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Machining Parameter optimization by using Taguchi Technique for CNC turning of Grade T6 Aluminium alloy

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Abstract: With the increase in demand for producing products with good surface finish within reduced time. Selection of suitable parameters for machining in CNC lathe is much required from the operator's point of view. To attain the desired parameters this study deals taguchi technique as a tool in process parameter optimization using carbon insert CNMG tool in turning of AA6063 alloy. L9 orthogonal array is selected for conducting the experiments and for this Feed, Cutting Speed, Depth of Cut are the process parameters. The ANOVA and S-N ratio is used to analyse the characteristic performance of the turning operation performed. From the results of ANOVA the most influential parameter in reducing the surface roughness is found as depth of cut. Finally for various process parameter combinations the surface roughness is calculated and the optimum parameter for machining is attained by using Taguchi. For authentication of the optimum output attained in optimization experiments have been conducted to get maximum surface finish when machining the aluminium alloy in CNC turning.

Keywords: AA6063 alloy, Taguchi, ANOVA, Surface Roughness.

I. INTRODUCTION

In every manufacturing industry the main work involved is machining. In order to get reduced time in machining of components with good quality the selection of process parameters plays an important role. Improper selection of parameters results in reduced material removal rate, increase in machining time, reduced finishing, tool life will be reduced and tool wear will be high. In the process of turning operation there are large number of parameters like feed, depth of cut and speed plays a major role in machining which influences the output like as Surface Roughness [Ra], Material Removal Rate [MRR], tool wear, vibration, geometric tolerance etc. One of the most extensively used operation during machining is turning and hence the need for getting the desired high quality products in in the industries grasp the attention of researchers in finding the optimum parameters to get the good quality products in the expense of less energy. This work aims in optimizing the parameters in machining of Aluminium Alloys on a CNC turning lathe. Aluminium alloy selected in this experimental work will have the following characteristics, higher strength, brilliant corrosion resistance and good machinability. AA6063 alloy is selected because of its most widely used in the production of Structural and architectural parts, Petroleum and Chemical industry components- Chemical piping, cryogenic tank, Automobile-Space frames and Marine Transportation-Structural beams.The altered ways of performing optimization are genetic algorithm, Taguchi, ANOVA, fuzzy logic. ANOVA and Taguchi techniques are the most commonly used methods of optimization. The ANOVA approach helps to distinguish which parameter is mainly noteworthy for given input parameters, while the Taguchi technique is used to find the optimal parameters with reduced number of experimental runs.

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II. WORK METHODOLOGY

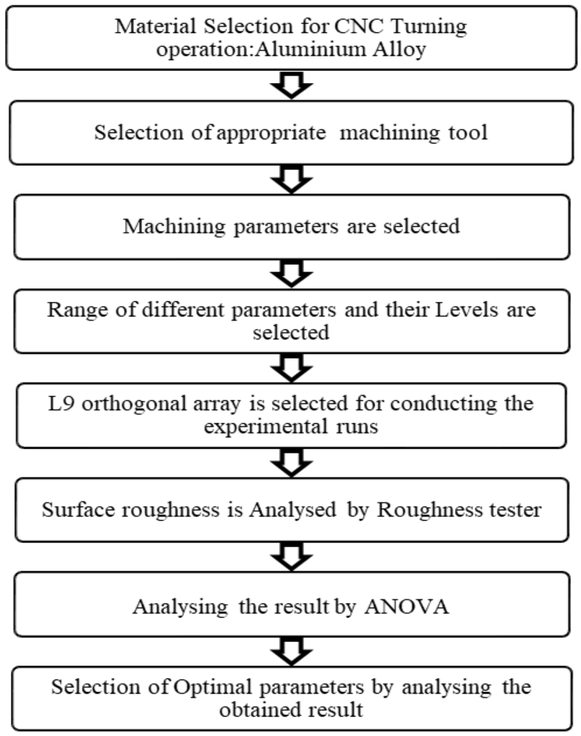

Fig. 1. Methodology for Experimental plan and analysis

A. Aluminum Alloy Work material

Aluminum alloys symbolize some of the most versatile engineering materials due to their distinctive blend of properties. In this work the heat treated tempered alloys with a temper grade of T6 i.e, AA6063 T6 is selected in this study which necessitate the need to substantiate the machinability of this alloy. Table-I and Table-II shows the chemical proportion and their physical properties of AA6063

Table-I: Chemical Proportion of AA6063

Element	Weight %
Si	0.6
Fe	0.34
Cu	0.09
Mn	0.09
Mg	0.88
Ti	0.092
Cr	0.092
Zn	0.095
Al	97.721

Table-II: Mechanical properties of AA6063

S. No	Properties	Value
1	Ultimate tensile strength	215 MPa to 240 Mpa
2	Density	2.7 g/cc
3	Modulus of elasticity	69000 Mpa
4	Melting point	616°C - 654°C
5	Shear strength	150 Mpa
6	Poisson's Ratio	0.33

B. Cutting Tool

The Standard Carbide insert CNMG tool is selected as the cutting tool for conducting the experiments. From literature review it is evident that performance of the Coated carbide tools will be better than the uncoated carbide tools. The CNMG tool used in this work is shown in Fig. 2.

Fig. 2. Cutting tool

C. Selection of Parameters for Machining

In this study, a three-level full factorial experimental design was selected for performing the turning operation. Cutting operations are performed by involving the following three cutting parameters Feed rate (mm/rev), Cutting Speed (rpm), Depth of Cut (mm) with three levels and total of 9 experiments were done and accounted. Table-III shows the values of a range of parameters used for experiments

Table-III: Machining parameters and their levels

Process Parameter	Unit	Symbol	Level 1	Level 2	Level 3
Speed	rpm	A	1000	1300	1600
Feed	mm/rev	B	0.10	0.15	0.20
Depth of Cut	Mm	C	0.20	0.40	0.60

In this work L9 mixed type orthogonal array is selected for conducting the experimental runs using Taguchi method. For the various combinations of parameters the amount of material removed and surface roughness was used as response variables.

D. Experiment Based on the Taguchi Method

For conducting the experiments the specimens are prepared having a diameter of 28mm,100mm in length and after performing the turning operation the final diameter of the specimen is reduced to 24mm and length by 96mm. CNC program is prepared and is fed into the machine for experimental runs with selected process parameters. L9 orthogonal array is preferable for the experiment. Change the levels and take 9 trails according to the L9 array. After machining the average roughness of the specimens is measured by using Time 3100 Surface Roughness Testing device. The different values used for machining, according to the L9 orthogonal array and their response is shown in the Table-IV.

Fig. 3. Specimens after Turning in CNC lathe.

Table-IV: Process variables and their corresponding Responses

Experimenta l runs	Speed in rpm	Feed rate in mm/rev	Depth of cut in mm	Roughnes s Value (μm)
1	1000	0.10	0.20	0.110
2	1000	0.15	0.40	0.135
3	1000	0.20	0.60	0.195
4	1300	0.10	0.40	0.190
5	1300	0.15	0.60	0.135
6	1300	0.20	0.20	0.100
7	1600	0.10	0.60	0.145
8	1600	0.15	0.20	0.085
9	1600	0.20	0.40	0.095

III. RESULTS AND DISCUSSION

A. Taguchi method for Parameter optimization in machining

Taguchi approach, a statistical method is used to manipulate the variables in large numbers using a reduced number of experimental runs which is selected by the theory of design of experiments. Valid conclusions can be attained from small number of experimental runs over the over the entire Experimental region for variable operating conditions.

In this study the Taguchi approach design is involved to study the effects of the machining parameters. A three level three factor, L9 (3^3) nine experimental design was preferred to perform the experimental trials. Taguchi technique uses a loss function which is changed to signal-to noise ratio to conclude the quality of the specimen.

For analysing the data obtained from the experimental work a statistical software Minitab is employed. After analysing the experimental data Taguchi technique provides the signal-to-noise ratio from the obtained results. The effect of different process parameters on surface roughness is calculated and plotted against the variation of process parameters from one level to another. The average ratio of S/N has been calculated to find the impact of various parameters and also their levels. From the experimental results, S/N ratio is calculated and is shown in Fig. 4.

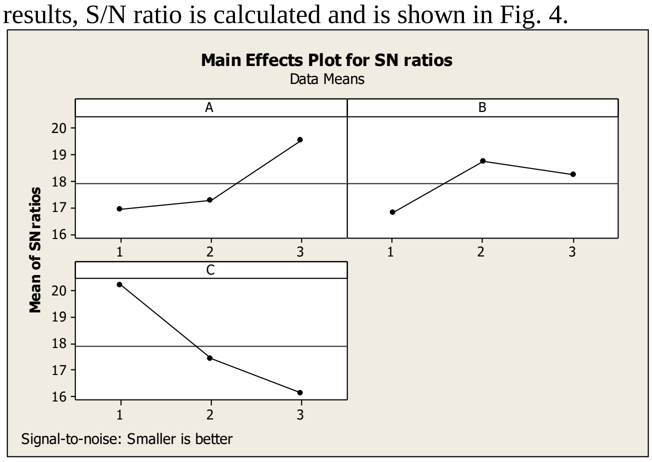

Fig. 4. S/N Ratio plot for design parameters

After analyzing the machining parameters and levels, S/N ratio plot is obtained by optimization using Taguchi technique. For minimizing the roughness value the condition smaller is better is taken from the signal to noise ratio plot. From optimization the Spindle speed 1600 rpm, depth of cut 0.20 mm, feed 0.15 mm/rev is selected as the best design parameters by which we can obtain good surface finish for turning of Aluminium alloy in CNC lathe

B. Analysis of variance (ANOVA)

For analysing the experimental data obtained ANOVA is used as a tool to check the capability of the model developed by using Taguchi. The results obtained by analysing the experimental data is shown in Table-V, it is noted that the effect of process parameters and their square combinations of all the factors like spindle speed , feed rate and depth of cut are most noteworthy, as its values are probably zero.

Table-V: ANOVA Results

Parameter	Degree of freedom	Sum of square	Mean square	% Contribution
A	2	0.002606	0.000019	20.67
B	2	0.001635	0.000847	12.97
C	2	0.006674	0.003337	52.94
Error	2	0.001691	0.000846	13.41
Total	8	0.012606		

From the results of ANOVA, percentage contribution of depth of cut is weighed against other parameters are shown in Fig. 5. Surface roughness is impacted mainly by depth of cut. The parameter set which can produce minimum surface roughness is obtained from the S/N ratio plot.

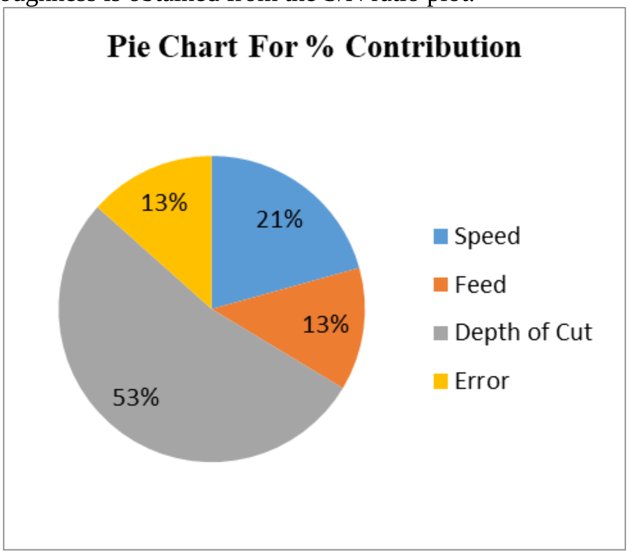

Fig. 5. Percentage contribution of machining parameters

IV. CONCLUSION

In this work the operational design was carried out using Taguchi method to reduce the number of experiments and to achieve high accuracy results. This process has been conducted to choose the optimal cutting parameters for machining AA6063 aluminium alloy on a CNC machine.

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Design experimental trials was performed by using Taguchi method, with an implementation of ANOVA to investigate the specific effect of each parameters on the surface roughness of the machined component. In this study following parameters like speed, feed and depth of cut was selected. ANOVA result shows that the influence of depth of cut is very high in obtaining the surface roughness of the finished product. The optimized experimental runs show a much improved process performance. Overall, the precise optimization study helped us to save the experimental time necessary to get the specimen with good surface finish

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