Investigation and analysis of main effect and interaction effect for turning of Aluminium alloy Al7050

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Abstract-An attempt has been made to carry out an experimental investigation on aluminium alloys by using Taguchi technique mainly to find and correlate the technological factors to the economics of machining process. The Taguchi method is a systematic application of design and analysis for experiments. It is an effective approach to produce high quality products at relatively low cost. Improvement of one parameter leads to degradation of other parameters and optimization of multiple parameters is much more complicated. Hence, Taguchi method is used to investigate the multiple performance characteristic in the turning operation.

Keywords: *Machinability, Taguchi technique, cutting parameters, machining environment.*

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I. INTRODUCTION:

Traditionally, the machinability of materials involve tool life, cutting forces, productivity or chip formation, with less attention paid to particle emission. In this work, the authors address the machinability of aluminium alloys from several points of view, including cutting forces, chip formation and segmentation and metallic particle emission.

The main properties which make aluminium a valuable material are lightweight, strength, recyclability, corrosion resistance, durability, ductility, formability and conductivity. Due to this unique combination of properties, the variety of applications of aluminium continues to increase.

The analysis of the data during manufacturing by using suitable statistical designs is of high importance for precise evaluation to be obtained from the process. Design and methods such as factorial design, response surface methodology and Taguchi methods are now widely in use in place of one-factor-at-a-time experimental approach which is time consuming and exorbitant in cost. Peigne et al. studied effects of the cutting vibratory phenomena and their impacts on the surface roughness of the machined surface. Franco et al., developed a numerical model for predicting the surface profile and surface roughness in face milling with round insert cutting tools. Kishwy et al., researched the effect of flood coolant and dry cutting on tool wear, surface roughness and cutting forces. Grzesik. et al, examined two face milling cutter system in high-speed cutting of gray cast iron under a determined cutting condition. Silver et al., calculated optimal operating conditions to obtain the best possible compromise between the roughness of machined mould surfaces and the duration of finishing cut using software GONNS. Sachin studied the surface integrity produced by end mill tool using a Taguchi orthogonal array. Horng et al, analyzed the influence of cutting condition and tool geometry on surface roughness. Alauddin et al. developed an in-process-based recognition system to predict the surface roughness of machined parts in the end milling process. Choudhury et al, identified the most influential and common sensor features for dimensional accuracy and surface roughness in CNC milling operations using three different material types. Mital et al. investigated the effect of machining forces, surface texture and work piece breakout.

II. PROBLEM DEFINITION

Innovative machining strategies are characterized by maximum cutting speeds and feed rates in order to obtain the highest possible metal removal rates. Refraining from massive use of cooling lubricant represents an important demand with reference to the environmental impact. Process safety and an increase in productivity are the pre-requisites for a favorable market position and thus competitiveness. The machining properties of aluminium are perfectly suitable for putting modern machining concepts into practice.

Machinability is a consideration in the materials selection process for automatic screw machine parts. The case with which a metal can be machined is one of the principal factors affecting a products utility, quality and cost. The usefulness of means to predict machinability is obvious; machinability is so complex a subject that it cannot be unambiguously defined. Depending on the application, machinability maybe seen in forms of tool wear rate, total power consumption, attainable surface finish or several other bench marks. Machinability therefore depends a great deal on the view point of the observer, in fact, the criterion for one application frequently conflict with those for another.

III. OBJECTIVES OF THE WORK:

The objective of the work is to discuss the various methods of Taguchi technique and strategies that are adopted in order to find the following parameters by both experimentally and Taguchi techniques.

i) To develop relationship between the control parameters and response parameters during machining.
ii) To study the effect of nose radius on the machinability response i.e., surface finish, material removal, machining force and power consumption.
iii) To optimize turning operation parameters for surface roughness, material removal, machining force and power consumption.
iv) To optimize unit production cost and it is established on the basis of actual machining time, setup time, tool re-use time, tool life and tool changing time.

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IV. EXPERIMENTAL STUDY

The as-received Al 7050 alloys were used in this study. Their chemical composition are given in the Table 1. Al 7050 alloy is the least expensive and most versatile of the heat treatable among the aluminum alloys. It offers a range of good mechanical properties and also good corrosion resistance. Its strength to weight ratio is excellent and it is ideally used for highly stressed parts. It may be formed in the annealed condition and subsequently heat treated.

TABLE I. Chemical composition 7050 Aluminum alloys in weight percentage

Alloy	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Zr**	**Al**
Al7050	0.12	0.15	2-2.6	0.1	1.9-2.6	0.04	5.7-6.7	0.08-0.15	Bal

V. TAGUCHI TECHNIQUE

A. L16 technique

Experimental design was done using Taguchi method. Hence, it has been possible to reach more comprehensive results with doing fewer experiments. In this sense, time and money have been used more efficiently [7-8]. In the determination of the characteristics of the quality as the rates of surface roughness to be measured, MRR, cutting time, and cutting force were required to be minimum, “less is more” principle has been applied among the quality values expected to be reached at the end of the experiments.

The goal of this research was to produce minimum surface roughness (Ra) in a turning operation. Smaller Ra values represent better or improved surface roughness. Therefore, a smaller-the-better quality characteristic was implemented and introduced in this study [9].

The Taguchi method, which is a powerful tool in the design of an experiment, is used to optimize the turning parameters for effective machining of Al 7050 alloy. This method recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. To obtain optimal testing parameters, the-lower-the-better quality characteristic for machining the Al was taken due to the measurement of the surface finish. The S/N ratio for each level of testing parameters was computed based on the S/N analysis. This design is sufficient to investigate the four main effects and the influence of their interactions on the surface roughness. With S/N ratio analysis, the optimal combination of the testing parameters could be determined.

The control parameters were cutting speed (V), feed rate (f), depth of cut (d) and tool’s nose radius (r). Four levels were specified for each of the factors as indicated in Table 2. The orthogonal array chosen was L16 combinations as shown in table 3. The first column was assigned to the cutting speed (V), the second column to the feed rate (f), the fourth column to the depth of cut (d), the eighth column to the tool’s nose radius (r) and the remaining columns to the interactions.

TABLE II. Assignment of the levels to the factors

Serial Number	**Factor/Level**	**Minimum**	**Intermediate**	**Intermediate**	**Maximum**
1	Cutting Speed (rpm)	500	1000	1500	2000
2	Feed (mm/rev)	0.5	1	1.5	2
3	Depth of cut (mm)	0.02	0.04	0.06	0.08
4	Nose Radius (mm)	0.4	0.8	0.4	0.8

TABLE III. Physical Layout for L16

Experiment number	**Cutting Speed (rpm)**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Nose Radius (mm)**
1	500	0.02	0.5	0.4
2	1000	0.02	0.5	0.8
3	1500	0.02	0.5	0.4
4	2000	0.02	0.5	0.8
5	500	0.04	1	0.8
6	1000	0.04	1	0.4
7	1500	0.04	1	0.8
8	2000	0.04	1	0.4
9	500	0.06	1.5	0.4
10	1000	0.06	1.5	0.8
11	1500	0.06	1.5	0.4
12	2000	0.06	1.5	0.8
13	500	0.08	2	0.8
14	1000	0.08	2	0.4
15	1500	0.08	2	0.8
16	2000	0.08	2	0.4

B. Taguchi analysis for Al 7050 alloy

Similar methods are followed to measure S/N ratio for surface roughness, material removal rate, machining time, cutting force and power requirement for Al7050 alloy given in Table 4-8 respectively.

TABLE IV. Experimental results and S/N ratio of Ra for Al 7050 alloy

`	**Cutting Speed (rpm)**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Nose Radius (mm)**	**Surface Roughness (µm)**	**S/N Ratio**
1	500	0.5	0.02	0.4	0.6005	4.4297
2	1000	0.5	0.02	0.8	1.639	-4.2916
3	1500	0.5	0.02	0.4	0.6905	3.2167
4	2000	0.5	0.02	0.8	6.735	-16.5668
5	500	1	0.04	0.8	0.1897	14.4387
6	1000	1	0.04	0.4	0.826	1.6604
7	1500	1	0.04	0.8	0.7817	2.1392
8	2000	1	0.04	0.4	0.841	1.5041
9	500	1.5	0.06	0.4	1.1885	-1.5
10	1000	1.5	0.06	0.8	0.595	4.5097
11	1500	1.5	0.06	0.4	1.3875	-2.8447
12	2000	1.5	0.06	0.8	0.5055	5.9256
13	500	2	0.08	0.8	1.5107	-3.5836
14	1000	2	0.08	0.4	1.4097	-2.9825

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15	1500	2	0.08	0.8	2.3517	-7.4276
16	2000	2	0.08	0.4	1.536	-3.7278

TABLE V. Experimental results and S/N ratio of MRR for Al 7050 alloy

SL. No.	Cutting Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Nose Radius (mm)	Surface Roughness (µm)	S/N Ratio
1	500	0.5	0.02	0.4	0.6005	4.4297
2	1000	0.5	0.02	0.8	1.6390	-4.2916
3	1500	0.5	0.02	0.4	0.6905	3.2167
4	2000	0.5	0.02	0.8	6.7350	-16.5668
5	500	1.0	0.04	0.8	0.1897	14.4387
6	1000	1.0	0.04	0.4	0.8260	1.6604
7	1500	1.0	0.04	0.8	0.7817	2.1392
8	2000	1.0	0.04	0.4	0.8410	1.5041
9	500	1.5	0.06	0.4	1.1885	-1.5000
10	1000	1.5	0.06	0.8	0.5950	4.5097
11	1500	1.5	0.06	0.4	1.3875	-2.8447
12	2000	1.5	0.06	0.8	0.5055	5.9256
13	500	2.0	0.08	0.8	1.5107	-3.5836
14	1000	2.0	0.08	0.4	1.4097	-2.9825
15	1500	2.0	0.08	0.8	2.3517	-7.4276
16	2000	2.0	0.08	0.4	1.5360	-3.7278

TABLE VI. Experimental results and S/N ratio of machining time for Al 7050 alloy

SL. No.	Cutting Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Nose Radius (mm)	Material Removal Rate (mm3/rev)	S/N Ratio
1	500	0.5	0.02	0.4	1178.097	-61.4236
2	1000	0.5	0.02	0.8	2356.194	-67.4442
3	1500	0.5	0.02	0.4	3534.290	-70.9660
4	2000	0.5	0.02	0.8	4712.388	-73.4648
5	500	1.0	0.04	0.8	4712.380	-73.4648
6	1000	1.0	0.04	0.4	9424.770	-79.4854
7	1500	1.0	0.04	0.8	14137.160	-83.0072
8	2000	1.0	0.04	0.4	18849.550	-85.5060
9	500	1.5	0.06	0.4	10602.870	-80.5085
10	1000	1.5	0.06	0.8	21205.750	-86.5291
11	1500	1.5	0.06	0.4	31808.620	-90.0509
12	2000	1.5	0.06	0.8	42411.500	-92.5497
13	500	2.0	0.08	0.8	18849.550	-85.5060
14	1000	2.0	0.08	0.4	37699.110	-91.5266
15	1500	2.0	0.08	0.8	56548.660	-95.0484
16	2000	2.0	0.08	0.4	75398.220	-97.5472

VI. Results and Discussion

The main objective of the experiment is to optimize the turning parameters (cutting speed, feed rate, Depth of cut and nose radius) to achieve optimum value of the cutting parameters.

The experimental data for the surface roughness values and the calculated signal-to-noise ratio are shown in Table 4 for Al 7050 alloy. The S/N ratio values of the surface roughness are calculated, using the smaller the better characteristics. Taguchi recommends analyzing data using the S/N ratio that will offer two advantages; it provides guidance for selection the optimum level based on least variation around on the average value, which closest to target, and also it offers objective comparison of two sets of experimental data with respect to deviation of the average from the target [10].

Table 4 shows the surface roughness along with its computed S/N ratio value. Average S/N ratio for each level of experiment is calculated based on the value of Table 4.

Figure 2 gives a Main effects plot for S/N ratio vs cutting parameters to determine the optimum surface roughness value.

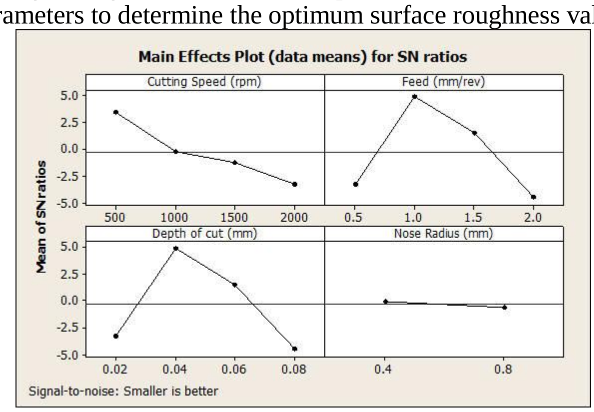

Figure 2. Main effect plot for S/N ratio vs. parameters for surface roughness

Figure 3 gives an Interaction plot for S/N ratio vs the cutting parameters which shows the effect of two or more parameters.

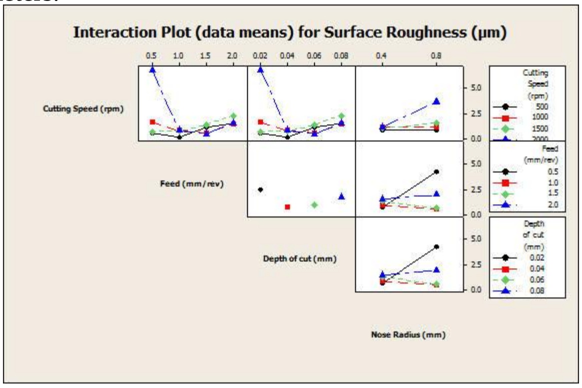

Figure 3. Interaction effect plot for S/N ratio vs. parameters for surface roughness

Table 5 shows the material removal rate along with its computed S/N ratio value. Average S/N ratio for each level of experiment is calculated based on the value of Table 5.

Figure 4 gives a Main effects plot for S/N ratio vs cutting parameters to determine the optimum material removal rate.

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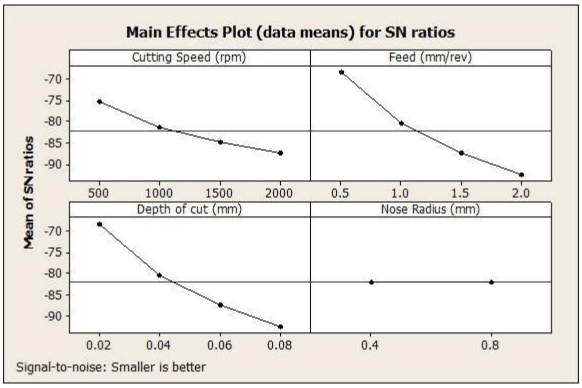

Figure 4. Main effect plot for S/N ratio vs. parameters for material removal rate

Figure 5 gives an Interaction plot for S/N ratio vs the cutting parameters which shows the effect of two or more parameters.

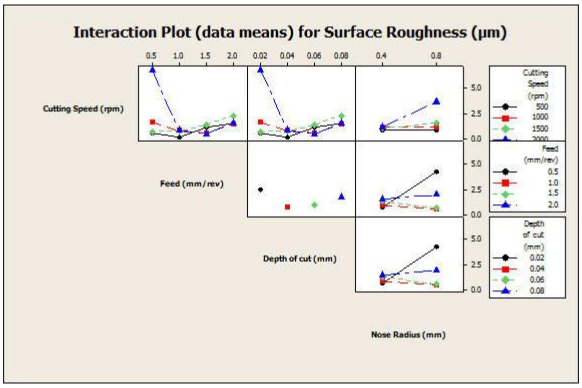

Figure 5. Interaction effect plot for S/N ratio vs. parameters for material removal rate

Table 6 shows the machining time along with its computed S/N ratio value. Average S/N ratio for each level of experiment is calculated based on the value of Table 6.

Figure 6 gives a Main effects plot for S/N ratio vs cutting parameters to determine the optimum machining time.

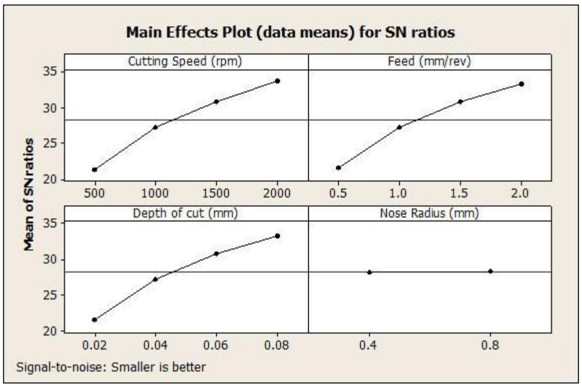

Figure 6. Main effect plot for S/N ratio vs. parameters for machining time

Figure 7 gives an Interaction plot for S/N ratio vs the cutting parameters which shows the effect of two or more parameters.

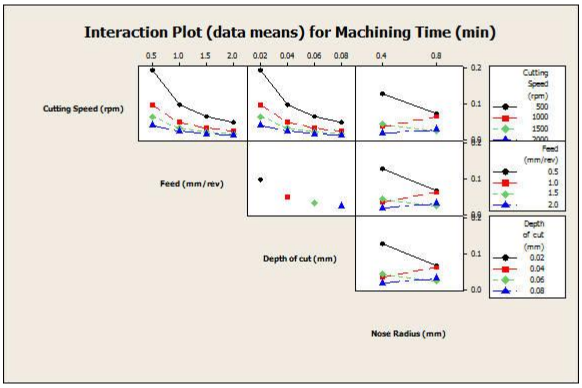

Figure 7. Interaction effect plot for S/N ratio vs. parameters for machining time

CONCLUSIONS

An experimental design was carried out using Taguchi technique to reduce the number of experiments done for 4 factors and 4 levels. The experiment was conducted to optimize the cutting parameters for turning of aluminium alloy Al 7050 on a CNC machine.

The Taguchi analysis using Signal to Noise Ratios for each parameter (ie., Surface roughness, Material removal rate and machining time) was done to find the optimum parameter setting. The following conclusions can be drawn from the results obtained

i) Surface roughness is minimum for an intermediate value of Cutting speed (500 rpm), Feed rate (1.5 mm/rev), Depth of Cut (0.06 mm) and Nose radius (0.4 mm)
ii) Material removal rate is maximum for Cutting speed (2000 rpm), Feed rate (2 mm/rev), Depth of Cut (0.08 mm) and Nose radius (0.4 mm)
iii) Surface roughness is minimum for Cutting speed (500 rpm), Feed rate (0.5 mm/rev), Depth of Cut (0.02 mm) and Nose radius (0.4 mm)

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