering And Technology, 4, 2014.

[24.] NJ Saraswat, A Yadav, A Kumar, BP Srivastava. Optimization of Cutting Parameters in Turning Operation of Mild Steel, International Review of Applied Engineering Research, 4, 2014, .251-256.

[25.] SKNayak, JK Patro, S Dewangan, S Gangopadhyay. Multi objective optimization of machining parameters during dry turning of AISI 304 Austenitic stainless steel using Grey Relational Analysis, 2004, 701-708.

[26.] A Alrashdan, O Bataineh, M Shbool. Multi-criteria End Milling Parameters Optimization of AISI D2 Steel Using Genetic Algorithm, International Journal of Advanced Manufacturing Technology, 73(5-8), 2014, 1201-1212.

[27.] M Sahu, K Sahu. Optimization of Cutting Parameters on Tool Wear, Workpiece Surface Temperature and Material Removal Rate in Turning of AISI D2 Steel, International Journal of Advanced Mechanical Engineering, 4(3), 2014, 291-298.

[28.] P Warhade, SK Bhilare, SR Gaikwad. Modeling and Analysis of Machining Process using Response surface methodology, International Journal of Engineering and Development, 2, 2013.

[29.] V Francis, SR Singh, N Singh, AR Rizvi, S Kumar. 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, 4, 2013, 47-53.

[30.] Taguchi methods,(n.d.). In Wikipedia. Retrieved September 10, 2016, from https://en.wikipedia.org/wiki/Taguchi_methods

[31.] Aluminium alloy 7075,(n.d.). https://en.wikipedia.org/wiki/6082_aluminium_alloy

[32.] Signal-to- Noise ratio,(n.d.). Wikipedia. https://en.wikipedia.org/wiki/Signal-to-noise_ratio

[33.] SV Alagarsamy, P Raveendran, S AV Sagayaraj, T Vendan. Optimization of machining parameters for turning of aluminium alloy 7075 using Taguchi method . 3(1), 2016.

[34.] [35] HR Ghan, SD Ambedkar. Optimization of cutting parameter for Surface Roughness, Material Removal rate and Machining Time of Aluminium LM-26 Alloy, 3(2), 2014.