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Taguchi Method Based Study of Influence of Process Parameters During Machining of Aluminium.

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Abstract: In the modern manufacturing, in order to produce high quality finished parts machining is an essential process requiring a good control over the process parameters affecting the quality. Vibration , temperature , cutting forces are few variables associated with a given machine tool which influence the quality of surface finish obtained and manufacturers seek various methods to control them for improving the surface finish. Process input parameters such as cutting speed, depth of cut and feed rate influence vibration, temperature and cutting forces. Selection and optimization of input process parameters leading to better surface roughness is an important aspect in a manufacturing process. The objective of present study is to the influence of input parameters on the surface roughness. A turning operation of aluminium on a CNC lathe has been selected for conducting experiments wherein the set of input process parameters were selected based on Taguchi orthogonal array technique and resulting vibration of cutting tool, tool temperature and surface roughness of the machined specimen were taken as output. Relation between input and output has been established using analysis of variance (ANOVA) tool. An attempt has been made to obtain the significant input parameter influencing the vibration of the cutting tool, tool temperature and surface roughness.

Index Term: Input process machining parameter, vibration of cutting tool, surface roughness, Taguchi method, analysis of variance

1. INTRODUCTION

Input process parameters play a vital role during optimization of output such as vibration of a machine tool or surface roughness of the machined surface. Surface roughness depends on vibration of cutting tool or machine structure, cutting forces, temperature of cutting tool interface etc. The optimization of these input process parameters results in enhanced quality of product. Therefore, prediction or monitoring of the surface roughness has been an important area of research.

Various experiments have been conducted to study the effect of various input parameters on surface roughness. A study carried out on AISI1045 steel using HSS cutting tool for process parameter optimization of machining parameters and tool geometry on lathe , illustrates that feed rate has significant effect compared to other parameters on surface roughness [1]. Similar study using ANN Based Prediction Model [2] for the prediction of surface roughness under various conditions of machining parameters during turning operation on lathe made use of L9 Taguchi orthogonal array. Further, an experimental study on LM6 Al/5%SiC composites which are fabricated by stir casting route for metal removal rate in electrochemical machining, resulted in feed rate significance on the metal removal rate [3]. An experimental study on EN 8 steel bars with HSS tool on tool wear monitoring in turning reveals that increase in cutting speed leads to increase in tool wear [4]. A study on aluminum Alloy 7039 on Gas Tungsten Arc Welding Process for application of Taguchi Methods and ANOVA for optimization concluded that peak current has the highest contribution on the process [5]. A study of CNC turning of aluminum 6061 with cemented carbide insert type of tool consisted of optimizing process parameters such as tool rake angle, tool nose radius, cutting speed, feed rate, depth of cut showed that small increase in feed rate deteriorates the quality of surface finish to a large extent as compared to that of small amount of increase of depth of cut [6]. Further, an experimental study was carried out to study the influence of the temperature during turning and drilling operation. The study revealed the influence of machining regime, tool material and cutting tool geometry, on the cutting temperature [7]. A study of machining Al 6063 without any cutting fluid and a CCGT-09T30FL turning insert to predict and control of cutting tool vibration in CNC lathe demonstrates that the depth of cut and cutting speed are the main parameters that influence the vibration of cutting tool [8]. In the present study the influence of process parameters on the vibration of cutting tool and the quality of surface finish during machining of aluminium using Taguchi method has been attempted.

2. DESIGN OF EXPERIMENT (DOE)

Execution of a preplanned or predesigned experiment can provides a lot of information more than an experiment conducted at random. This type of design of experiment includes holding certain factors constant or varying it at a certain levels simultaneously. The design of experiments depends on the number of factors and number of levels in each factor. Factorial design and Taguchi orthogonal array are the most frequently used design of experiments methods in experimental studies.

Factorial design: A full factorial design of experiment consists of two or more factors, each with discrete possible values or "levels", and experiments are performed for all possible combinations of these levels across all such factors. Based on these factors they are classified as 2^k factorial designs and 3^k factorial designs. Full factorial design was designed initially in the present work considering three cutting parameters or factors such as depth of cut (DOC), feed rate (FR) and spindle speed (SS) with three levels of operation for each factor [9] and experiments were carried out to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable.

Taguchi orthogonal array: As the number of levels and factors increase, the number of trials in an experimental work also increases which leads to more machining time and cost. A unique technique, called Taguchi orthogonal array tool is used to get an optimal number of experiments there by reducing number of trials and hence reducing machining time and cost involved. The Taguchi method utilizes orthogonal arrays from design of experiments theory to study a large number of variables with a small number of experiments. Using orthogonal arrays significantly reduces the number of experimental configurations. Furthermore, the conclusions drawn from small scale experiments are valid over the entire experimental region spanned by the control factors and their settings. The Taguchi method can reduce research and development costs by improving the efficiency of generating information needed to design systems that are insensitive to usage conditions, manufacturing variation, and deterioration of parts. As a result, development time can be shortened significantly; and important design parameters affecting operation, performance, and cost can be identified. Furthermore, the optimum choice of parameters can result in wider tolerances so that low cost components and production processes can be used. Thus, manufacturing and operations costs can also be greatly reduced [10].

3. ANALYSIS OF VARIANCE (ANOVA)

The ANOVA procedure performs analysis of variance (ANOVA) for balanced data from a wide variety of experimental designs. In analysis of variance, a continuous variable, known as a dependent variable is measured under experimental conditions identified by independent variables. The variation is assumed to be due to effects in the classification, with random error accounting for the remaining variation. ANOVA can be as one way ANOVA and Two ways ANOVA. In general one way ANOVA technique is used to study the effects of a single factor over a variety of levels. But this cannot be used for a multi factor analysis as in this experiment, hence, two way ANOVA techniques along with multiple level is made use of in present study. The F-test in ANOVA is used to assess whether the expected values of a variable within several pre-defined factors and levels differ from each other. Based on the F-test in ANOVA the factors affecting the output of the experiment and to what amount each of these factors affect it can be determined [11].

4. EXPERIMENTAL SETUP

In the present study, experiments have been carried out on the prediction of surface roughness of aluminum specimen machined under different combinations of machining parameters in a CNC turning machine (make: ACE designer) with dry run condition. Use of carbide cutting tool insert has been made. The machining parameters are cutting speed, depth of cut and feed rate as listed in Table 1. The different combinations of machining parameters for each trial set has been developed by using Taguchi’s L9 orthogonal array as listed in Table 2. For each trial, cutting tool vibrations in tangential and axial directions, tool temperatures and surface roughness have been measured. The vibration of cutting tool was measured by mounting the accelerometers on the cutting tool in the tangential and axial directions and temperature at the cutting zone of cutting tool was measured with the help of non contact Beetech Infrared thermometer as shown in the figure 1. Surface roughness of the machined surface of the specimens was measured by using Mitutoyo SJ-201 instrument.

Table 1: Process parameter and their levels

Levels	Cutting Speed (A)	Depth of cut (B)	Feed Rate (C)
	m/min	mm	mm/rev
1.	150	0.50	0.10
2.	200	0.75	0.20
3.	250	1.00	0.30

Table 2: Number of trials as per Taguchi L9 orthogonal array

Exp No	A	B	C
1	150	0.50	0.10
2	150	0.75	0.20
3	150	1.00	0.30
4	200	0.50	0.20
5	200	0.75	0.30
6	200	1.00	0.10
7	250	0.50	0.30
8	250	0.75	0.10
9	250	1.00	0.20

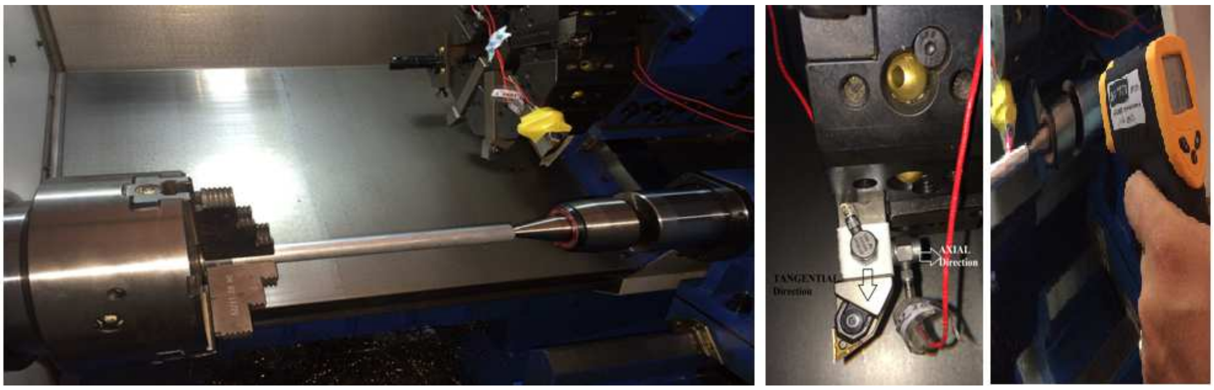

Figure 1: The experimental setup

The measured values of output i.e., vibration in tangential and axial directions, tool temperature and surface roughness are listed in Table 3. The effect of influence of these output parameters were further studied with the aid of Analysis of Variance (ANOVA) tool.

Table 3: Measured output characteristic values

Exp No.	Vibration (gn rms)		Tool Temperature (°C)	Surface Roughness (µm)
	Tangential	Axial		
1	0.0104	0.0161	29.8	1.13
2	0.0098	0.0236	30.7	5.56
3	0.0751	0.0204	31.7	9.52
4	0.0664	0.0132	29.6	4.32
5	0.0345	0.0133	30.3	8.65
6	0.0814	0.0236	30.9	1.06
7	0.0305	0.0135	28.9	1.99
8	0.0295	0.0134	29.8	0.92
9	0.0697	0.0489	33.1	4.81

5. RESULTS AND DISCUSSION

The relationship between input and output parameters is built using ANOVA tool. A software application, Statistica, which has the inbuilt ANOVA, has been used in the data analysis. A data sheet is generated for the selected number of input and output parameters according to the Taguchi's orthogonal array and the respective data was inserted in the data sheet. This data sheet was further submitted for the analysis by defining the input parameters as independent variables and output parameters as the dependent variables with the experimental design option. In the ANOVA results, F-test values were used at 95% confidence level to decide the significant factors affecting the process and percentage of contribution. As per ANOVA the least value of 'p' and largest value of 'f' indicate the influence of machining parameter on the output.

From Table 4, it is clear that the depth of cut is influencing the increased vibration amplitude of cutting tool and temperature at the cutting zone and the feed rate influences the surface roughness of the machine part.

Table 4: ANOVA results for Taguchi design on Temperature

	Sum of Square (SS)	Degree of freedom (DOF)	Mean of square (MS)	Frequency (F)	Percentage of contribution (p)
VIBRATION IN TANGENTIAL DIRECTION					
Cutting Speed	0.001280	2	0.000640	2.034512	0.329542
Depth of Cut	0.004276	2	0.002138	6.797275	0.128250
Feed rate	0.000110	2	0.000055	0.175250	0.850883
Error	0.000629	2	0.000315		
VIBRATION IN AXIAL DIRECTION					
Cutting Speed	0.000112	2	0.000056	0.681709	0.594633
Depth of Cut	0.000487	2	0.000243	2.965880	0.252151
Feed rate	0.000287	2	0.000143	1.746497	0.364100
Error	0.000164	2	0.000082		

TOOL TEMPERATURE					
Cutting Speed	0.346667	2	0.173333	0.258707	0.794466
Depth of Cut	9.446667	2	4.723333	7.049751	0.124227
Feed rate	1.646667	2	0.823333	1.228856	0.448661
Error	1.340000	2	0.670000		
SURFACE ROUGHNESS					
Cutting Speed	8.74702	2	4.37351	1.63220	0.379910
Depth of Cut	2.14056	2	1.07028	0.39943	0.714576
Feed rate	62.67575	2	31.33788	11.69537	0.078769
Error	5.35902	2	2.67951		

6. CONCLUSION

This study describes the use of Taguchi technique in optimizing the cutting parameters such as depth of cut, feed rate and spindle speed in CNC lathe for better surface finish during dry turning operation. Taguchi orthogonal array and Analysis of variance tools are effectively used in this study to select the optimum experimental trials and analyze the relationship between input and output parameters. This study reveals that Depth of cut has more significance on temperature and vibration while feed rate has more significance on surface roughness than other cutting parameters.

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