"Optimisation of Tool Wear and Cutting Forces on the basis of different Cutting Parameters"

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ABSTRACT

In this era, increasing productivity and quality of machined parts are key challenges to manufacturing industries. As this is the era of customized market rather than custom market, thus the company have to keep pace with it.
In this global environment, all the companies are continuously trying to produce high quality products at least cost and it is only possible it companies will reduce the defect rate.
Optimization methods in any manufacturing process plays a vital role for continuous improvement of results considering numerous factors which affect it.
In present research work an attempt has been made to optimize cutting parameters such that to reduce the value of tool wear in turning operation on mild steel work piece.
All the experiments were designed as per design of experiment (DOE) i.e. Taguchi Methodology and 27 runs work conducted as per L-27 Array Technique. Furthermore, Signal to Noise Ratio and Analysis of Variance (ANOVA) were applied and tables were generated to study various performance conditions at varying parameters. For performing experiments, different parameters were chosen at various levels i.e. Depth of cut, Spindle speed, Feed rate, etc. and cutting force is also taken as dependent variable.
The results obtained from this work will be highly beneficial for any small scale industry and will definitely reduce the tool wear and will improve the quality of product.
From the results and analysis finally it is identified that Depth of cut is the main parameter which affect the tool wear. Thus all the machinist or industries should keep Depth of cut in precise range, so that better results can be obtained.

Keywords *:- DOE, Customization, Custom, Taguchi, Tool Wear, ANOVA*

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1. INTRODUCTION

The effects of machining parameters on the tool wear and cutting force in the turning of mild steel with high speed steel tool were investigated. Taguchi's L27 array was used for conducting the experiments. For the determination of optimal machining conditions (cutting tool, cutting speed and feed rate) for minimum tool wear and cutting force, Taguchi's signal-to-noise ratio was used. In addition, linear and quadratic regression analyses were applied to predict the measured value. Finally, the reliability of developed models was tested by the confirmation experiments.

1.1 Motivation

In recent years, many advances have been achieved in automation of the cutting process. However, the development of a fully automated machining system cannot be realized until practical methods are developed to sense the amount of tool wear. Such a development would also improve the quality of the product by ensuring that the surface and geometrical specifications were within the tolerance zone. In addition, there would be possibilities of increased cutting speeds, leading to a decrease in cutting time, all of which could result in overall savings of the total machining cost. Tool wear is one of the important factors affecting production optimization. The complex stochastic nature of tool wear is one of the obstacles in achieving manufacturing automation. To take full advantage of this technology there should be a reliable tool wear monitoring technique. This technique requires a model to get on-line values of difficult to measure parameters such as tool wear from easily measurable values like tool forces, cutting speed, feed, depth of cut, work piece diameter, etc. Advances in the design of cutting tools have introduced more complexity into the type and range of tools suited to a particular machining task. Due to increased demands for improved economic performance, cutting tool manufacturers have used two approaches to meet this challenge. One approach has been to utilise modern surface coatings and tool substrate combinations to give a greater machinability range for a general-purpose cutting tool design. The other has been to utilise the coating/substrate combinations with application specific geometries for a higher performance tool but with a narrow mach inability range.

Tool wear monitoring/sensing should be one of the primary objectives in order to produce the required end products in an automated industry so that a new tool may be introduced at the instant at which the existing tool has worn out, thus preventing any hazards occurring to the machine or deterioration of the surface finish. Cutting tools may fail due to the plastic deformation, mechanical breakage, cutting edge blunting, and tool brittle fracture or due to the rise in the interface temperatures.

1.2 Problem Statement

The turning operation is one of the main operations used in machining of different parts. Mainly single point cutting tool is used in the turning operation. For this purpose, variety of cutting tools available in the market. These tools have different geometry and different materials to machine a variety of steels and alloys. High speed steel is mainly used for turning operation and other operation for machine parts as it is very hard steel. Machining of mild steel requires special cutting tool materials. The study of tool wear in this case is very important for economical machining and good surface finish. The objective of this thesis work is to analyze the tool wear of the single point cutting tool used in the turning operation of MS. The single point cutting tool is used for machining cylindrical shape specimen of HSS. A number of tests are performed with different cutting 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 process. Different graphs of cutting forces Vs cutting speed and tool wear Vs cutting speed are plotted and these graphs shows the variation of tool wear and cutting forces.

1.3 Objective

- Experimental measurements of cutting force and Tool Wear at different cutting parameters and study its effect on tool wears.
- Optimizations of cutting parameter to reduce the tool wear and cutting force.
- This work is focused on the modeling of Tool Wear and cutting force in lathe machine.
- Study the tool wear and cutting force for High Speed Steel tool and Mild Steel work piece.
- Comparison of experimental and predicted values of tool wear and cutting force showing good agreement between them.
- Developing a condition which is recommended to be used for predicting tool wear.

1.4 Research Scope

With increasing competitiveness as observed in the recent time, manufacturing system in the industries are being driven more aggressively So there is always need for perpetual improvement. Thus for getting more actual result we can take in to account few more parameter as given:

- CNC machine can be used for the experimentation to have the better control of the process variable and also parameter can be set to the desired accuracy.

- The other combination of machine, cutting tool and work piece material can be studied.
- The study can also be extended on other hard tool material e.g.CBN etc.
- The range of different parameter can be studied.
- The Experiment can be conduct for constant time period.

1.5 Effects of Tool Wear

Some General effects of tool wear include:

- Increased cutting forces
- Increase in surface roughness
- Lower production efficiency and component quality
- Increased Vibrations
- Increased cutting temperatures
- Poor surface finish
- Decreased accuracy of finished part
- May lead to tool breakage

2. LITERATURE REVIEW

The main problem facing companies in the metal-cutting industry is the need to increase manufacturing quality and at the same time to decrease production costs. There are many variables which affect the quality and production costs of the product, including cutting parameters, tool wear, cutting force, tool materials, tool geometry, coating technology, lubricants, etc. Consequently, companies are forced to operate by using the trial and error method. The optimization of controllable variables can make a considerable contribution towards solving the problem. At this point, the variables leading to a final solution are being optimized by using the Taguchi method, thus considerably reducing the number of tests needed. Therefore, by employing the trial and error method production costs will decrease significantly and time loss will be minimal. As a result, nowadays, this and similar methods have become the focus of interest for both academics and companies, with the goal of increasing production quality and operating with greater efficiency.

Ozel Tugrul et al. studied that Tool flank wear reaches to a tool life criterion value of VBC = 0.15mm before or around 15 min of cutting time at high cutting speeds due to elevated temperatures. Neural network based predictions of surface roughness and tool flank wear are carried out and compared with a non-training experimental data. These results show that neural network models are suitable to predict tool wear and surface roughness patterns for a range of cutting conditions.

Ghaniet et al. applied the Taguchi method to optimize cutting parameters in end milling when machining hardened AISIH13 steel with TiN-coated P10 carbide insert tools under semi-finishing and finishing conditions of high-speed cutting. An orthogonal array, signal-to-noise ratio and Pareto analysis of variance were employed to analyze the effect of the milling parameters. The analysis of the results showed that the optimal combination for a low-resultant cutting force and a good surface finish was a high cutting speed, low feed rate and low depth of cut.

Aggarwal and Singh et al. it is necessary to select the most appropriate machining settings in order to improve cutting efficiency. Generally, this optimum parameter selection is determined by the operator’s experience knowledge or the design data book which leads to decrease in productivity due to sub-optimal use of machining capability this causes high manufacturing cost and low product quality.

Hardeep Singh et al. In actual practice, there are many factors which affect these performance measures, i.e. tool variables (tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle, etc.), workpiece variables (material, hardness, other mechanical properties, etc.) and cutting conditions (cutting speed, feed, depth of cut and cutting fluids). Many papers has been published in experimental based to study the effect of cutting parameters on surface roughness.

3. MATERIALS AND METHODS

3.1 Materials And Its Specification

The suitability of a cutting tool material in a machining application depends on its properties. which useful in determining desirable tool-material characteristic for a particular application.

To produce quality product, a cutting tool must have three characteristics:

- Hardness: hardness and strength at high temperatures.
- Toughness: so that tools do not chip or fracture.
- Wear resistance: having acceptable tool life before needing to be replaced.

Cutting tool materials can be divided into two main categories:- stable and unstable.

Unstable Materials (usually steels) are substances that start at a relatively low hardness point and are then heat treated to promote the growth of hard particles (usually carbides) inside the original matrix, which increases the overall hardness of the material at the expense of some its original toughness. Since heat is the mechanism to alter the structure of the substance and at the same time the cutting action produces a lot of heat, such substances is inherently unstable under machining conditions.

Stable Materials (usually tungsten carbide) are substances that remain relatively stable under the heat produced by most machining conditions, as they don't attain their hardness through heat. They wear down due to abrasion, but generally don't change their properties much during use. Most stable materials are hard enough to break before flexing, which makes them very fragile. To avoid chipping at the cutting edge, most tools made of such materials are finished with a sightly blunt edge, which results in higher cutting forces due to an increased shear area. Fragility combined with high cutting forces results in most stable materials being unsuitable for use in anything but large, heavy and stiff machinery. Unstable materials, being generally softer and thus tougher, generally can stand a bit of flexing without breaking, which makes them much more suitable for unfavorable machining conditions, such as those encountered in hand tools and light machinery.

3.2 Experimental Setup

The experimental setup involves the complete set of machineries which are used for completion of the present work. All the required data are collected from this experimental setup for individual run. The experimental setup includes the following component and machine tool:

- Lathe machine
- Sample of Work piece
- Lathe tool Dynamometer
- Profilometer

A brief description of all these components has been presented below

3.2.1 Center Lathe Machine

The complete set of experimentation is performed using Center lathe machine.A machine tool selection is a crucial factor which affects the outcome of experiment work. Thus it should be selected in such a manner that it incorporates the basic need of the present study like desired range of spindle speed, depth of cut and feed etc. So that Center lathe was proven to be best choice which fulfills all necessities of present study which shown in fig.

Fig.3.1 Center Lathe Machine

Sr.No.	Specifications	Range
1	turning diameter over bed	380 mm
2	turning diameter	over slide rest mm
3	turning length	1000 mm
4	spindle bore	56 mm
5	turning speeds	45-2000 U/min
6	total power requirement	4 kW
7	weight of the machine	ca. 1,8 t
8	dimensions of the machine	ca. 2350 x 1000 x 1401 mm
9	Centre height	180 mm
10	face slide travel	215 mm
11	cross slide – travel	115 mm

Table 3.0: Technical Specifications of Centre Lathe Machine

3.2.2 Lathe tool Dynamometer

Lathe Tool Dynamometer is a cutting force measuring instrument used to measure the cutting forces coming on the tool tip on the Lathe Machine. The sensor is designed in such a way that it can be rigidly mounted on the tool post, and the cutting tool can be fixed to the sensor directly. This feature will help to measure the forces accurately without loss of the force. The sensor is made of single element with three different wheat stones strain gauge bridge. Provision is made to fix 1/2" size Tool bit at the front side of the sensor. The tool tip of the tool bit can be grind to any angle required. Forces in X - Y - Z directions will be shown individually & simultaneously in three Digital Indicators Supplied.

Fig 3.2: Lathe Tool Dynamometer

3.2.3 Profilometer

The Baty Shadomaster SM20 with its 500mm screen and high specification presents the capability to make simple comparative measurements through to complex results storage and tolerance with SPC capability. The vertical light beam configuration is ideally suited for workpieces which are more readily mounted flat or horizontally.

Fig 3.3: Baty SM20 - Profile Projector

3.3 Design of Experiments

This section presents a detailed description about experimental strategy, design of experiment (DOE) via fractional and data collection system for the present work. A brief review about these techniques employed in the study also has been introduced in this section.

3.3.1 Experimentation Strategy

The present work is divided basically into two phases. In the first phase, analysis task is performed over the collected data using various Graphs between cutting parameters. In the second phase, the design of experiment is carried out according to fractional design (taguchi) approach. , the experiments are performed for individual run at different levels and all the data are collected.. In the present work, the complete above mentioned strategy has been implemented in following stages: In this stage, for fractional design of experiment, Taguchi L27 orthogonal array with the objective of least experiment (twenty seven) was employed. Signal to Noise (S/N) ratio, analysis of variance (ANOVA) and regression analysis are taken up to get the desired optimal levels of the controlled cutting parameters for obtaining predicted tool wear and cutting force

3.3.2 Taguchi Design of Experiment

Taguchi method is a statistical method to improve the quality of manufactured goods, and more 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 thus called 'Fractional' design approach. Taguchi method uses a special set of arrays called 'Orthogonal Arrays'. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of 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.

3.3.3 Steps for Taguchi Method

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

1) Define the process objective
2) Selection of independent variables
3) Selection of number of level settings for each independent variable
4) Selection of orthogonal array
5) Assigning the independent variables to each column
6) Conducting the experiments
7) Analyzing the data
8) Inference

3.3.4 Experimental Levels and Orthogonal Array Selection

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 have been determined, the levels at which these parameters should be varied must be determined. Determining 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 parameters in the experimental design is chosen to be the same to aid in the selection of the proper orthogonal array. Knowing the number of parameters and the number of levels, the proper orthogonal array can be selected. Using the array selector table as shown in Table 3.4 and the name of the appropriate array can be found by looking at the column and row corresponding to the number of parameters and number of levels. Once the name has been determined (the subscript represents the number of experiments that must be completed), the predefined array can be looked up. There is one more approach by which the array can be selected directly by statistical software approach i.e. MiniTab statistical software. This is also 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 has been on using 'MiniTab-17' statistical software [Minitab-17 Free Trial, 2014]. For the present work, the experimental levels for the controlled factors are as shown in Table 3.5, where all the three controlled factors i.e. spindle speed (SS), depth of cut (DC) and feed rate (FR) has three levels.

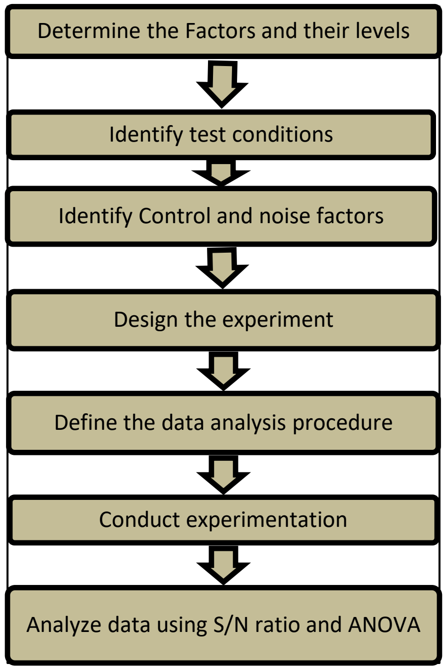

Fig 3.4: Pictorial Depiction of Steps in Taguchi.

Number of Levels	Number of Parameters (P)																										
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32
3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36	L36	L36	L36	L36						
4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32																		
5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50																

Table 3.1: Orthogonal Array Selector

Thus, for the present experimental levels, from the given orthogonal array selector table, L9 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 3.2.

Parameters	Unit	Levels		
		L1	L2	L3
Depth of Cut (DC)	mm	0.2	0.4	0.6
Feed (F)	mm/rev	0.08	0.12	0.16
Spindle Speed (SS)	rpm	520	710	900

Table 3.2: Cutting parameters and their levels

3.3.5 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 3.3. The work piece from the bar were turned with specified cutting conditions. The dry turning 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 pieces was measured using profilometer.

s.no	1	2	3	4
1.	1	1	1	1
2.	1	1	1	1
3.	1	1	1	1
4.	1	2	2	2
5.	1	2	2	2
6.	1	2	2	2
7.	1	3	3	3
8.	1	3	3	3
9.	1	3	3	3
10.	2	1	2	3
11.	2	1	2	3
12.	2	1	2	3
13.	2	2	3	1
14.	2	2	3	1
15.	2	2	3	1
16.	2	3	1	2
17.	2	3	1	2
18.	2	3	1	2
19.	3	1	3	2
20.	3	1	3	2
21.	3	1	3	2
22.	3	2	1	3
23.	3	2	1	3
24.	3	2	1	3
25.	3	3	2	1

26.	3	3	2	1
27.	3	3	2	1

Table 3.3: Design of Experiment via Taguchi Method

3.3.6 Analysis Methodology

Once the experimental design is determined and the trials have been carried out, the measured performance characteristic from each trial can be used to analyze the relative effect of the different parameters. To determine the effect of each 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. While analyzing through Taguchi method, there are three categories for analysis of S/N Ratio i.e. the smaller is better, the larger is better and the nominal is best. The S/N ratio for each level of process parameter is computed by S/N analysis. Regardless of the category, the larger S/N ratio is always recommended for better performance. Thus, the optimal parameter for any factor is the level having highest S/N ratio.

4. RESULTS AND DISCUSSION

4.1 Experimental Analysis

The aim of this experiment is to analyse the effect of cutting parameters on the tool wear and cutting force. The experimental results are shown in Table 4.1give very strong correlation between tool wear, cutting force and cutting parameter. In this table depth of cut as varying from 0.2mm to 0.6mm and feed varying from 0.08 mm/rev to 0.16 mm/rev, spindle speed vary from 520 rpm to 900 rpm. Cutting force and tool wear are the response parameters which are measured at varying levels of cutting parameters.

4.2 Taguchi Analysis For Tool Wear

The experiments were planned to optimize the number of the machining test and evaluate the effects of certain factors on some specific results using Taguchi's orthogonal array in the design of experiments.The experiments were conducted according to a three level, L27 (orthogonal array).

4.2.1 Analysis of S/N ratios and Analysis of Variance.

For Taguchi analysis, experimental results of tool wear are transformed into signal to noise (S/N) randomized schedule of runs was created at various combinations according to Taguchi design of ratio. Here 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. Usually, there are three categories for analysis of S/N Ratio i.e. the smaller is better , the larger is better , the nominal is best. The S/N ratio for each level of process parameter is computed by S/N analysis. Regardless of the category, the larger S/N ratio is recommended for better performance. Thus, the optimal parameter for any factor is the level having highest S/N ratio.

Usually, the objective of the first category is to optimize the system when the response is as small as possible while the second category is used when the response is as large as possible and the objective of the third category is to reduce the variability around the specific target.

Tool wear were measured via the experimental design for each combination of the control factors by using Taguchi techniques, optimization of the measured control factors were provided by signal-to-noise (S/N) ratios. The lowest values of tool wear are very important for quality improvement of the product and lowering production costs. For this reason, the ''Smaller is better" equation was used for the calculation of the S/N ratio.

For this experimental analysis, the first category i.e. "The smaller is better" was employed to calculate S/N ratio and its main effect plots are generated for S/N Ratio using MiniTab-17 statistical software . The first category was chosen to obtain the optimization conditions for minimization of tool wear which is the desired condition for turned machined parts. The following equation was used to calculate S/N ratio.

$$\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \qquad (4.1)$$

Where η is the Signal to Noise ratio, n is the no. of repetitions of the experiment and y is the measured value of the quality characteristics. The S/N ratios are expressed on the decibel scale. While applying Taguchi design analysis to these experimental data, the data tables for analysis of S/N ratios was generated as by which rank value of the factors can be obtained for S/N ratios.

Source	DF	Esq. Ss	Ad Ss	Ad MS	F	P	Percent Contribution
Spindle Speed(rpm)	2	1.795	1.795	0.8977	1.27	0.441	7.403
Feed(mm/rev)	2	3.466	3.466	1.7332	2.44	0.290	14.291
Depth of cut(mm)	2	17.566	17.566	8.7831	12.39	0.075	72.449
Residual Error	2	1.418	1.418	0.7092			5.848
Total	8	24.246					
S = 0.8421 R-Sq. = 94.2% R-Sq. (ad) = 76.6%							

Table 4.1: Analysis of variance for SN ratios

The experimental results were analyzed with analysis of variance, which used for identifying the factors significantly affecting the performance measures. The results of the analysis of variance with the tool wear are shown in table 4.1. This analysis was carried out for significance level of α=0.05 i.e. for a confidence level of 95%. The sources with a P-value less than 0.1 are considered to have a statistically significant contribution to the performance measures. The last column of the tables shows the percentage contribution of significant source of the total variation and indicating the degree of influence on the result.

As shown in table 4.1 percentage contribution of spindle speed is 7.403 %, feed 14.291% and depth of cut 72.449 % residual error 5.848%. So the depth of cut has maximum contribution and spindle speed has lowest contribution.

The identical sets of results have been obtained by analysis of variance (ANOVA) as shown in table 4.1 by which most significant variable can be analyzed. From table 4.1, it can be seen that the depth of cut is the highest statistically significant factor (F-value = 12.39)(P-value = 0.075), while the effect of spindle speed has not been found statistically significant (F-value = 1.27), (P-value = 0.441). Identical sets of results also depend upon the R-square from table 4.1 (R-Square = 94.2%) which is significant.

Level	Spindle Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	31.17	29.69	32.41
2	30.34	30.82	30.19
3	30.14	31.14	29.04
Delta	1.03	1.45	3.37
Rank	3	2	1

Table 4.2 : Response for signal to noise ratios.

It can be seen from the table 4.2 and the corresponding rank value for each factor that the depth of cut (Rank 1) is the highest influencing factor which has strongest effect on the tool wear followed by feed (Rank 2) and last by spindle speed (Rank 3).

4.2.2 Main effects plot for S/N ratios

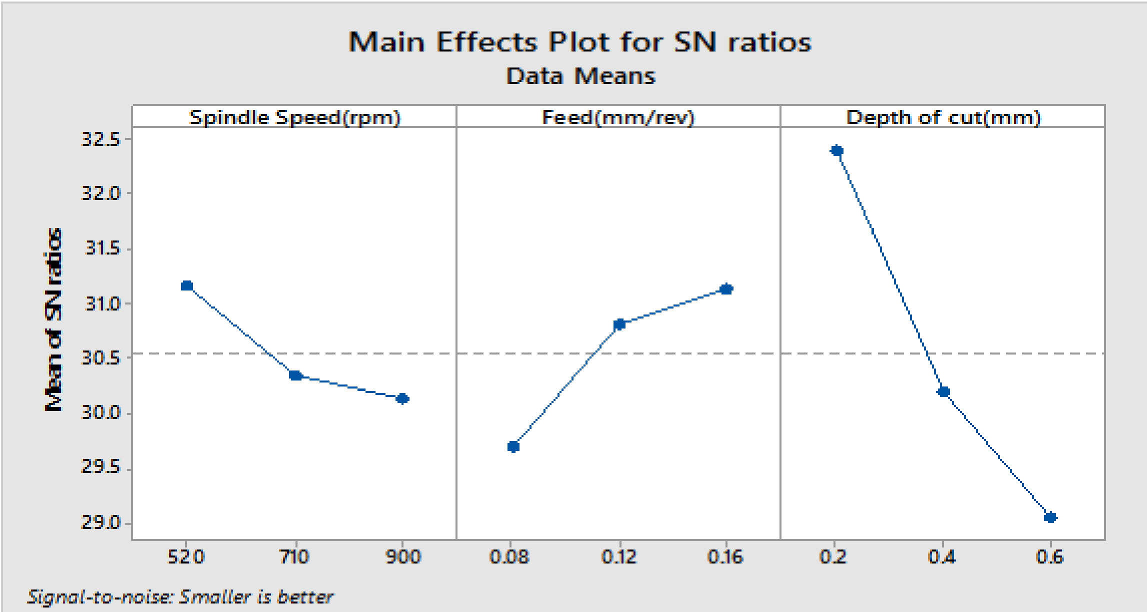

Figure 4.1 : S/N Ratios verses Cutting parameters (SS, DC, FR) plots

It can be analyzed from the main effect plots of S/N ratio as shown in figure.4.16, that in order to obtain optimized value of tool wear, feed rate should be set to its highest value (0.16 mm/rev) and the spindle speed and depth of cut to their lowest values i.e. 520 rpm and 0.2mm respectively because for optimization, largest S/N ratio should be employed. Although, spindle speed has third rank, so it's any level can be chosen because it will not influence the tool wear.

4.3 TAGUCHI ANALYSIS FOR CUTTING FORCE

The experiments were planned to optimize the number of the machining test and evaluate the effects of certain factors on some specific results using Taguchi's orthogonal array in the design of experiments.The experiments were conducted according to a three level, L27 (orthogonal array).

4.3.1 Analysis of S/N Ratios and Analysis of Variance (ANOVA)

Source	DF	Esq. Ss	Ad Ss	Ad MS	F	P	Percent Contribution
Spindle Speed(rpm)	2	6.2651	6.2651	3.1325	10.61	0.086	7.53837
Feed(mm/rev)	2	18.2494	18.2494	9.1247	30.90	0.031	21.6867
Depth of cut(mm)	2	58.0043	58.0043	29.0022	98.22	0.010	69.7927
Residual Error	2	0.5906	0.5906	0.2953			0.67453

Total	8	83.1094					
S = 0.5434 R-Sq. = 99.3% R-Sq. (ad) = 97.2%m							

Table 4.3 Analysis of Variance for S/N Ratios.

Level	Feed (mm/rev)	Spindle speed (rpm)	Depth ofCut (mm)
1	-27.67	-25.11	-22.56
2	-25.76	-25.47	-26.31
3	-24.18	-27.03	-28.74
Delta	3.48	1.92	6.17
Rank	2	3	1

Table 4.4 Response for Signal to Noise Ratios.

4.3.2 Main Effects Plot for S/N ratio

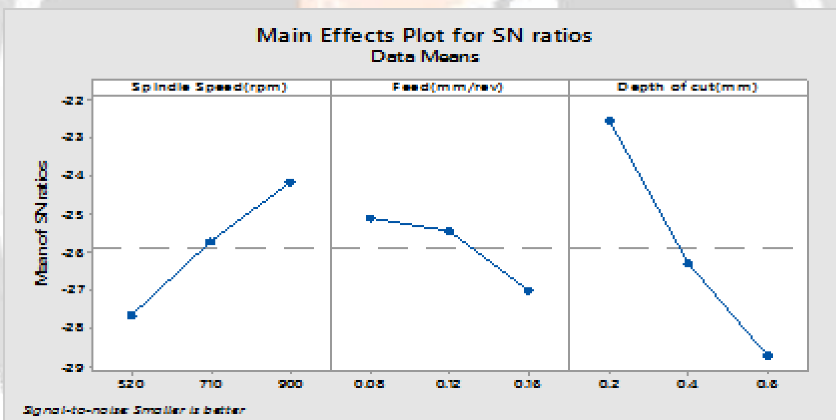

Figure 4.2 S/N Ratios verses Cutting Parameters (SS, DC, and FR) Plots

It can be analyzed from the main effect plots of S/N ratio as shown in Fig.4.17, that in order to obtain optimized value of cutting force, spindle speed should be set to its highest value (900 rpm) and the feed and depth of cut to their lowest values i.e. 0.08 mm/rev and 0.2mm respectively because for optimization, largest S/N ratio should be employed. Although, spindle speed has third rank, so it's any level can be chosen because it will not influence the too cutting force.

5. CONCLUSION

CONCLUSION OF TAGUCHI METHOD

- The Taguchi parameter design is an effective way of determining the optimal cutting parameters for achieving low tool wear and low cutting force i.e the optimized values of response parameters.
- The percentage contributions of depth of cut (72.449%) and Feed (14.291%) in affecting the variation of tool wear are significantly larger as compared to the contribution of the Spindle Speed (5.848%).
- In order to obtain optimized value of tool wear, feed rate should be set to its highest value (0.16 mm/rev) and the spindle speed and depth of cut to their lowest values i.e. 520 rpm and 0.2 mm respectively.

- The percent contributions of depth of cut (69.7927%) and feed (21.6867%) in affecting the variation of cutting force are significantly larger as compared to the contribution of the spindle speed (7.53837%).
- In order to obtain optimized value of cutting force, spindle speed should be set to its highest value (900 rpm) and the feed and depth of cut to their lowest values i.e. 0.08 mm/rev and 0.2 mm respectively.
- Thus, finally it can be concluded that whatever range of spindle speed can be chosen because it is least affecting parameter for both response values i.e. cutting force and tool wear.
- Major emphasis should be given to the depth of cut and feed for achieving optimized values of response parameters because these two are the major emphasizing parameters..

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