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# Optimization of CNC Machining Parameter for Al6061 to Improve Surface Roughness and Material Removal Rate

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***ABSTRACT***
*In the present study effect of cutting parameter on material removal rate and surface roughness are measured and they are optimized. The experiment is performed on Al6061 work material. Design of experiment is done with Taguchi method. Input parameters taken for experiment are speed, feed and depth of cut for turning and surface roughness and material removal rate are output responses parameter. The analysis is carried out using S/N ratio to get optimum process parameter. Hardness is also calculated before and after machining of work material. The effect of process parameters on surface roughness and material removal rate is discussed in this paper.*

**Keywords:** Al6061, ANOVA, hardness, material removal rate, S/N ratio

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## INTRODUCTION

The CNC turning process is widely used in industry because of its versatility and efficiency. Applications of the turning process can be found in many industries ranging from large engine manufactures to small die shops. The constraints that affect the turning process are vibration, tool wear, surface roughness etc. Among this surface roughness is an important factor that affects the quality in manufacturing process. As per literature review in this research we select Al6061 material. The main objective of this work is to predict the surface roughness, material removal rate and hardness on aluminum 6061, by optimizing the input parameters such as speed, feed and depth of cut.

Now a days, in manufacturing industry alloys are preferred over the pure metals. This is because of better properties of the alloys such as good machining properties, high strength to weight ratio, better thermal and mechanical properties, good toughness, good machining properties etc. From them aluminum 6061 alloy is one. It is mostly used in the aerospace industry, cycle industry, valves, couplings and marine fittings. For the manufacturing of cylindrically symmetrical products turning process is used.

In the recent time manufacturing industry, surface finish of the product is very important with high material removal rate (MRR). To get high surface finish various processes are done on the product such as grinding, buffing and polishing. But these processes are very costly and time consuming. To cut the manufacturing time and cost we are trying to get higher surface finish by only turning process. Because turning is the first most machining operation to get finished surface. Automated and flexible manufacturing system is used in the industries. CNC machines are used because they are proficient of attaining repeatability and high accuracy. There are many factors that affect the surface roughness of the product for example cutting speed, feed rate, depth of cut, coolant used, tool geometry, chattering, material properties of work piece and cutting tool used.

Due to the advancement of technology demand of the hour is increasing. The prime concern in industries is to maintain economic production using the resources in an optimal way. Machining of metals is one of them. Challenges are to maximize the performance of manufacturing by finding out optimal parameters for. In industries, nowadays dimensional accuracy, surface finish and hardness of material are specially focused.

Umashankar et al. [1] have attempted to review literature review on optimization of cutting parameter using Taguchi method, suggested that speed, feed and depth of cut are main controllable factor for optimization of cutting parameter. Ramaiah et al. [2] have reported that CNMG cutting tool used for machining for Al6061 work material under dry condition cutting temperature and cutting force are measured for different combination influential parameter and optimum parameter condition is determined. Syed [3] have investigated tool wear during dry machining and compared with different PVD and CVD coated inserts, CVD coated has shown less tool wear. Singh et al. [4] in this study Al6061 is machined using insert CNMG120408ENTM and surface roughness is measured for combination of different cutting parameter using response surface methodology. Thakkar et al. [5] have concluded study on SS 410 material during turning operation and response parameter are studied surface roughens and material removal rate by ANOVA method. Shirpurkar et al. [6] has studied different techniques of optimization from conventional to latest for turning operation and found that Taguchi is most widely used in industries for making product insensitive to any uncontrollable factors. Ranganath et al. [7] has studied surface roughness for different material by different researcher and analyze their data for getting optimization of cutting parameter by usi.ng response surface methodology. Dharindom et al. [8] concluded that Taguchi method is most useful method to find out optimization cutting parameter for minimum surface roughness in turning and found that feed is most affecting parameter for it. Govindan et al. [9] concluded that turning is important factor in manufacturing and surface roughness is significant constraint in maximize production rate.it gives idea about how quality surface affect on machining parameter and production of industry. Ramanathan et al. [10] provides calculation of machining time, material removal rate and surface roughness for the CNC milling parameter speed and feed for the aluminium AA6063 by Taguchi method. The feed rate become dominant parameter for operation. Wang [11] has studied for reducing energy consumption for 7050-T7451 aluminium alloy for proper selection of cutting parameter and cutting tool angle to lower specific cutting energy. Bhanuprakash et al. [12] investigated optimization of cutting parameter for Aluminum alloy 6082 in CNC end milling operation. Data is developed for surface roughness calculation. And attempt is made to compare the result response surface methodology and genetic algorithm method. Akkkurt [13] has investigated microstructure and hardness variation for cut surfaces for different conventional and non-conventional cutting methods for pure aluminium and Al6061 alloy. Deepak et al. [14] studied the material removal rate for Al6061 by turning with coolant and without coolant using Taguchi method. And gives result that supply of coolant produce higher material removal rate than without coolant.

## METHODOLOGY AND DESIGN OF EXPERIMENT

***Table 1.*** *Process parameter.*

| Sr. no | Process parameter | Parameter | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| 1 | Cutting speed | A | 800 | 1000 | 1200 |
| 2 | Feed rate | B | 0.05 | 0.07 | 0.09 |
| 3 | Depth of cut | C | 0.10 | 0.15 | 0.20 |

After finalizing the values for parameters, experiments are performed according to design of experiments (DoE). Among the available methods, Taguchi method is one of the most powerful DoE methods for design of experiments. Experiments are performed with L9 orthogonal array of Taguchi method.

### Experimental Setup

The turning operation was performed on the Ace Designer CNC Jobber Junior lathe machine using high speed steel is selected for the tool. The work material raw material was in the form of long rod and it cut down into specimens. Nine experiments were performed.

***Fig. 1.*** *Ace designers CNC Jobber Junior Lathe.*

***Fig. 2.*** *Experiments conducted on work pies.*

## RESULT AND DISCUSSION

### Surface Roughness Tester

We used Mitutoyo surface roughness tester for measuring the surface roughness. Probe diameter of surface roughness tester is 1 mm, sampling length 8 mm and least count of 0.01 µm.

***Fig. 3.*** *Surface roughness measurements setup.*

### Material Removal Rate

Material removal rate is generally defined as the amount of material removed per minute for each experiment conducted. It also expressed as the volume of material removed divided by machining time. The material removal rate is calculated by the formula given below.

Material Removal Rate= $\pi$ x $D_{avg}$ x Feed x Speed x Depth of cut

## Hardness

The Rockwell hardness test method is most commonly used hardness test method. In this method, the permanent depth of indentation produced by force/load by an indenter is measured. The method used in this analysis is ASTM E-10 and the value of load used was 100 kgf.

## Results of Experiments

After performing all the experiments with predetermined values of parameters, the values of surface roughness, hardness are measured. The results are given in the Tables 3–5.

***Table 2.*** *Hardness values for experiments.*

| Exp. no. | $RC_1$ | $RC_2$ | $RC_3$ | $RC_{avg}$ |
|---|---|---|---|---|
| 1 | 54 | 56 | 53 | 54 |
| 2 | 53 | 54 | 53 | 53 |
| 3 | 56 | 54 | 53 | 54 |
| 4 | 55 | 54 | 54 | 54 |
| 5 | 53 | 55 | 54 | 54 |
| 6 | 56 | 55 | 54 | 55 |
| 7 | 54 | 53 | 56 | 54 |
| 8 | 55 | 56 | 56 | 56 |
| 9 | 55 | 54 | 54 | 54 |

***Table 3.*** *Results of trial experiments.*

| Sr. no. | Speed RPM | Feed mm/min | Depth of cut (mm) | Ra (µm) | MRR $mm^3$/min | S/N ratio | S/N ratio MRR |
|---|---|---|---|---|---|---|---|
| 1 | 800 | 0.05 | 0.10 | 0.322 | 376.08 | 9.84 | 51.52 |
| 2 | 800 | 0.07 | 0.15 | 0.258 | 778.09 | 11.76 | 57.82 |
| 3 | 800 | 0.09 | 0.20 | 0.423 | 1311.2 | 7.47 | 62.35 |
| 4 | 1000 | 0.05 | 0.15 | 0.380 | 706.5 | 8.40 | 56.98 |
| 5 | 1000 | 0.07 | 0.20 | 0.422 | 1296.8 | 7.49 | 62.25 |
| 6 | 1000 | 0.09 | 0.10 | 0.418 | 819.54 | 7.57 | 58.27 |
| 7 | 1200 | 0.05 | 0.20 | 0.530 | 1130.0 | 5.51 | 61.06 |
| 8 | 1200 | 0.07 | 0.10 | 0.505 | 778.09 | 5.93 | 57.82 |
| 9 | 1200 | 0.09 | 0.15 | 0.512 | 1475.1 | 5.81 | 63.3 |

***Table 4.*** *Analysis of variance for surface roughness.*

| Source | DoF | Seq SS | F-Value | P-value | % Contribution |
|---|---|---|---|---|---|
| Cutting Speed | 2 | 0.056139 | 62.57 | 0.016 | 63.86 |
| Feed | 2 | 0.010295 | 11.47 | 0.080 | 11.71 |
| Depth of Cut | 2 | 0.020577 | 22.93 | 0.042 | 23.407 |
| Error | 2 | 0.000897 | - | - | 1.020 |
| Total | 08 | 0.087909 | - | - | - |
| | S = 0.02118 | | R-Sq = 98.97% | | R- Sq(add) = 95.95% |

***Table 5.*** *Analysis of variance of MRR.*

| Source | DoF | Seq SS | F-value | P-value | % Contribution |
|---|---|---|---|---|---|
| Cutting speed | 2 | 142482 | 4.18 | 0.193 | 13.95 |
| Feed | 2 | 323928 | 9.51 | 0.095 | 31.71 |
| Depth of cut | 2 | 520814 | 15.29 | 0.061 | 51 |
| Error | 2 | 34053 | - | - | 3.33 |
| Total | 08 | 1021276 | - | - | - |
| | S = 130.485 | | R-Sq = 96.67% | | R- Sq(adj) = 86.66% |

## Analysis of the Signal-to-Noise (S/N) Ratio

The mean response refers to the normal values of the performance characteristics for each flexible at various levels. In Taguchi method, higher the levels for S/N ratio, the better the overall performance, it means that the factor levels with the highest S/N ratio value should always be selected.

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with the highest S/N ratio value should always be selected. The average values of S/N data for surface roughness, material removal rate, separately in Tables 6 and 7.

## Main Effect Plots

The main effect plots are drawn by considering the mean average of the parameters of their each level of raw data.

***Table 6.*** *Average values of S/N data for surface roughness and MRR.*

| Sr. no. | Speed (RPM) | Feed (mm/min) | Depth of cut (mm) | Ra (μm) | MRR ($mm^3$/min) | S/N ratio Ra | S/N ratio MRR |
|---|---|---|---|---|---|---|---|
| 1 | 800 | 0.05 | 0.10 | 0.322 | 376.08 | 9.84 | 51.52 |
| 2 | 800 | 0.07 | 0.15 | 0.258 | 778.092 | 11.76 | 57.82 |
| 3 | 800 | 0.09 | 0.20 | 0.423 | 1311.264 | 7.47 | 62.35 |
| 4 | 1000 | 0.05 | 0.15 | 0.380 | 706.5 | 8.40 | 56.98 |
| 5 | 1000 | 0.07 | 0.20 | 0.422 | 1296.82 | 7.49 | 62.25 |
| 6 | 1000 | 0.09 | 0.10 | 0.418 | 819.54 | 7.57 | 58.27 |
| 7 | 1200 | 0.05 | 0.20 | 0.530 | 1130.04 | 5.51 | 61.06 |
| 8 | 1200 | 0.07 | 0.10 | 0.505 | 778.092 | 5.93 | 57.82 |
| 9 | 1200 | 0.09 | 0.15 | 0.512 | 1475.12 | 5.81 | 63.37 |

***Table 7.*** *S/N response table for surface roughness.*

| Level | Cutting speed | Feed rate | Depth of cut |
|---|---|---|---|
| 1 | 9.695 | 7.921 | 7.785 |
| 2 | 7.825 | 8.399 | 8.662 |
| 3 | 5.754 | 6.955 | 6.827 |
| Delta | 3.940 | 1.444 | 1.835 |
| Rank | 1 | 3 | 2 |

***Table 8.*** *S/N response table for MRR.*

| Level | Cutting speed (RPM) | Feed rate (mm/rev) | Depth of cut (mm) |
|---|---|---|---|
| 1 | 57.23 | 56.52 | 55.87 |
| 2 | 59.17 | 59.30 | 59.39 |
| 3 | 60.75 | 61.33 | 61.89 |
| Delta | 3.52 | 4.81 | 6.02 |
| Rank | 3 | 2 | 1 |

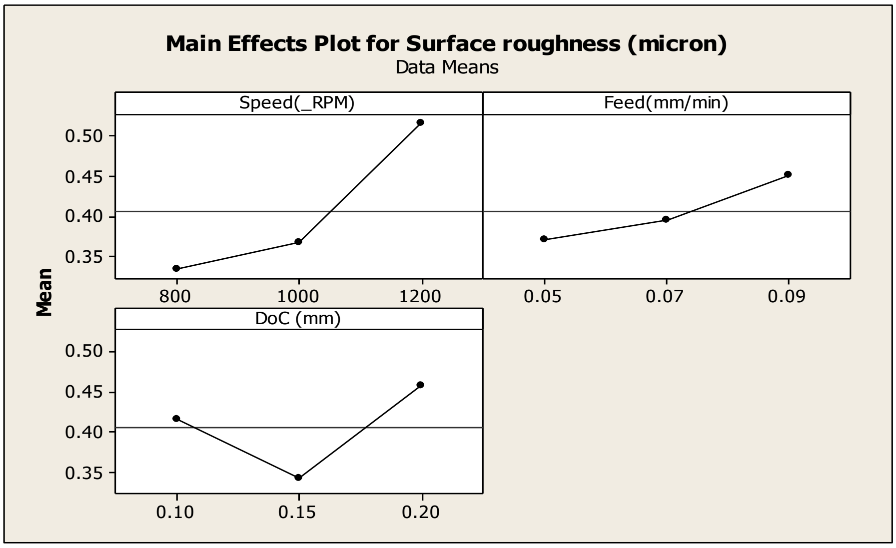


***Fig. 4.*** *Main effect plot for surface roughness.*

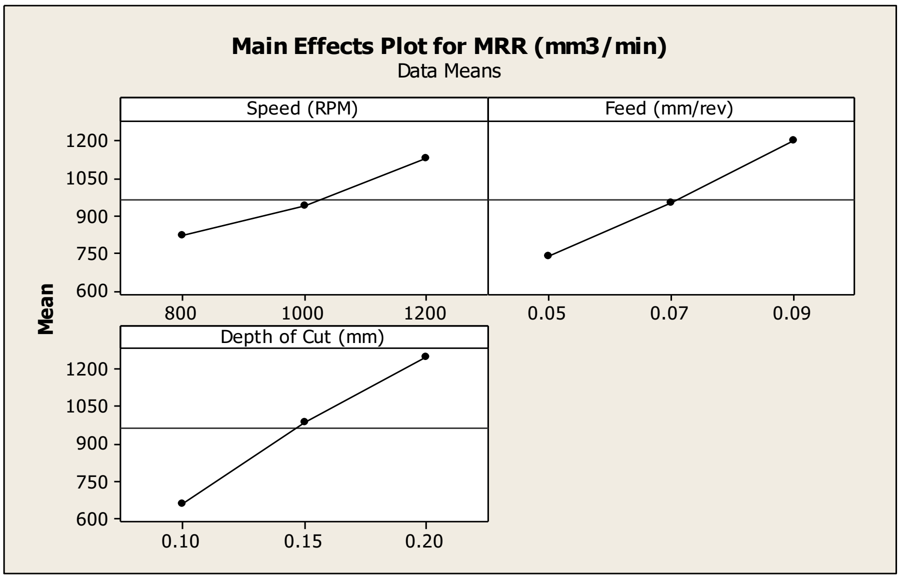


***Fig. 5.*** *Main effect plot for MRR.*

## CONCLUSION

1) During this dissertation work CNC turning of Al6061 material which is widely used in industrial applications is studied. To see the effect of CNC turning process parameter on the work piece material (Al6061), experiments are performed using L9 orthogonal array.
2) By using ANOVA and S/N ratio technique the analysis of response variables is carried out by using Minitab 17 software
3) Main effects plots and interaction plots are also drawn to study effects of each parameter on selected response variables
4) Surface roughness analysis: The ANOVA and S/N ratio revealed that the speed and depth of cut are significant parameters of surface roughness and remaining parameter that is feed as insignificant. The percentage contribution of speed, depth of cut and feed are 63.86%, 23.40%, and 11.71%, respectively. We are achieved up to 0.2 µm surface roughness.

***Table 9.*** *Conclusions for surface roughness.*

| Parameter | Rank | % Contribution |
|---|---|---|
| Speed | 1 | 63.86 |
| Feed | 3 | 11.71 |
| Depth of cut | 2 | 23.40 |

5) Material removal rate analysis: The ANOVA and S/N ratio revealed that the depth of cut and feed rate are significant parameters of MRR and remaining parameters are insignificant. The percentage contribution of depth of cut, feed rate, and cutting speed are 51%, 31.71% and 13.95%, respectively. We are achieved higher 1475.15 $mm^3$/min MRR.

***Table 10.*** *Conclusions for material removal rate.*

| Parameter | Rank | % Contribution |
|---|---|---|
| Speed | 3 | 13.95 |
| Feed | 2 | 31.71 |
| Depth of cut | 1 | 51 |

6) For first response variable that is surface roughness we achieved minimum value of 0.2 µm for experiment no. 2, whereas for material removal rate the maximum rate obtained for experiment number 9.
7) The value of surface roughness goes on increasing as we increase speed from 800 to 1200 rpm, same results obtained in case of feed that is surface roughness goes on increasing as we increase feed from 0.05 to 0.09 mm/min. But in case of depth of cut the value of surface roughness is decreases from 0.10 to 0.15 mm and it increases again for a value of 0.15–0.20 mm.

8) In case of material removal rate the value goes on increasing as we increase speed from 800 to 1200 rpm, feed from 0.050 to 0.07 mm/min and depth of cut from 0.10 to 0.20 mm.
9) Hardness values of Al6061 component is reduced after machining. The value of hardness of Al6061 was 60HRB before machining and after machining it becomes 54HRB.

## REFERENCES

[1] U.M. Rawat, V.V. Potdar. A review on optimization of cutting parameters in machining using Taguchi method, *Int J Innov Res Adv Eng (IJIRAE).* 1(11). ISSN: 2349-2163.
[2] P. Ramaiah, N. Rajesh, K. Dharma Reddy. Determination of optimum influential parameters in turning of Al6061 using fuzzy logic, *Int J Innov Res Sci Eng Technol*. 2013; 2(10).
[3] S.A.S. Azuan. Effect of dry machining on tool wear during turning Al 6061 by using different type of PVD and CVD coated carbide inserts, *Aust J Basic Appl Sci*. 2013; 7(4): 90–3p. ISSN 1991-8178.
[4] S. Singh, H. Singh, H. Garg. Study & optimization of parameters for optimum cutting condition during turning process using response surface methodology, In: *5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014).* December 12th–14th, 2014, IIT Guwahati, Assam, India.
[5] J. Thakkar, I. Patel Mitesh. A review on optimization of process parameters for surface roughness and material removal rate for SS 410 material during turning operation, *Int J Eng Res Appl*. 2014; 4(2): 235–42p. ISSN: 2248-9622.
[6] P. Shirpurkar, S.R. Bobde, V.V. Patil, B.N. Kale. Optimization of turning process parameters by using tool inserts – a review, *Int J Eng Innov Technol (IJEIT).* 2012; 2(6).
[7] M.S. Ranganath, V. Harshit. Optimization of process parameters in turning operation using response surface methodology: a review, *Int J Emerg Technol Adv Eng*. 2014; 4(10).
[8] S. Dharindom, T. Nath, D. Sarma. A review on optimization of cutting parameters on turning, *Int J Eng Trends Technol (IJETT).* 2015; 28(2).
[9] P. Govindan, M.P. Vipindas. Surface quality optimization in turning operations using taguchi method – a review, *Int J Mech Eng Robot Res*. 2014; 3(1). ISSN 2278 – 0149 www.ijmerr.com.
[10] R. Ramanathan, S. Syed Abuthahir, P. Ranjithkumar. Analysis of CNC milling parameters for aluminum aa6063 by using Taguchi design, *Int J Adv Res Biol Ecol Sci Technol (IJARBEST).* 2015; 1(8).
[11] B. Wang. Proper selection of cutting parameters and cutting tool angle to lower the specific cutting energy during high speed machining of 7050-T7451 aluminum alloy, *J Cleaner Prod.*
[12] D. Bhanuprakash, G. RamaBalaji, A. Gopichand, V. Ajaykumar. Optimization of machining parameters for aluminium alloy 6082 in CNC end milling, *Int J Eng Res Appl (IJERA).* 2013; 3(1): 505–10p. ISSN: 2248-9622 www.ijera.com.
[13] A. Akkurt. The effect of cutting process on surface microstructure and hardness of pure and Al 6061 aluminium alloy, *Eng Sci Technol Int J*. 2015; 18: 303–8p.
[14] D. Deepak, B. Rajendra. Investigations on the surface roughness produced in turning of Al6061 (As-Cast) by Taguchi method, *Int J Res Eng Technol*. 295–8p. eISSN: 2319-1163.