International Journal of Ignited Minds (IJIMIINDS)

Optimization of Cutting Parameters Using Signal-to-Noise Ratio for Turning 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.*

1. 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. Lalwani et al. studied the effect of cutting parameters in turning on cutting forces and surface roughness. Dickinson, Grieve et al., and Fischer and Elrod developed a turning model in which tool nose radius and feed rate are taken into account but cutting speed is ignored. Thomas et al., used built up edge formation occurring during dry turning mild carbon steel and a full factorial design, taking into account the three-level interactions between the independent variables. Yang and Tarng have conducted study on optimal cutting parameters using Taguchi method in turning. Nian et al. investigated the optimization of CNC turning operations by Taguchi method with multiple performance characteristics. Lin et al. developed an objective network model to estimate the surface roughness and cutting forces. Wang et al. investigated the effect of tool nose vibration on surface roughness during turning theoretically and experimentally.

2. PROBLEM DEFINITION

Particularly in the field of transport engineering massive application of lightweight materials represents the order of the day. The goal of saving fuel and other energy forms can mainly be achieved through the reduction of vehicle weights. Apart from various synthetic materials, the classical light metal Aluminium offers the best pre-requisite for reaching this objective. In other application fields too, its numerous favorable properties make Aluminium an appreciated construction material for engineers.

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.

3. 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.

4. EXPERIMENTAL STUDY

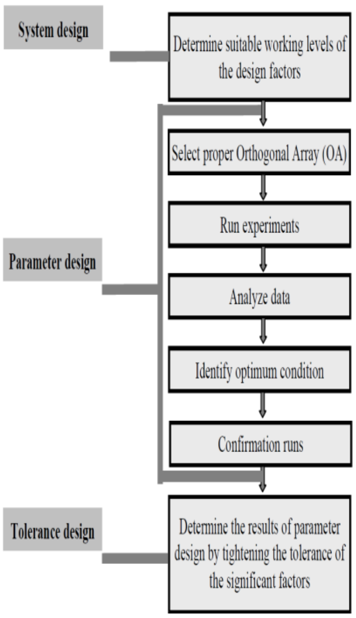

Fig 1: Methodology to Determine the Effectiveness of the Turning Parameters on Surface Roughness of Al 7050 alloy

The as-received Al 7050 alloys were used in this study shown in Fig. 1 and 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 Aluminium 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.

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**

Table 1: Chemical Composition 7050 Aluminium Alloys in Weight Percentage

5. TAGUCHI TECHNIQUE

5.1 L9 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.

$$SN = -10xlog\left[\frac{1}{n}\sum_{i}^{n} y_i^2\right] \tag{1}$$

Where n is the number of experiments done under experiment conditions and y represents the calculated characteristics.
Notice that these S/N ratios are expressed on a decibel scale. In this work use S/N if the objective is to reduce variability around a specific target, S/N if the system is optimized when the response is as large as possible. Factor levels that maximize the appropriate S/N ratio are optimal. 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). Three levels were specified for each of the factors as indicated in Table 2. The orthogonal array chosen was L9, which has 9 rows corresponding to the number of parameter combinations (8 degrees of freedom) [10]. The first column was assigned to the cutting speed (V), the second column to the feed rate (f).

Sl. No	Factor/Level	Minimum	Intermediate	Maximum
1	Cutting Speed (rpm)	500	1000	2000
2	Feed (mm/rev)	0.01	0.045	0.09

Table 2: Assignment of the Levels to the Factors

Expt. No.	Cutting Speed (rpm)	Feed (mm/rev)
1	500	0.01
2	500	0.045
3	500	0.09
4	1000	0.01
5	1000	0.09
6	1000	0.045
7	2000	0.09
8	2000	0.01
9	2000	0.045

Table 3: Physical Layout for L9

5.2 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.

Epxt. No	Speed	Feed	Average Ra (μm)	S/N ratio
1	500	0.01	1.2235	-1.75
2	500	0.045	2.8397	-9.07
3	500	0.09	0.8480	1.43
4	1000	0.01	3.5370	-10.97
5	1000	0.09	0.4937	6.13
6	1000	0.045	3.1400	-9.94
7	2000	0.09	0.5380	5.38
8	2000	0.01	8.1800	-18.26
9	2000	0.045	0.5905	4.58

Table 4: Experimental Results and S/N Ratio of Ra for Al 7050 Alloy

Expt No	Speed	Feed	MRR	S/N ratio
1	500	0.01	1178.1	-61.42
2	500	0.045	5301.4	-74.49
3	500	0.09	10602.9	-80.51
4	1000	0.01	2356.2	-67.44
5	1000	0.09	21205.8	-86.53
6	1000	0.045	10602.9	-80.51
7	2000	0.09	42411.5	-92.55
8	2000	0.01	4712.4	-73.46
9	2000	0.045	21205.8	-86.53

Table 5: Experimental Results and S/N Ratio of MRR for Al 7050 Alloy

Expt No	Speed	Feed	MT	S/N ratio
1	500	0.01	9.600	-19.65
2	500	0.045	2.133	-6.58
3	500	0.09	1.066	-0.56
4	1000	0.01	4.800	-13.62
5	1000	0.09	0.533	5.47
6	1000	0.045	1.066	-0.56
7	2000	0.09	0.266	11.50
8	2000	0.01	2.400	-7.60
9	2000	0.045	0.533	5.47

Table 6: Experimental Results and S/N Ratio of Machining Time for Al 7050 Alloy

6. RESULTS AND DISCUSSION

The main objective of the experiment is to optimize the turning parameters (cutting speed, feed rate) to achieve low 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.

Based on the calculated S/N ratio values, it can be seen that a speed of 500 rpm and a feed rate of 0.09 mm/rev gives the optimum values for turning of Al 7050 Aluminium alloy.

Fig 2, gives an Interaction effects plot for S/N ratio vs cutting parameters to determine the optimum surface roughness value.

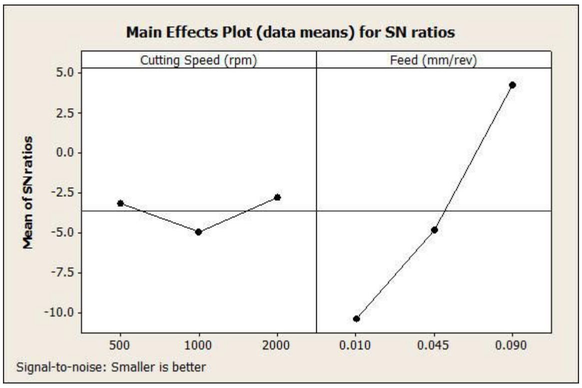

Fig 2: S/N Ratio Plot for Surface Roughness Values

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.

Based on the calculated S/N ratio values, it can be seen that a speed of 2000 rpm and a feed rate of 0.09 mm/rev gives the optimum values for turning of Al 7050 Aluminium alloy.

Fig 3, gives a Main effects plot for S/N ratio vs cutting parameters to determine the optimum material removal rate.

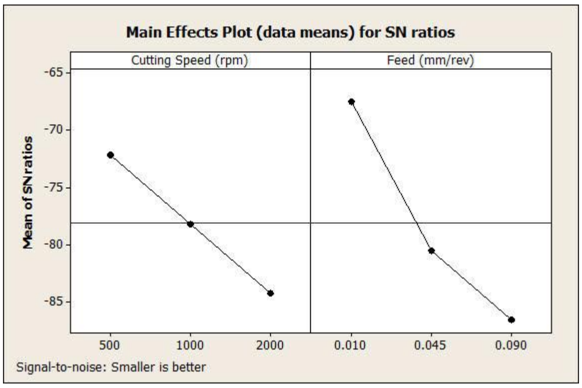

Fig 3: S/N Ratio Plot for Material Removal Rate

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.

Based on the calculated S/N ratio values, it can be seen that a speed of 500 rpm and a feed rate of 0.09 mm/rev gives the optimum values for turning of Al 7050 Aluminium alloy.

Fig 4, gives a Main effects plot for S/N ratio vs cutting parameters to determine the optimum machining time.

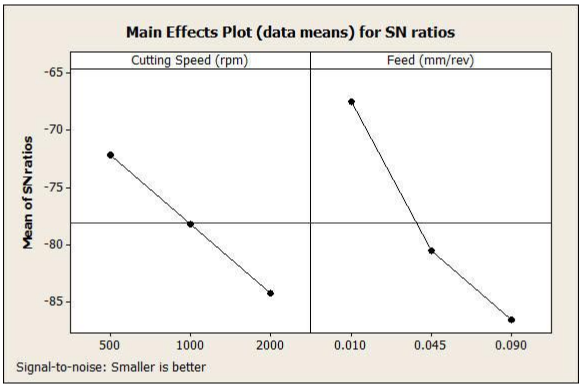

Fig 4: S/N Ratio Plot for Machining Time

7. CONCLUSION

An experimental design was carried out using Taguchi technique to reduce the number of experiments done for 2 factors and 3 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 (i.e. Surface roughness, Material removal rate and machining time) was done to find the optimum parameter setting. From the data collected we can say that surface roughness was minimum for a speed of 500 rpm and a feed of 0.09 mm/rev, material removal rate was maximum for a speed of 2000rpm and a feed rate of 0.09 mm/rev and machining time was minimum for a speed of 500 rpm and a feed of 0.09 mm/rev.

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