Optimization of Tool Wear and Cutting Force By Effective Use of Cutting Parameters In Center Lathe Machine of Mild Steel by HSS Tool

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Abstract- Metal cutting and forming are basic operations involved in the manufacturing process, however metal cutting is mostly used for object shape. Any machining process surface quality is determined by the way in which material is removed. To provide a quality surface, factors such as machine quality, the kind of material being machined, tool quality, the relative motion imparted to the work piece tool, chip cross section related parameters such as depth of cut, spindle speed and feed, etc are crucial. To produce the required form, the majority of machining operations strive to remove the most material.

The main objective of this thesis is to assess and improve the effects of the cutting parameters on tool wear and cutting force in order to decrease both of these aspects while converting mild steel using a single point cutting tool. Numerous research employ various spindle speeds, cut depths, and feed rates. This study examines the impact of machining settings on cutting force and tool wear while using high speed steel tools to convert mild steel. The Taguchi approach is then used to the collected data to optimise tool wear and cutting force. The L27 array optimisation method developed by Taguchi was employed for optimisation. Taguchi's signal-to-noise ratio was utilised to extend tool life while determining the best machining settings (Spindle speed, depth of cut, and feed rate) with the least amount of tool wear and cutting force. outcomes of the. The best feed, spindle speed, and depth of cut will result in less tool wear and a longer tool life, according to the Taguchi optimising approach.

Keywords: Tool wear, Cutting force, cutting parameter, Taguchi optimization technique

1. INTRODUCTION

Basic operations like cutting and moulding metal are part of the manufacturing process while turning uses metal cutting primarily for shaping the item. Any machining process' surface quality is determined by the way in which material is removed. In order to achieve a high-quality surface, factors such as machine quality, the kind of material being machined, tool quality, the relative motion imparted to the work piece and tool, chip cross section related parameters such as depth of cut, spindle speed and feed, etc., are crucial to consider. The cutting technique has advanced significantly in recent years. The material and grades of the cutting tool, workpiece material, and cutting circumstances are only a few of the many variables that influence the turning process and tool wear rate. Material, cutting edge geometry, clearance angle, cutting edge inclination angle, nose radius, rake angle, tool vibration, etc. are all examples of tool variables. Workpiece variables include material, mechanical qualities, chemical composition, and physical characteristics, among others. Cutting circumstances can include things like cutting speed, feed, and depth of cut Although choosing the best process parameters might be challenging, doing so is crucial for the control of the machining process in order to produce better products with higher levels of productivity at lower costs. In the manufacturing process tool wear is a crucial indication of the turning operation. Studies and assessments of the turning process commonly include cutting parameters such cutting speed, feed rate, and depth of cut. This paper intends to examine how these factors impact the prediction of tool wear during turning operations using Taguchi design of trials. The execution of machining tests under various cutting conditions was made possible by the use of test specimens. Such a development would also improve the product's quality by assuring the surface and geometrical parameters. Estimating tool wear during machining is crucial for the design of cutting tools and the choice of cutting conditions in tool change methods. We now have a much better knowledge of the issue because to the significant study that has been done in this field over the last century or so. To far no machining technique has been developed that can adequately relate tool wear cutting force, cutting circumstances, tool geometrical parameters, and tool material qualities. To produce the required end products in a given industry, one of the main goals should be tool wear monitoring or sensing. By using a new tool at the precise moment the old one has worn out, this avoids any risks to the machine or degradation of the surface finish. Cutting tools may shatter owing to tool brittle fracture, plastic deformation, mechanical breakage, blunting of the cutting edge, or an increase in interface temperatures. This study's primary goal is to stop cutting tool cutting edges from wearing down.

The cutting force and quality of the machining, tool life, and cost of the machining are all impacted by tool wear. Increased cutting force, vibration, and temperature cause poor surface integrity and out-of-tolerance dimension inaccuracy if a certain amount of tool wear is achieved. The cutting tool is no longer usable. In order to replace or grind the cutting tool, the cutting activity must then be paused. Costs and output are increased by the expense of tool replacement and the time required for machine tool calibration. Because it affects the cost-effectiveness of machining, tool wear prediction is essential for cutting process optimisation. This study's major goal was to experimentally measure cutting force and tool wear. In order to determine how the cutting parameter influenced the cutting force and tool wear, graphical analysis and Taguchi analysis were then applied. This will make it simpler to understand how cutting force and cutting parameter relate to one another.The whole series of tests are conducted using a centre lathe machine. The outcome of experiment work is significantly influenced by the choice of machine tool. The necessary range of spindle speeds, depth of cut, feed, etc., are only a few of the fundamental needs for the current study should be taken into consideration while choosing it. The Centre lathe was determined to be the best option since it satisfies all requirements for the current study, as indicated in Figure.

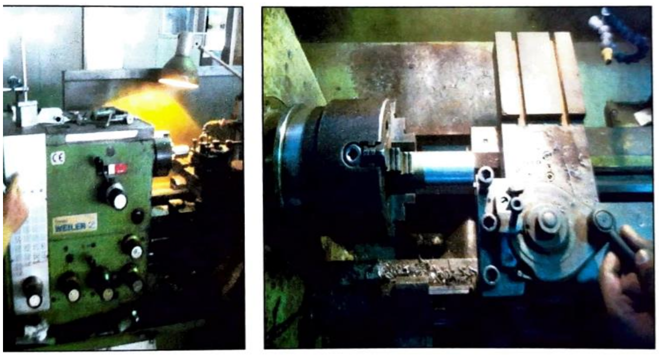

Figure 1.1 Center Lathe Machine

The surface characteristics of a sample are magnified using a profile projector (also known as an optical comparator or shadowgraph), an optical measurement equipment that enables measurement on a linear or circular scale. On the integrated projection screen, the projector enlarges the specimen's profile. For more ease in calculating linear dimensions, this projection screen zooms in to illustrate the sample's profile. The screen's grid may be used to align a sample's edge for analysis. Basic measurements for distances and other points might then be acquired. On a zoomed-in profile of the specimen, this is being done. The Baty Shadomaster SM20, with its 500mm screen and excellent specifications, offers the opportunity to do straightforward comparison measures thanks to its sophisticated results storing, tolerance, and SPC capability. Workpieces that are more easily positioned flat or horizontally are suitable candidates for the vertical light beam design.

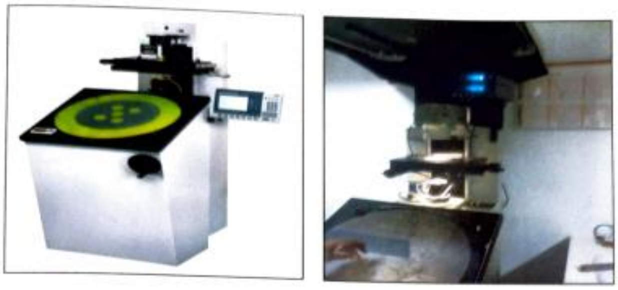

Figure 1.2 Baty SM20 - Profile Projector

2. EXPERIMENTAL PROCEDURES

This section provides a thorough explanation of the steps involved in establishing the link between the independent process variables (depth of cut, feed rate, and spindle speed) and the intended response (tool wear and cutting force), as well as the impact these variables have on responses. This section also includes a quick introduction to the Taguchi approach that was used in the study. Essentially, there are two phases to the current work. Using different Graphs between the cutting parameters and response parameter, analytical work is done on the gathered data in the first phase. The second step entails applying the Taguchi approach to the experiment design. Every run includes several levels of testing, and the findings are compiled. This section contains a description of the complete plan.

The Taguchi-L27 orthogonal array was applied with the aim of doing the minimum number of experiments (27). Using the Signal to Noise (S/N) ratio and Analysis of Variance (ANOVA) analysis, the ideal cutting parameter values needed for the best tool wear and cutting force are obtained.

2. Experimental and Graphical analysis

Analytical approach will be used to examine the gathered tabular data and drawn graphs. These results demonstrate the connection between cutting parameters (depth of cut) and outcomes (cutting force and tool wear). The procedures listed below will be applied in this part.

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

Table 3.2 lists the experimental levels for the three controlled elements—spindle speed, depth of cut, and feed—along with the three controlled factors themselves. To test all the parameters and analyse the findings, 27 experimental runs must be undertaken at the current experimental levels, which were selected from Table 3.3. In Table 3.3, which contains three levels for each of the three controlled elements (spindle speed, depth of cut, and feed rate) are the experimental levels for the controlled factors.

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 based on the cutting parameter with the feed changing from 0.08 mm/rev to 0.16 mm/rev, the depth of cut varied from.2 mm to 0.6 mm, and the spindle speed varying from 520 rpm to 900 rpm. At various cutting settings, the combined cutting force and tool wear will be measured. The combination of cutting parameters is shown in Table 3.4. Using depth cuts of 0.2, 0.4, and 0.6 mm at a constant feed rate of 0.08 mm per revolution, cutting force and tool wear are assessed. There will be 27 runs in all. The data are arranged as shown in Table 3.4 below because Taguchi analysis use the L27 array, which is discussed in 3.5.3. The array rule of Taguchi analysis is followed by this configuration. The L27 array states that a total of 27 runs are required with various combinations of cutting parameters.

Following the selection of a machine tool and cutting tool, the following key cutting conditions must be taken into account.

2.2.1 Spindle Speed

Spindle speed refers to how frequently the machine's spindle rotates, measured in revolutions per minute (RPM). The difference between the tool's and the task's surface feet per minute is known as cutting speed. The tool, the workpiece, or both may move when cutting. The machine tool must have a way to convert surface speeds into revolutions per minute (RPM), as it is intended to operate in RPM.

2.2.2 Depth of cut

The tool's cutting edge's depth of engagement with the job is connected to the cut depth. One linear dimension of the cut region is determined by the cut depth. The depth of cut, for instance, would be 0.250 mm to lower a workpiece's outer diameter by 0.500 mm.

2.2.3 Feed

In a lathe, the feed is the axial progress of the tool along the work during each rotation of the work, expressed in millimetres per revolution. Another term for the feed is MPM (mm per minute), which stands for the amount of distance traversed in a minute.

Productivity, tool life, and machine needs are directly impacted by feed, spindle speed, and cut depth. As a result, these parameters need to be carefully selected for every operation. The choice of the cutting parameter will be greatly influenced by whether the target is rough cutting or finishing.

The experimental run tables for both tabular analysis and complete factorial design of Taguchi analysis are produced by analysing various cutting parameters and their levels. These data tables were created using MiniTab-17 statistical software, which also provided the proper level values for each experimental run. This chapter provides a description of the data gathering and analysis tasks carried out in accordance with the suggested approach covered in Chapter 3. There are two phases to this entire project:

1) Experimental Analysis

2) Taguchi Design of Experiment

The trials were carried out in accordance with the predetermined amounts of data, and these data were afterwards used for tabular and graphical analysis using the Taguchi technique to reduce tool wear and cutting force.

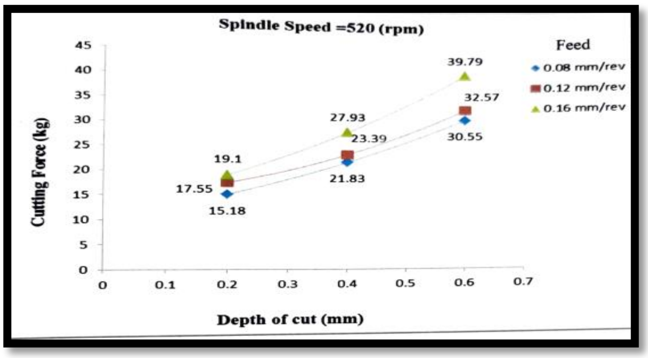

Figure 2.2 Variation of cutting force with depth of cut for constant spindle speed at different feed

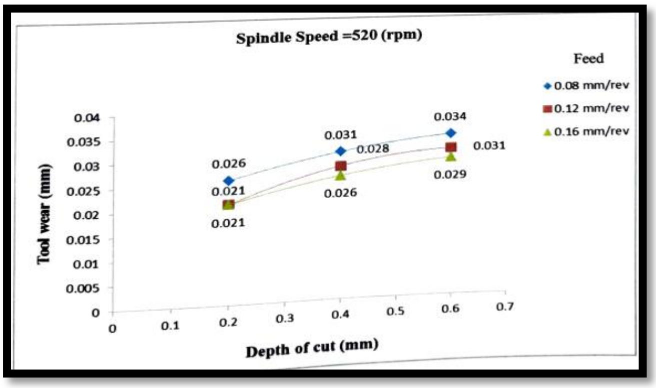

Figure 2.3 Variation of tool wear with depth of cut for constant spindle speed and at different feed

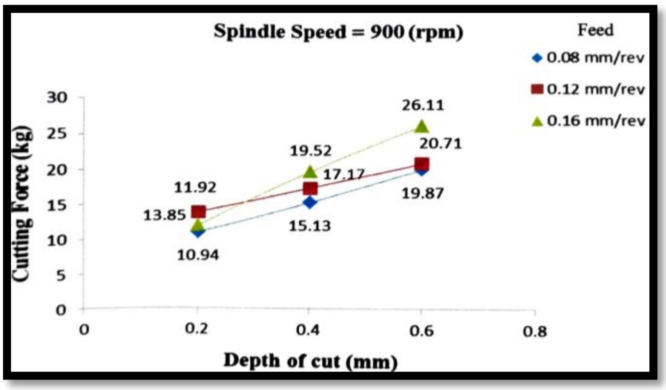

Figure 2.4 Variation of cutting force with depth of cut for constant spindle speed at different feed.

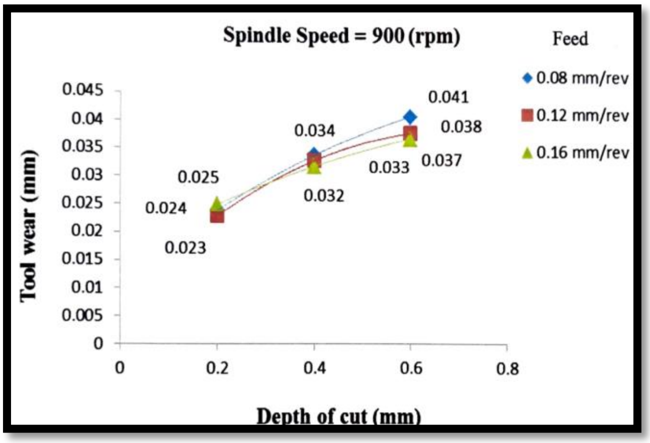

Figure 2.5 Variation of tool wear with depth of cut for constant spindle speed at different feed

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

This experimental analysis's first step is to classify. The S/N ratio was determined using the principle that "the smaller is better" and its principal effects were created using the statistical programme MiniTab-17. Minimum cutting force results in minimum tool wear. The first category was chosen in order to attain the optimum circumstances for cutting force reduction, which is the desired condition for turned machined components.

Table 2.4 Analysis of Variance for S/N Ratios.

Source	DF	Esq. SS	Ad SS	Ad MS	F	P	Percent Contribution
Spindle Speed (rpm)	2	18.2494	18.2494	9.1247	30.90	0.031	21.68
Feed (mm/rev)	2	6.2651	6.2651	3.1325	10.61	0.086	7.538
Depth of cut (mm)	2	58.0043	58.0043	29.0022	98.22	0.010	69.79
Residual Error	2	0.5906	0.5906	0.2953			0.674
Total	8	83.1094					
S=0.5434 R-Sq. = 99.3% R-Sq. (ad) = 97.2% m							

Table 2.2 Response for Signal to Noise Ratios

Level	Spindle Speed	Feed (mm/rev)	Depth of cut (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

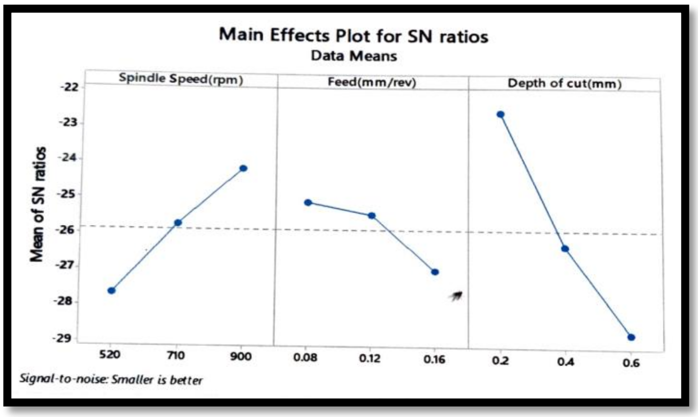

Figure 2.6 S/N Ratio verses Cutting Parameters (SS, DC and FR) Plots

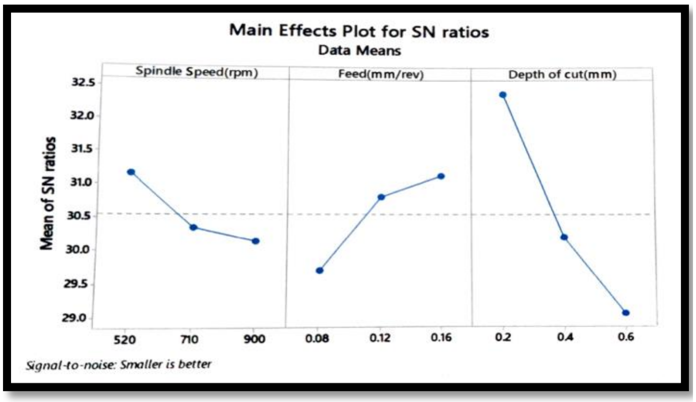

Fig 2.7 S/N Ratios verses Cutting Parameters (SS, DC, FR) plots

3. Conclusion

Based on the results of the graphical analysis, the Taguchi experimental analysis, and the literature review, the study's overall conclusion is made in this chapter. The effect of cutting parameters on tool wear and cutting force throughout the machining process has been examined in this study. The impact of cutting speed, feed, and depth of cut on tool wear and cutting forces during turning has been examined using a graphical approach and the Taguchi optimisation methodology on a centre lathe. Both show the correlation between cutting force and depth of cut, as well as between tool wear and depth of cut.

3.1 CONCLUSION OF GRAPHICAL ANALYSIS

1. Tool wear is proportional to the depth of cut.
2. As depth of cut increase the tool wear increases and as feed increases the tool wear decreases.
3. Tool wear (0.021 mm) is minimum at spindle speed 520 rpm and feed 0.16 mm/rev at depth of cut 0.2 mm
4. The cutting force and cut depth are inversely correlated.

5. Cutting force increases as depth of cut increases, and it also increases as feed increases.

6. At a spindle speed of 900 rpm, feed of 0.8 mm/rev, and a depth of cut of 0.2 mm, the cutting force (9.93 kg) is at its lowest.

3.2 CONCLUSION OF TAGUCHI METHOD

1. Compared to the percentage contribution of spindle speed (5.84%), the percentage contributions of depth of cut (72.44%) and feed (14.29%) in impacting the variance of tool wear are noticeably higher.

2. Experimental findings show that the tool wear is less than 0.021 mm at 520 rpm, 0.16 mm/rev feed, and 0.2 mm of cut depth. When the spindle speed is 900 rpm, the feed is 0.08 mm/rev, and the cut depth is 0.6 mm, the maximum amount of tool wear is 0.041 mm.

3.The feed rate should be adjusted to its greatest value (0.16 mm/rev), the spindle speed to 520 rpm, and the depth of cut to 0.2 mm for the best tool wear results.

4. In comparison to the feed's percentage impact (7.53%), the percentage contributions of the depth of cut (69.79%) and spindle speed (21.68%) on the variation of cutting force are noticeably greater.

5. Experimental findings show that the minimum cutting force is 9.93 kg at 900 rpm for the spindle, 0.08 mm per revolution for the feed, and 0.2 mm for the cut depth. When spindle speed is 520 rpm, feed is 0.16 mm/rev, and depth is 0.6 mm, tool wear is at its maximum of 0.041 mm.

6.For the best cutting force, the spindle speed should be set to its maximum (900 rpm), and the feed and depth of cut should be set to their lowest (i.e., 0.08 mm/rev and 0.2 mm).

3.3 SUGGESTIONS FOR FUTURE WORK Manufacturing systems are being driven more aggressively in the sectors due to the current increase in competition. Therefore, there is always a need for ongoing improvement. As a consequence, we might consider a few other factors, which are listed below, to obtain more accurate results:

I. A CNC machine may be used for experimentation so that process variables can be better controlled and parameters can be set to the appropriate precision.

- It is possible to research the alternative material, machine, and tool combination.

- Additional hard tool materials, such as CBN, can be included in the investigation.

- A variety of parameters can be investigated.

- The experiment can be carried out over a set amount of time.

4. REFERENCES

Aggarwal A. and Singh H., 2005. "Optimization of machining techniques". A retrospective and Literature Review. Sadhana Academy Proceedings in Engineering Sciences, 30(6): 699-711.

Astakhov V. P. and Shvets S.V., (2001). "A novel approach to operating force evaluation in high strain rate metal-deforming technological processes", Journal of Materials Processing Technology, 117 (1-2): 226-237.

Astakhov V.P. and Osman M.O.M., 1997. "Statistical design of experiments in metal cutting part 1: methodology", Journal of Testing and Evaluation, 25:322-327.

Brewer R.C. and Rueda R., 1963. "A Simplified Approach to the Optimum Selection of Machining Parameters", Engineers Digest, Vol. 24, No. 9, p. 133-150.

Byrne D.M. and Taguchi S., 1987. "The Taguchi Approach to Parameter Design", Quality Progress, pp. 19-26.

Chou Y.K., Barash M.M., Evans C.J., 1995. "Finish Performance and Wear Mechanism of Cubic Boron Nitride Tools in the Turning of Hardened 52100 Steels". Proceedings of the Ceramic Industry Manufacturing Conference and Exposition, 11-13, Pittsburgh, PA, pp 1-20.

Cook NH., 1966. "Manufacturing analysis Addison-Wesley publishing company", Inc. J. Machining and Machinability chap 2, Engineering; 4(3): 279-2843.

Elsayed E.A. and Chen A., 1993. "Optimal Levels of Process Parameters for Products with Multiple Characteristics", Int. J. Prod. Res., Vol. 31, No. 5, pp. 1117-1132.

Fowlkes W. Y. and Creveling C. M., 2006. "Engineering Methods for Robust Product Design: Using Taguchi Methods in Technology and Product Development. Reading", MA: Addison-Wesley.

Giusti F., Santochi M. and Tantussi G., 1987. "On-line sensing of flank and crater wear of cutting tools", Annals of the CIRP, 36(1): 41-44.

Isik Y., 2007. "Investigating the machinability of tool steels in turning operations"