A REVIEW PAPER ON EXPERIMENTAL MEASUREMENTS OF MATERIAL REMOVAL RATE AT DIFFERENT CUTTING PARAMETERS AND STUDY THEIR EFFECT ON TOOL RAKE ANGLE

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ABSTRACT

In machining operation, select of optimum values of the cutting parameters are typical task to for achieving good performance. Usually, these parameters are determined on the basis of experience and by the use of Machinery's Handbook. Some machine operators employ 'trial and error' method to set-up turning machine cutting conditions. These methods are not effective or efficient and the achievement of a desirable value in repetitive process can be very time consuming. In place of that, the experimental strategy will follow to optimize the machining conditions and cutting parameters for the desired quality. To achieve the same, the experimental strategy and Taguchi techniques can be applied which are suitable to find out the best combination of independent variables in order to predict output values.

The objective of this study is to analyze the tool wear and cutting force of a single point cutting tool of high speed steel (HSS) used in the turning operation. The single point cutting tool is used for machining cylindrical shape specimen of mild steel (MS). For measuring the cutting force and tool wear number of tests are performed with different spindle speed, depth of cut and feed. Cutting forces and tool wear is measured from these experiments. This data will be helpful in analyzing the cutting parameter and measured variable.

1. INTRODUCTION

1.1 OBJECTIVE

- Experimental measurements of cutting force at different cutting parameters and study their effect on tool wear.
- Optimizations of cutting parameter to reduce the tool wear

1.2 EFFECTS OF TOOL WEAR

Some general effects of tool wear are given below:

- Increase in cutting forces
- Increase in surface roughness
- Lower production efficiency and component quality
- Increase in Vibrations
- Increase in cutting temperatures
- Increase in the noise.
- Decreased accuracy of finished part
- Tool breakage

1.3 OVERVIEW

In order to predict tool wear in a fundamental way, a in-depth understanding of tool wear mechanisms is required. The present work uses available data related to tool wear and cutting force which is influenced by type of tool material used, cutting conditions and tool geometry. The comparison of their data with the data will be obtained from the experimental method, conducted for combination the cutting parameters.

This Chapter presents an overview of motivation towards present work, problem statement and objectives along with the scopes of the work. A review of literature related to the present work is presented in chapter.the material and methods including the type of material, experimental setup along with their technical specification, data collection systems, methodology used for completion of this task and overview of analytical method and full factorial design of Taguchi experimental approach are discussed in chapter.the experimental result for both analytical method and Taguchi method of experiment approach is described. These results include data collection, their analysis and developing the manual as well as software-based graphs relevant to collected data. The analytical method and Taguchi method will establish the relation between tool wear, cutting force and cutting parameter. The analytical method gives the graphical representation of response data (tool wear, cutting force) to the cutting parameter (depth of cut, feed, and spindle speed). In this method, tool wear and cutting force will be analyzed by graphical representation of cutting force, tool wear with the depth of cut.

Taguchi analyses will establish the relation between tool wear, cutting force and depth of cut by the signal to noise ratio. It also gives the percentage contribution of cutting parameters. Taguchi method gives the optimum performance of

parameters and result of which has less contribution for tool wear and cutting parameters are discussed in this chapter Finally, the thesis concludes with the conclusions of this study is given in this chapter Furthermore, at last references related to literature along with a brief about recommendations for future work, summary and abstract of the thesis has been presented. After deciding machine tool and cutting tool, the following main cutting conditions have is to be considered.

Spindle Speed

The spindle speed is the rotational frequency of the spindle of the machine, measured in revolutions per minute (RPM). Cutting speed refers to the relative surface speed between tool and work, expressed in surface feet per minute. Either the workpiece, or the tool, or both, can move during cutting. Because the machine tool is built to operate in revolutions per minute, some means must then be available for converting surface speeds into revolutions per minute (RPM).

Depth of cut

The depth of cut related to the depth the tool cutting edge engages the work. The depth of cut determines one linear dimension of the area of cut. For example to reduce the outside diameter of a workpiece by 0.500 mm, the depth of cut would be

0.250mm.

Feed

The feed for lathe turning is the axial advance of the tool along the work for each revolution of the work expressed as mm per revolution .The feed is also expressed as a distance travelled in a single minute or MPM (mm per minute).

Feed, spindle speed and depth of cut have a direct effect on productivity, tool life, and machine requirements. Therefore, these parameter must be carefully chosen for each operation. Whether the objective is rough cutting or finishing will have a great influence on the cutting parameter selected.

TURNING PROCESS

In the turning process, the cutting tool is set at a certain depth of cut (mm or in) and travels to the left with a certain velocity as the workpiece rotates. The feed (mm/rev) is the distance the tool travels horizontally per unit revolution of the workpiece. This movement of the tool produces a chip, which moves up the face of the tool.

In order to analyze the process a cutting tool moves to the left along the workpiece at a constant velocity and a depth of cut. A chip is produced ahead of the tool by plastically deforming and shearing the material continuously along the shear plane.

EXPERIMENTAL PROCESS

This section presents a detailed description of procedure for determining the relationship between the independent process parameters (depth of cut, feed, spindle speed) with the desired response (tool wear, cutting force) and exploring the effect of these parameters on responses. A brief review about Taguchi technique employed in the study is also introduced in this section. The present work is divided basically into two phases. In the first phase, analysis work is performed over the collected data using various Graphs between cutting parameters and response parameter. In the second phase, the design of experiment is carried out according to Taguchi approach. The experiments are performed for individual run at different levels and all the data are collected. In this section, the complete strategy is explained. Taguchi-L27 orthogonal array with the objective of least experiment (twenty seven) was employed. Signal to Noise (S/N) ratio and analysis of variance analysis are taken up to get the desired optimal levels of the controlled cutting parameters for obtaining optimum tool wear and cutting force

2. EXPERIMENTAL AND GRAPHICAL ANALYSIS

The collected tabular data and plotted graphs will be analyzed by analytical method. This show the relation between cutting parameters (depth of cut) and response (cutting force and tool wear). The following steps will be used in this section.

- For analysis steps are as follows.
- Selection of cutting parameter levels
- Collection of data as per table
- Analysis of tabular data
- Graphical representation of tabular data and Analyze the Graphs
- Conclusion of tabular data and graphical representation

(i) Selection of cutting parameter levels

The experimental levels for the controlled factors are as shown in Table 3.2, which show all the three controlled factors i.e., spindle speed depth of cut and feed. The present experimental levels, f:rom the given Table 3.3 were chosen which requires 27 experimental runs to be conducted to test all the factors to analyze the results. The experimental levels for the controlled factors are as shown in Table 3 .3 where all the three controlled factors i.e., spindle speed depth of cut and feed rate has three levels.

Table 2.1 Cutting parameters and their levels

Parameters	Unit	Levels		
		L1	L2	L3
Depth of Cut	mm	0.2	0.4	0.6
Feed	mm/rev	0.08	0.12	0.16
Spindle Speed	m/min	520	710	900

(ii) Collection of data

Data will be collected as per level of cutting parameter depth of cut will be vary from O .2 mm to 0.6 mm, feed will vary from 0.08 mm/rev to 0.16 mm/rev and spindle speed 520 rpm to 900 rpm. At various cutting parameters combination of the tool wear and cutting force will be measured. The combination of cutting parameters combination is shown in Table 3.4. Cutting force and tool wear measure by varying depth cut 0.2 mm, 0.4 mm, and 0.6 mm at constant feed 0.08mm/rev. A total 27 runs will be performed.

Data is arranged as shown in Table 3.4 given below data arrangement follows the array rule of Taguchi analysis because Taguchi analysis follow the L27 array which is explained in 3.5.3. As per L27 array it will require total of 27 run at different combination of cutting parameters.

Table 2.2 Experimental Run Table

Spindle Speed	Feed (mm/rev)	Depth of cut (mm)	Tool Wear (mm)	Cutting Force (kg)
520	0.08	0.2		
		0.4		
		0.6		
	0.12	0.2		
		0.4		
		0.6		
	0.16	0.2		
		0.4		
		0.6		
710	0.08	0.2		
		0.4		
		0.6		
	0.12	0.2		
		0.4		
		0.6		
	0.16	0.2		
		0.4		
		0.6		

900	0.08	0.2		
		0.4		
		0.6		
	0.12	0.2		
		0.4		
		0.6		
	0.16	0.2		
		0.4		
		0.6		

(iii) Analysis of tabular data

In this step, Data will be analyzed by analytical method. By this method the cutting force and tool wear will be analyzed for different cutting parameters. It will show the relation between measured data and input cutting parameters. This shows at which combination of cutting parameters the tool wear and cutting force will minimum. Minimum tool wear and cutting force will increase the tool life and improve the surface quality of object.

(iv) Graphical representation of tabular data and analyzation of graphs

In this step various graphs will be plotted on basis of output parameter and measured parameter. The graph will be plotted between depth of cut versus cutting force and tool wear versus depth of cut. It will show the relation between cutting force and tool wear with depth of cut at constant spindle speed and feed. As per Table 3.3 various combination of depth of cut with tool wear will be plotted. These graphs will show the relation between them which can helpful to correlate between them.

(v) Conclusion of tabular data and graphical representation

After analyzing tabular data and Graphical representation the analyzed graphs of data will give the final conclusion at which cutting parameter is more effective to tool wear and cutting force. It shows the relation between tool wear with depth of cut, and cutting force with depth of cut.

In this step, tabular analysis gives the result at which cutting parameter tool wear and cutting force is minimum. Graphical analysis gives co-relation between cutting parameter with tool wear and cutting force.

Taguchi Design of Experiment

Taguchi method is a statistical method to improve the quality of manufactured goods, and recently this technique is widely applied to engineering problems. These are the optimization tools by which best set of results can be obtained by conducting minimum number of experiments called 'Fractional' design approach.

Taguchi method uses a special set of arrays called 'Orthogonal Arrays'. These standard arrays stimulate the way of conducting the minimal number of experiments which could give the full information to all the factors that affect the performance parameter. The bottom of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment.

The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Fisher, (1925). The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors but, a full factorial design results in a large number of experiments. To reduce the number-of experiments to a practical level, only a small set from all the possibilities is selected. Thus, partial or fractional design of experiment is a method of selecting a limited number of experiments which produces most information via Taguchi method.

This method involves a technique of reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer and was firstly developed by Dr. Genichi Taguchi of Japan who maintained that variation. This method allows for the collection of the necessary data to determine which factors affects most product quality with a minimum amount of experimentation, thus saving time and resources.

3. STEPS FOR TAGUCHI METHOD

The design of an experiment by Taguchi method involves the following steps:

- Defining the process objective
- Selection of independent variables
- Selection of number of level settings for each independent variable
- Selection of orthogonal array
- Assigning the independent variables to each column
- Conducting the experiments
- Analyzing the data

A brief description of the major steps involved in the Taguchi Method is as follows:

(i) Defining the process objective- It involves a strategy to choose a target value for a performance measure of the process. The target of a process is to maximize or minimize the output.

(ii) Selection of independent variables- Parameters are the variables within the process that affect the performance measure that can be easily controlled. The number of levels that the parameters should be varied at must be specified. The increment in the number of levels of the parameters will increase the number of experiments to be conducted.

(iii) Selection of number of levels set for each independent variable.- The effect of various parameters on the performance characteristic in a condensed set of experiments can be examined by using the orthogonal array experimental design proposed by Taguchi. Once the parameters affecting a process that can be controlled is determined, the levels at which these parameters should be varied must be determined. The determination the levels of a variable requires an in-depth understanding of the process, including the minimum, maximum, and current value of the parameter. Also, the cost of conducting experiments must be considered when determining the number of levels of a parameter to be included in the experimental design. Typically, the number of levels for all the parameters in the experimental design is chosen to be the same to aid in the selection of the proper orthogonal array.

(iv) Selection of orthogonal array- It involves a step for selecting the parameter design indicating the number of end conditions for each experiment using 'Orthogonal Array' approach. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter. Before. selecting the orthogonal array, the minimum number of experiments to be conducted shall be fixed based on the total number of degrees of freedom. The minimum number of experimental run to study the factors shall be more than the total degrees of freedom available. The number of degrees of freedom associated with each factor under study, equals one less than the number of levels available for that factor.

There is one more approach by which the array can also be selected directly by statistical software approach i.e., MiniTab-17 statistical software. It is a quite easy approach in which just by entering the number of factors and their corresponding number of levels, the software will itself provide us the suitable type of orthogonal arrays for particular study. These statistical software are '30 Days Trial-Versions' available at free of cost on the internet for academicians and scholars. For present study major emphasis is on using 'MiniTab-17 statistical software [Minitab-17 Free Trial,2014].

Thus, for the present experimental levels, from the given orthogonal array selector table, L27 orthogonal array was chosen which requires nine experimental runs to be conducted to test all the factors to analyze the results. The combinations of these cutting parameters for experimentation were obtained by Taguchi design of experiment through MiniTab-17 statistical software as shown in Table 3.5.

Table 3.1 Orthogonal Array Selector

(v) Assigning the independent variables to columns

The order in which the independent variables are assigned to the vertical column is very essential. In case of mixed level variables and interaction between variables, the variables are to be assigned at right columns as stimulated by the orthogonal arrays shown in Table 3.3.

Finally, the actual level values of each design variable is decided. It shall be noted that the significance and the percentage contribution of the independent variables changes depend on the level of values assigned. Hence, a proper experimental levels should be chosen to conduct the study.

(vi) Conducting the experiments

Once the orthogonal array is selected, the experiments are conducted as per the level of combinations. The interaction columns and dummy variable columns shall not be considered for conducting the experiment, but are needed while analyzing the data to understand the interaction effect.

(vii) Experimental Procedure

For completion of the present study, a randomized schedule of runs was created at various combinations according to Taguchi design of experiments as shown in Table 3.6. The workpiece from the bar were turned with specified cutting conditions. A dry turning process was performed for each run in order to get accurate cutting force and tool wear. During the finish turning, in-process cutting force data were collected using lathe tool dynamometer collection system as discussed earlier. After completion of all each runs, the tool wear of cutting tool were measured using profilometer.

Table 3.2 Design of Experimental via Taguchi Method

S No	1	2	3	4
1	L1	L1	L1	L1
2	L1	L1	L1	L1
3	L1	L1	L1	L1
4	L1	L2	L2	L2
5	L1	L2	L2	L2
6	L1	L2	L2	L2
7	L1	L3	L3	L3
8	L1	L3	L3	L3
9	L1	L3	L3	L3
10	L2	L1	L2	L3
11	L2	L1	L2	L3
12	L2	L1	L2	L3
13	L2	L2	L3	L1
14	L2	L2	L3	L1
15	L2	L2	L3	L1
16	L2	L3	L1	L2
17	L2	L3	L1	L2
18	L2	L3	L1	L2
19	L3	L1	L3	L2

20	L3	L1	L3	L2
21	L3	L1	L3	L2
22	L3	L2	L1	L3
23	L3	L2	L1	L3
24	L3	L2	L1	L3
25	L3	L3	L2	L1
26	L3	L3	L2	L1
27	L3	L3	L2	L1

The Ll's, L2's, L3's represent the level l, level2, and level3 of the parameters and l's, 2's, 3's are cutting parameter, and 4's is response parameter.

4. CONCLUSION

Since each experiment is the combination of different factor levels, it is essential to segregate the individual effect of independent variables. This can be done by summing up the performance parameter values for the corresponding level settings. In other words, by conducting the analysis of variance (ANOVA), one can decide which independent factor dominates over other and the percentage contribution of that particular independent variable.

variable on the output, the signal-to-noise (S/N) ratio needs to be calculated for each experiment conducted. In S/N ratio, the signal is representing the desirable value i.e. mean of the output characteristics while the noise represents the undesirable value i.e. squared deviation of output characteristics.

5. RESEARCH SCOPE

With increasing competitiveness observed in the recent time, manufacturing system in the industries are being driven more aggressively. So, there is always need for perpetual improvement. Thus, to get more accurate results we can take into account few more parameters as given below:

- CNC machine can be used for the experimentation to have a better control of the process variables and also parameter can be set to the desired accuracy.
- The other combination of machine, cutting tool and work piece materials can be studied.
- The study can also be extended on the other hard tool materials e.g., CBN etc.
- The range of different parameters can be studied.
- The experiment can be conducted for constant time period.

6. REFERENCES

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