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Analysis of turning operation on Aluminium alloy 6062

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Abstract:

Every manufacturing Industry aims at producing a large number of products within relatively lesser time. Along with this they aim at producing fine surface finish as much as possible. They aim at minimizing their cost of production. They adopt some technique which may be statistical or partially statistical for the purpose of achieving above task. In this project a similar effort has been made to optimize the speed, feed and depth of cut using Taguchi method and Central Composite Design of ANOVA (Analysis Of Variance) .Taguchi L9 orthogonal array is used to analyse the result. At last ANOVA is used to decide the confidence level and determine the percentage contribution of individual factors on outcome. Further the effort is to find the optimum cutting parameters and at the same time confirm the outcomes obtained from ANOVA.

Key Words: Feed force, Cutting force, Radial force and material removal rate, Analysis-of-Variance (ANOVA) etc.

Introduction

The turning process is most extensively used in the field of conventional machining. In turning, material removal takes place through the cutting tool from the rotating work piece. In simple straight turning, the feed of the cutting tool is provided in a parallel direction to the rotation axis of the work-piece. In a turning operation, the lathe machine produces the power for rotation of the workpiece with a particular speed, and provides feed and depth of cut to the cutting tool. Thus, these input parameters of machining, cutting speed, feed, and depth of cut are important during the turning.

In mechanical manufacturing, high cutting edge parameters provide opportunities to increase productivity, but this also includes the greater risk of further degradation and tool life. Over the past decade great strides have been made in the development of cutting tools to make ‘hard cutting’ machines. The costs involved in producing new conversion tools are very high. To overcome this cost factor researchers have tried to bring about changes in the turnaround system using existing tools. A good understanding of cutting conditions, temperature production, failure methods, and cutting power leads to effective control of the conversion process. Most researchers investigated the effects of different cutting parameters in responses (output) with one variable at a time. The current study considers simultaneous variations in cutting speed, feed, cutting depth, tool nasal radius and percentage of solid liquid lubricants according to the factorial design for testing, prediction, responses. This method is known as response surface methodology (RSM).

B.Vijaya Ramnath et al. [1] this study, the Taguchi method was used to obtain optimal condition for Friction Stir Welding of AA8011-6062 aluminium composite. Experimental results were evaluated using ANOVA. The results can be drawn as follows: , A maximum tensile strength of 153MPa was exhibited by the FSW joints fabricated with the optimized parameters of 1400 r/min rotational speed, 75mm/min welding speed, 7 kN axial force, shoulder diameter of 15.54mm, pin diameter of 5.13mm, and tool material hardness of 600 HV. , Tool rotation speed was the major factor affecting the impact strength , Tool rotational speed of 1200 r.p.m, welding speed of 100 mm/min and Axial force of 5 KN is the optimum machining condition to get a good impact strength , The optimum machining condition to get high tensile strength is tool rotation speed of 1400 r.p.m, welding speed of 75 mm/min and axial force of 125.73 kN. , Welding speed has negligible influence on Tensile strength.

Mukesh Kumar Verma, et al. [2-3] Machining of EN 8 STEEL is important because it is used in axle, gear etc.. so machining parameters optimization plays a very important role for fabrication of component using EN 8 steel. Effect of depth of cut is the most significant factor on feed force in turning operation of EN 8 steel. It has 57.89% contribution which is highest in compare to other input process parameters. Effect of feed is significant factor on feed force in turning operation of EN 8 steel. It has 26.82% contribution. Effect of speed is significant factor on feed force in turning of EN8 steel. It has 14.68% contribution. Effect of depth of cut is the most significant factor on cutting force in turning operation of EN 8 steel. It has 70.37 % contribution which is highest in compare to other input process parameters. Effect of feed is significant factor on feed force in turning operation of EN 8 steel. It has 16.43 % contribution. Effect of speed is significant factor on feed force in turning of EN8 steel. It has 13.06 % contribution.

Ramendra Singh Niranjan et al. [4] Machining of Inconel 718 offers many difficulties in machining but due to high application of this super alloy, machining operation parameters optimization plays a very important role for fabrication of components using Inconel 718. Effect of cutting speed is most significant factor on radial cutting force in turning operation of Inconel 718. It has 97.17% contribution which is highest in compare to other input process parameter. Effect of feed is significant factor on radial cutting force in turning operation of Inconel 718. It has 1.12% contribution which is minimum in all three input process parameter. Effect of depth of cut is significant factor on radial cutting force in turning operation of Inconel 718. It has 1.14% contribution.

Ali Abdallah et al. [5] A parameter design that used the Taguchi method is a simple, systematic, and efficient methodology for the optimization of process parameters. Based on the results obtained in this study, the following can be concluded: the Taguchi optimization method was applied to find the optimal process parameters, which maximized MRR and minimized the surface roughness (Ra) during the cutting process. Taguchi orthogonal array, S/N ratio, and ANOVA were used for the optimization of the cutting parameters. ANOVA results show that feed rate, cutting speed, and depth of cut affect the MRR and surface roughness. A confirmation experiment was conducted and verified the effectiveness of the Taguchi optimization method.

Jean Brice Mandatsy Moungomo et al. [6] This study showed that dry machining results in longer shavings that alter the surface of the workpiece and thus impact the surface finish. Furthermore, this machining condition increases the temperature that promotes the mass concentration of metal particles, especially for 6061 R recycled alloy, which is more ductile than 6061 R-T6 recycled alloy. The use of lubrication during the machining of the two recycled alloys causes chip fragmentation, gives a good surface finish and reduces the mass concentration of metal particles to almost 82%. The lubrication, the high hardness and the reduction of the feed give a good surface finish for the two recycled alloys. Both 6061 R and 6061 R-T6 recycled alloys have good machinability. Thus, we note that the feed, the hardness of the material and the lubrication considerably influence the machinability of the two recycled alloys. The machinability of the two recycled alloys can be assessed by considering the predictive models established in this study.

Ranganath M S et al. [7] This work presented an experimentation approach to study the impact of machining parameters on surface roughness. Strong interactions were observed among the turning parameters. Most significant interactions were found between work materials, feed and cutting speeds. A Systematic approach was provided to design and analyze the experiments, and to utilize the data obtained to the maximum extend. The following are conclusions drawn based on the experimental investigation conducted at three levels by employing Taguchi technique to determine the optimal level of process parameters. From the data collection it has been observed that the increase in cutting speed tends to improve the finish, thus the average surface roughness value decreases.

N. Zeelan Basha [8] This investigation attempts the application of genetic algorithm and found that optimal solution of the cutting conditions achieved on spindle speed (rpm)= 1999.999, feed rate (mm/min)= 0.041 and depth of cut (mm)=0.6 for giving the minimum value of surface roughness(µm)=0.611 using genetic algorithm. The confirmatory test was conducted and found that the percentage of error within 0.32%.

Mahir Akgu¨et al. [9] In this study, the effects of cutting tool coating and cutting parameters on cutting force and surface roughness in turning AA 6061 alloy have been investigated experimentally and statistically.

Rafael F. Garcia et al. [10] This work presented the comparative study between the surface roughness of AA 6082-T6 produced by dry and RQL turning, seeking the parameters optimization.

Vladimir Aleksandrovich Rogov et al. [11] This paper presents the application of Taguchi method for optimizing surface roughness and natural frequency in turning of AA2024 under dry condition. Spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting parameters. Two cutting tools with the same material made of AISI 5140 but different constructions were used to perform turning operation. Using signal to noise (S/N) ratio and ANOVA results the significance of cutting parameters was determined to get lower natural frequency and better surface roughness.

C. Veera ajay et al. [12] in this work presented the high surface finish can be obtain at higher cutting speed at this condition it have a lower cutting force. If the DOC increases during machining, the quality of the surface finish will reduce. Finally for obtaining polished it is recommended to go for higher cutting speed (s) and lower depth of cut (d) and feed rate (f).

Pankaj Kumar Singh et al. [13] Machining activity on Al alloy 2011 are performed and cutting parameters for example feed rate, depth of cut and shaft speed have been improved for metal removal rate(MRR) and surface roughness by utilizing Taguchi method. CNC lathe machine is utilized for turning activity so as to decide metal removal rate (MRR). The primary target of the present research is to explore the impact of procedure parameters on the presentation of by and large machining procedure and on surface unpleasantness in turning activity utilizing CNC machining of Aluminium composite.

Mata Dayal Agrahari, et al. [14] the experimental analysis for the effect of control parameters on forces in the dry turning of Al-7075 is performed. The results showed that both the cutting and feed force increases with an increase in feed and depth of cut. Whereas the spindle speed showed the least influence on the forces. Further, the FE based numerical simulation of the turning process is performed to estimate the forces using Deform-3D software. The obtained simulation results are in agreement with the experimental cutting and feed force with 16.40% and 13.79% average relative error. Hence, the simulation-based technique is found suitable to predict the process performance in terms of cutting forces reducing the experimental efforts. This study has also revealed the scope to validate other responses like tool wear, chip morphology, and residual stress, etc. and to compare the obtained simulation results with other FE based simulation tool.

G. List et al. [15] The proposed study allows a better knowledge of the tool wear mechanisms during machining of aluminium alloy with uncoated cemented carbide. At low cutting conditions, the built-up edges are formed on the tool rake face and take over the function of the cutting edge. The interface temperature is low and the adhesion of BUE is principally achieved in mechanical way. Continuous sliding of BUE fragments between tool and chip causes an increasing tool wear. These particles coming off with the chip material can be a cause of abrasion on the tool rake face. At low cutting speed, as the adhesion mechanism is more mechanical than physical, the use of large rake angle and polished tool surface can be suggested. At severe cutting conditions, temperature is higher; mechanisms of tool wear involve chemical action and diffusion. On the one hand, aluminium elements diffuse into the tool through the Co binder phase. No diffusion of tool chemical species towards the chip was detected. On the other hand, a thin built-up layer is formed on the tool surface.

P. Venkata Ramaiah et al. [16] The influence of spindle speed, feed and depth of cut on cutting temperature and cutting forces in turning operation is studied. Optimum machining parameter combination has been found using fuzzy logic technique which yields good results in turning of Al 6061 with minimum cutting force and temperature. This method can also be used for other process while turning different materials.

Prabakaran M P et al. [17] The present work deals with the mathematical modelling and analysis of machining response such as the surface roughness and tool wear in the turning of aluminum alloy 6061. There are several process parameters namely spindle speed, depth of cut and feed rate used to determine the quality of surface roughness. Experiments are conducted as per central composite face centered design. Among the following process parameter the spindle speed, depth of cut and feed rate for the purpose of analysis. Response surface methodology is utilized to develop an effective mathematical model to predict optimum level.

M.S. Najiha et al. [18] This paper presents an experimental investigation of coated carbide cutting tool performance on the surface roughness of aluminum alloy 6061-T6 machining through end mill processes using the minimum quantity lubrication technique. It is observed that the surface roughness depends significantly on depth of cut and feed rate, followed by spindle speed for both the coated carbide inserts. The performance of the dual-layered coating of TiAlN+TiN is competent as compared to the surface quality obtained with TIAlN-coated inserts.

Sohail Akram et al. [19] The aim of this research was to investigate the residual stresses in an aluminum alloy Al-6061 workpiece after machining. Numerical simulations of orthogonal cutting of the workpiece were carried out at various preselected combinations of feed rate and cutting speed. The simulation results showed that residual stresses were insensitive to changes in cutting speed, however, residual stresses were clearly affected by the change in feed rate.

Devendra Singh et al. [20] in this paper aims to investigate the effect of nose radius on surface roughness, in CNC turning of Aluminium (6061) in dry condition. The effect of cutting conditions (speed, feed and depth of cut) and tool geometry (nose radius) on surface roughness were studied and analysed. The analysis of the results for surface roughness shows that the nose radius is the most significant factor followed by feed.

Sonali Priyadarshini et al. [21] In this paper, the effects of the machining parameters were evaluated on surface roughness, when step turning of Al Alloy under dry cutting condition were performed by using Taguchi methodology.

Every metal working industry is facing the problem of improving the production rate without sacrificing these parameters. The present paper reveals the facts about why one cannot increase the cutting parameters of the turning process in order to achieve the higher rate of production. Further there may some another methods which ensures improving of the production rate without affecting the above said factors i.e. tool life, surface finish and cost of production. Such methods should be ideal one for the mass production industry where there is a large number of quantities being machines with little or no variations at all.

MATERIALS AND METHODS

Aluminum / Aluminum 6061 alloy is used in the various fields such as- General structural and high-pressure applications, Heavy-duty structures, Aerospace applications etc.

Figure-Aluminum 6062

Chemical Composition

The following table shows the chemical composition of Aluminum Alloy 6062-

Table 1

Element	Content (%)
Aluminium/ Al	97.9
Magnesium, Mg	1
Silicon, Si	0.60
Copper, Cu	0.28
Chromium, Cr	0.20

Mechanical Properties

The mechanical properties of Aluminium 6062 alloy are tabulated below-

Properties	Metric
Tensile strength	310 MPa
Yield strength	276 MPa
Shear strength	207 MPa
Fatigue strength	96.5 MPa
Elastic modulus	68.9 GPa
Poisson's ratio	0.33
Elongation	12-17%
Hardness, Brinell	95

Experimental Procedure:

The experiment was done to analyze the effect of control parameters such as feed rate, speed and depth of cut on surface roughness. The design parameters were studied at three levels & three factors. The design of experiments is based on Taguchi method of selection of orthogonal array L9. The experiment was carried out in dry condition on NH-22 LATHE MACHINE.

Figure – NH-22 Lathe Machine

Cutting Tool

Cemented carbides are a class of hard materials used extensively for cutting tools, as well as in other industrial applications. It consists of fine particles of carbide cemented into a composite by a binder metal.

Dynamometers for Force Measurement

The Kistler 9257B, which can measure the forces and torque in the 3-orthogonal axis.

Figure – Dynamometer

Design of Experiments

A well planned set of experiments, in which all parameters of interest are varied over a specified range, is a much better approach to obtain systematic data. Mathematically speaking, such a complete set of experiments ought to give desired results.

In the present investigation experiment consists of turning of Aluminium 6062 alloy on a lathe machine. Three process parameters along with their 3-levels are given below.

Table 1. Process parameters and their levels

Factors	Unit	Level-1	Level-2	Level-3
Speed	Rpm	420	550	715
Feed	mm/rev	0.05	0.10	0.14
DOC	mm	1.0	1.5	2.0

RESULT DISCUSSION AND ANALYSIS

The following observation noted for experiments carried out for taguchi's orthogonal L9 array.

Table- experimental results with L9 Orthogonal array

Exp.	N (rpm)	Feed (mm/rev)	Doc (mm)	Fx (N)	Fy (N)	Fz (N)	MRR (mm3/s)
1	420	0.05	1.0	4.5	7.5	4.0	52.56
2	420	0.10	1.5	18.0	19.0	7.0	147.83
3	420	0.14	2.0	30.0	31.0	7.5	447.45
4	550	0.05	1.5	2.5	6.0	3.0	167.10

5	550	0.10	2.0	11.5	15.5	2.5	422.12
6	550	0.14	1.0	7.0	11.5	5.0	300.52
7	715	0.05	2.0	10.5	12.5	1.0	176.56
8	715	0.10	1.0	5.0	10.0	5.0	174.00
9	715	0.14	1.5	12.5	17.0	6.5	374.06

FEED FORCE:

Regression Equation-

FEED FORCE = -3.4 - 0.0258 N + 118.3 FEED + 11.83 D.O.C

Table- Analysis of Variance for Feed Force

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Regression	3	468.38	156.13	7.09	0.030
N	1	87.58	87.58	3.97	0.103
FEED	1	170.76	170.76	7.75	0.039
D.O.C	1	210.04	210.04	9.53	0.027
Error	5	110.18	22.04		
Total	8	578.56			

Table- Response Table for Signal to Noise Ratios (Smaller is better) for feed force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	-22.57	-13.82	-14.65
2	-15.36	-20.10	-18.33
3	-18.78	-22.79	-23.73
Delta	7.21	8.98	9.08
Rank	3	2	1

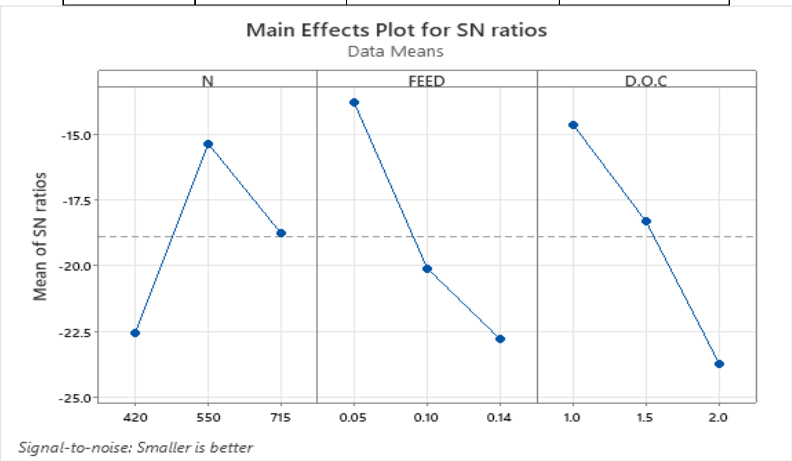

Figure- Effect of process parameters on feed force

Table - Response Table for Means for Feed Force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	17.500	5.833	5.500
2	7.000	11.500	11.000
3	9.333	16.500	17.333
Delta	10.500	10.667	11.833
Rank	3	2	1

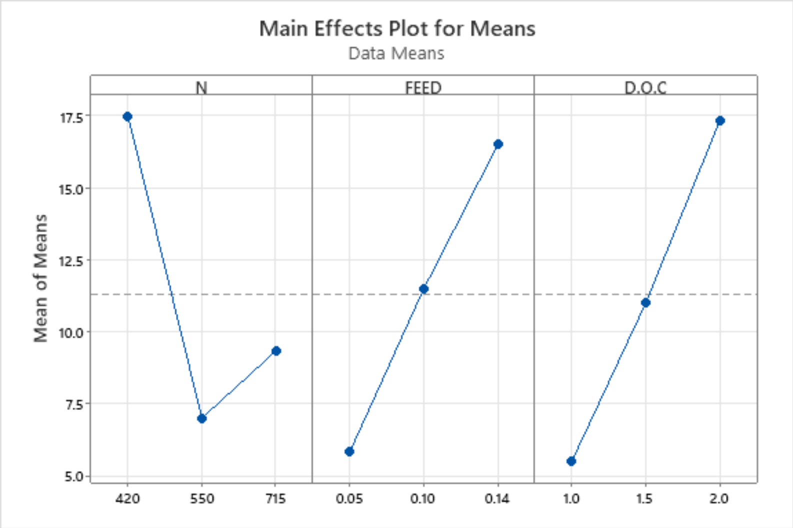

Figure- Effect of process parameters on feed force

- For Feed Force, depth of cut is the most significant factor as can be seen from response table for SN ratio and for means, followed by feed and speed.
- From ANOVA table it is clear that depth of cut makes 36.30% contribution on Feed force while feed makes 29.51% contribution and speed makes 15.14% contribution only.
- Both R-sq and R-sq(predicted) values are above 90% indicating a good prediction of the variation of response around mean due to above factors for the parameters level values as well as for other values also.
- From main effects plot for Means and it can be seen that the optimal combination for Feed Force is speed at 550 rpm, feed of 0.05 mm/rev and depth of cut of 1.0 mm.

CUTTING FORCE

Regression Equation-

CUTTING FORCE = -1.95 - 0.0189 N + 124.0 FEED + 10.00 D.O.C

Table- Analysis of Variance for Cutting Force

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Regression	3	384.40	128.13	9.17	0.018
N	1	46.68	46.68	3.34	0.127
FEED	1	187.72	187.72	13.44	0.014
D.O.C	1	150.00	150.00	10.74	0.022
Error	5	69.83	13.97		
Total	8	454.22			

Table- Response Table for Signal to Noise Ratios (Smaller is better) for Cutting Force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	-24.30	-13.33	-19.57
2	-20.19	-23.13	-21.92
3	-22.18	-25.22	-25.19
Delta	4.11	6.88	5.62
Rank	3	1	2

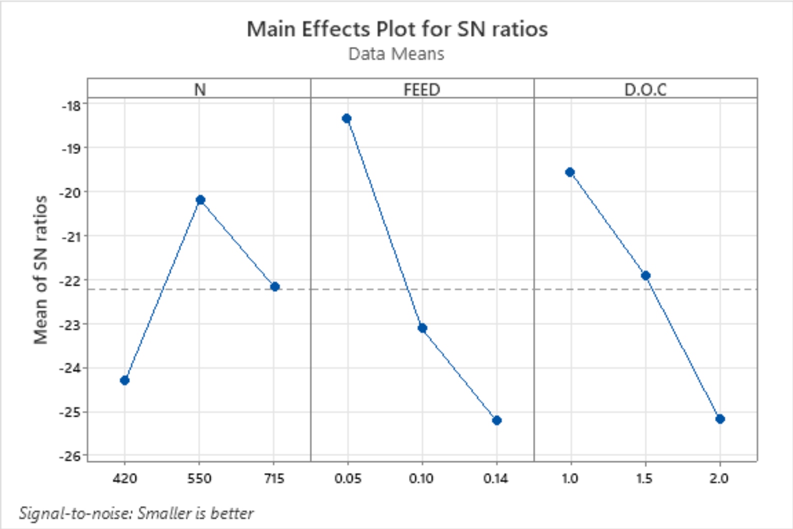

Figure- Effect of process parameters on Cutting Force

Table - Response Table for Means for Cutting Force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	19.167	8.667	9.667
2	11.000	14.833	14.000
3	13.167	19.833	19.667
Delta	8.167	11.167	10.000
Rank	3	1	2

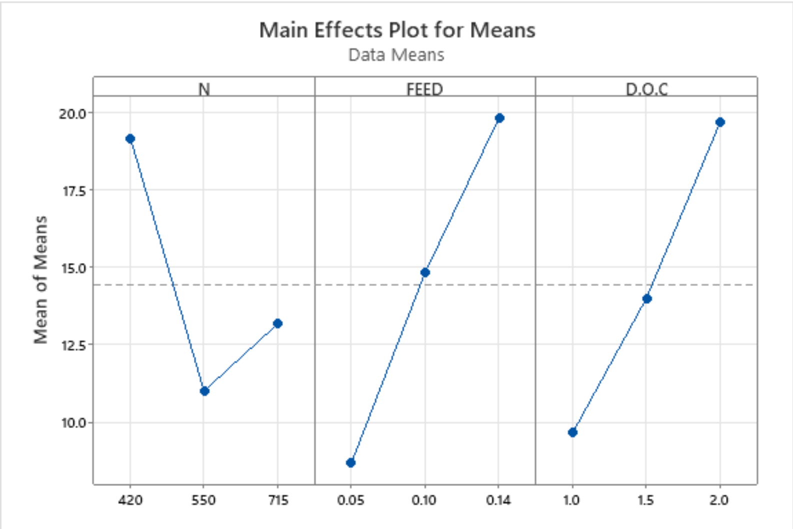

Figure- Effect of process parameters on Cutting Force

- For Cutting Force, Feed is the most significant factor as can be seen from response table for SN ratio and for means, followed by depth of cut and speed.
- From ANOVA table it is clear that depth of cut makes 33.02% contribution on Cutting force while feed makes 41.33% contribution and speed makes 10.28% contribution only.
- R-sq value is around 84% indicating a good prediction of the variation of response around mean due to above factors for the parameters level values. R sq predicted value is about 70% indicating a fair prediction of variation as well as for other values also.
- From main effects plot for Means and it can be seen that the optimal combination for Cutting Force is speed at 550 rpm, feed of 0.05 mm/rev and depth of cut of 1.0 mm

RADIAL FORCE

Regression Equation-

RADIAL FORCE = 5.70 - 0.00630 N + 40.8 FEED - 1.00 D.O.C

Table- Analysis of Variance for Radial Force

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	27.066	9.022	3.98	0.085
N	1	5.211	5.211	2.30	0.190
FEED	1	20.355	20.355	8.99	0.030
D.O.C	1	1.500	1.500	0.66	0.453
Error	5	11.323	2.265		
Total	8	38.389			

Table- Response Table for Signal to Noise Ratios (Smaller is better) for Radial Force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	-15.481	-7.195	-13.333
2	-10.494	-12.947	-14.234
3	-10.079	-15.913	-8.487
Delta	5.402	8.718	5.748
Rank	3	1	2

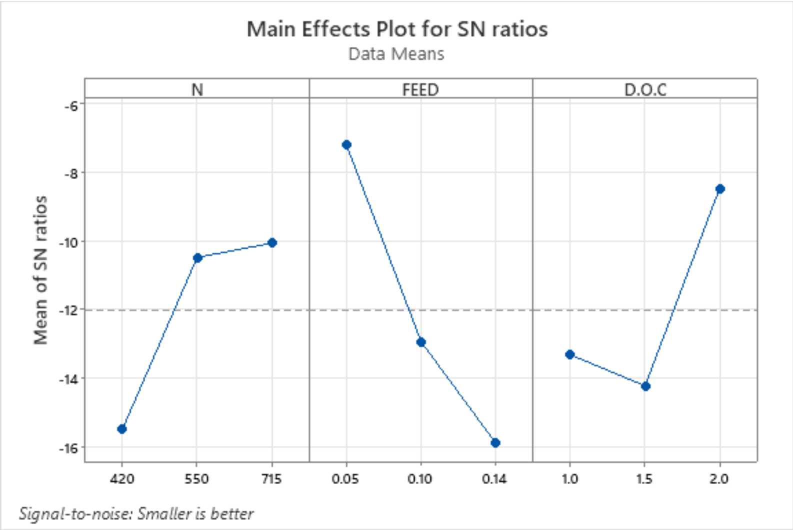

Figure- Effect of process parameters on Radial Force

Table - Response Table for Means for Radial Force

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	6.167	2.667	4.667
2	3.500	4.833	5.500
3	4.167	6.833	3.667
Delta	2.667	3.667	1.833
Rank	2	1	3

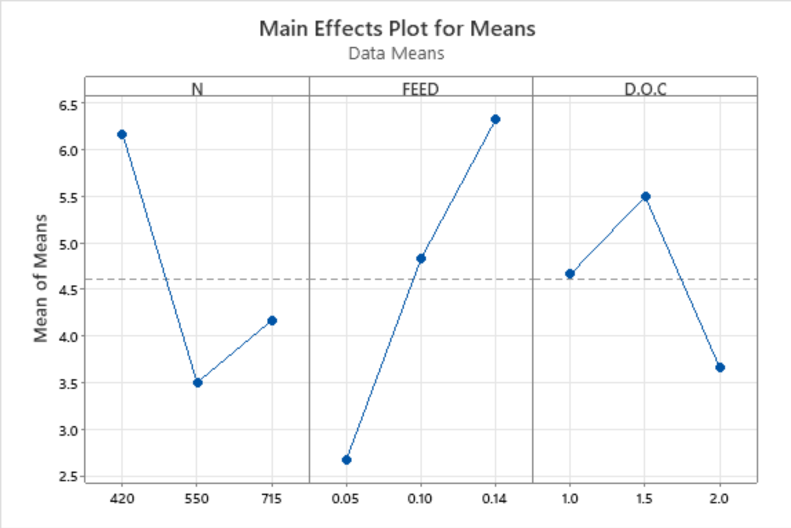

Figure- Effect of process parameters on Radial Force

- For Radial Force, Feed is the most significant factor as can be seen from response table for SN ratio and for means, followed by speed and depth of cut.
- From ANOVA table it is clear that depth of cut makes 3.91% contribution on Radial Force while feed makes 53.03% contribution and speed makes 13.55% contribution only.
  Error contributes about 29.5% indicating some more significant factor present (maybe interactions, tool nose radius, etc.).
- R-sq value is around 87% indicating a good prediction of the variation of response around mean due to above factors for the parameters level values. Rsq predicted value is about 76% indicating a fair prediction of variation as well as for other values also.
- From main effects plot for Means and it can be seen that the optimal combination for Radial Force is speed at 550 rpm, feed of 0.05 mm/rev and depth of cut of 2.0 mm.

Material Removal Rate(MRR)

Regression Equation-

MRR = -305 + 0.068 N + 2673 FEED + 173.0 D.O.C

Table- Analysis of Variance for MRR

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Regression	3	132683	44227.5	10.37	0.014
N	1	611	610.9	0.14	0.721
FEED	1	87170	87169.6	20.44	0.006
D.O.C	1	44902	44902.2	10.53	0.023
Error	5	21319	4263.8		
Total	8	154002			

Table- Response Table for Signal to Noise Ratios (Larger is Better) for MRR

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	43.61	41.27	42.93
2	48.84	46.90	46.44
3	47.07	51.34	50.15
Delta	5.23	10.07	7.23
Rank	3	1	2

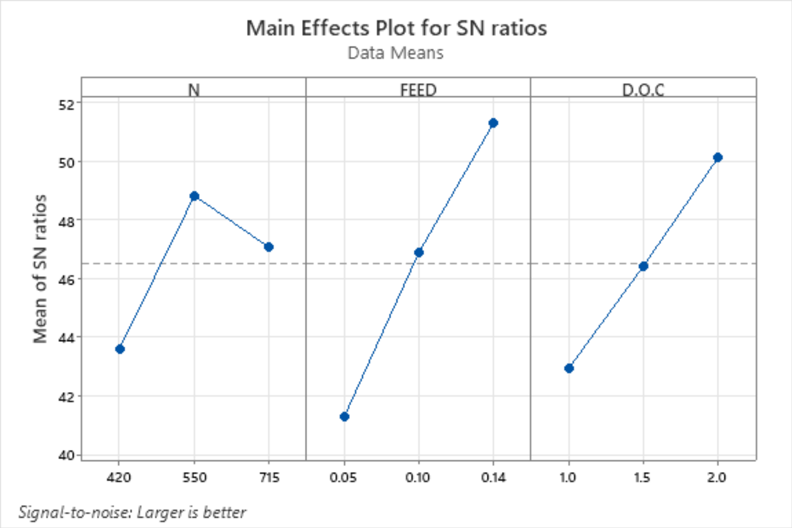

Figure- Effect of process parameters on MRR

Table - Response Table for Means for MRR

Level	N(rpm)	FEED(mm/rev)	DOC(mm)
1	215.9	132.1	175.7
2	296.6	248.0	229.7
3	241.5	374.0	348.7
Delta	80.6	241.9	173.0
Rank	3	1	2

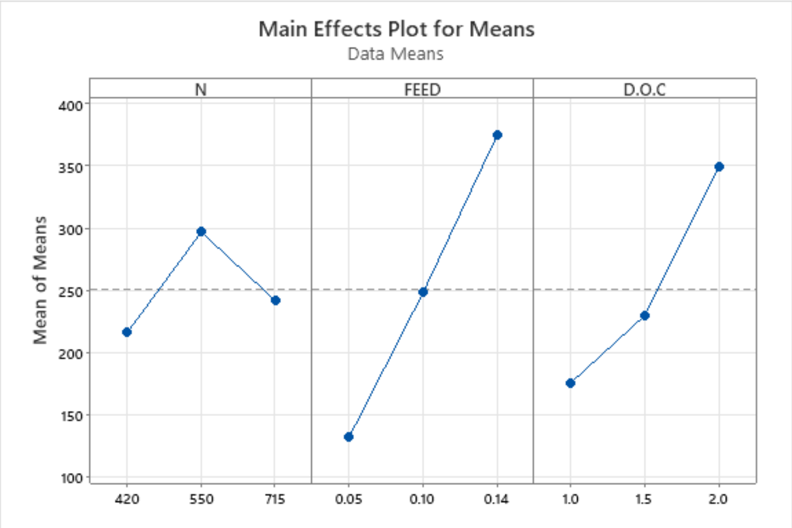

Figure- Effect of process parameters on MRR

- For MRR, Feed is the most significant factor as can be seen from response table for SN ratio and for means, followed by depth of cut and speed.
- From ANOVA table it is clear that depth of cut makes 29.16% contribution on MRR while speed makes 0.40% contribution and feed makes 56.6% contribution only. Error contributes about 13.84% indicating not much dependence of other factors on response.
- Both R-sq and R-sq predicted values are above 99% indicating an excellent prediction of variation of response around mean.
- From main effects plot for Means and it can be seen that the optimal combination for MRR is speed at 550 rpm, feed of 0.14 mm/rev and depth of cut of 2.0 mm.

CONCLUSION

The study demonstrates that when feasible process parameters are selected, Aluminum Alloy 6062 could be efficiently turned using ceramic carbide insert. It can be seen easily that depth of cut is major contributing factor on the feed force. .For cutting force the major contributing factor is Feed. For radial force while the major contributing factor is Feed and For MRR also Feed is major contributing factor. The research into the machining of Aluminum Alloy 6062 is continuing in several fronts, including turning processes. An experimental approach to the evaluation of material removal rate, feed force, radial force and cutting force in naming Aluminum Alloy 6062 by ceramic carbide using Taguchi method and Anova.

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