OPTIMIZING THE CUTTING PARAMETERS USING TAGUCHI METHOD TO REDUCE THE CUTTING TOOL VIBRATION

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering
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107ME048

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CERTIFICATE

This is to certify that the project entitled "Optimizing The Cutting Parameters using Taguchi Method to Reduce The Cutting Tool Vibration" submitted by Nishant Kumar in partial fulfillment of the requirements for the award of Bachelor of Technology, NIT Rourkela, is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the project has not been submitted to any Institute/University for the award of any degree or diploma.

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ACKNOWLEDGEMENT

It is with a feeling of great pleasure that I would like to express my most sincere heartfelt gratitude to Prof. S.K. Sahoo, Department of Mechanical Engineering, NIT Rourkela for suggesting the topic for this report and for his ready and able guidance throughout the course of preparation of the report. I am greatly indebted to him for his constructive suggestions and criticism from time to time during the course of progress of the work.

I express my sincere thanks to Prof. R.K Sahoo, Head of the Department of Mechanical Engineering, NIT, Rourkela for providing me the necessary facilities in the department. I am also thankful to all the staff members of the Department of Mechanical Engineering.

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Abstract

In any machining operation, minimizing the vibration of the tool is a very important requirement for any turned workpiece. Thus the choice of optimized cutting parameter is very important for minimizing the vibration of the cutting tool. The focus of this study is the collection of tool vibration data generated by the lathe dry turning of SS304 samples of diameter 31mm using ISO 6R 1212 as the cutting tool at different levels of speed (140, 220, 360rpm), feed (0.1, 0.16, 0.25mm/rev) and depth of cut (0.5, 0.6, 0.7mm) and then analyzing the obtained data using taguchi analysis to show how tool vibration varies within a given range of speed, feed & depth of cut. The vibration here is represented by its peak acceleration. The analysis revealed that for the specified range of speed, feed and depth of cut, any change in the depth of cut causes a large change in the tool vibration while change in the cutting speed causes comparatively lowest change in tool vibration.

Nomenclature

s – cutting speed (m/min)

f – feed rate (mm/rev)

d – depth of cut (mm)

w – workpiece length (cm)

D – diameter of workpiece

ϒ - rake angle

Λ – angle of inclination

K_r – entering angle

n – number of samples

μ - mean value of y

Δ – tolerance level

A – loss caused by exceeding tolerance level

k – proportionality constant

m – target value

y – value of quality characteristic

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1. <u>Introduction</u>

In any machining operation, controlling the tool vibration is an important requirement of any turned workpiece. An uncontrolled vibration in a turning operation may damage the cutting tool, surface finish and may also create annoying noise. Tool vibration is one of the most important factors limiting its performance. Research is being done all around the world to minimize this problem, either by improving the dynamic compliance of structure or by minimizing the cutting conditions so that vibration does not occur. However, it has also been found that, limiting conditions minimizes the production rate [1]. A large number of analytical and experimental study has been carried out for vibration control [2,3,4]. Vibration in a turning operation can be classified into three categories [3] i.e; free vibration, forced vibration and self-excited vibration. Free vibration because of its short transient response has little practical significance compared to forced & self excited vibrations. Self excited vibration actually results from a dynamic instability of the turning process. Forced vibration arises with the application of periodic cutting forces acting on the cutting tool and becomes large when the frequency ratio is unity. This phenomenon is known as resonance and should be avoided in turning. Tool vibration analysis [2,5] has revealed that cutting parameters not only have an effect on the amplitude of vibration, but also on the variation of the natural frequency of the tool. [6] predicts surface roughness based on the cutting parameters and tool vibrations in turning operations. [7] also predicts surface roughness and dimensional deviation by measuring cutting forces and vibrations in turning process. [8], it was concluded that the taguchi method provides an organised and efficient methodology for the design optimization of the cutting parameters. It was also shown that the tool life and surface roughness can be improved significantly for turning operations. According to [9], the cutting forces depend mainly on the feed rate and the depth of cut. It was also concluded that the optimum parameters for reducing vibration and increasing tool damping are a low depth of cut, low feed rate, high cutting speed and a large tool nose radius. It was also observed that increasing the tool vibration, by increasing the tool vibration, by increasing the depth of cut, when operating at low cutting speed helps in improving surface accuracy.

The aim of this project is to predict the behaviour of tool vibration in terms of peak acceleration of vibration with respect to varying cutting speed, feed & depth of cut. After the dry turning of the workpiece, the data thus obtained were analysed using the taguchi analysis technique. [8] Taguchi method provides a simple, efficient and systematic approach to optimize designs for performance, quality & cost. It is also considered as a very powerful tool for the design of high quality systems. [Dehnad 1989, Nair 1992] The taguchi method aims to determine the optimal level of the important controllable factors based on the concept of robustness and also helps in minimizing the effects of noise.

2. Experimental Procedure

2.1 Tools and Equipments used

2.1.1 Cutting Tool: Brazed Turning Tool, ISO 6R 1212

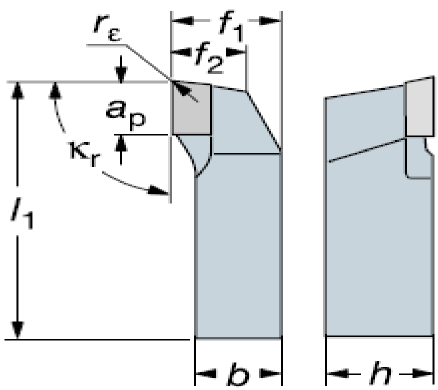

Fig 2.1 Cutting Tool Specifications, Reference: [12]

Table 2.1. Specification of the Cutting Tool

Ordering Code	Tip	Dimensions (mm)								
		h	b	µ	f_1	f_2	a_p	r_E	$\Upsilon^{1)}$	$\Lambda^{2)}$
ISO 6R 1212	C10	12	12	100	17	7,5	10	0,4	12^0	0^0

reference: [12]

2.1.2 Workpiece:

Stainless Steel 304 of diameter 31mm was used in the experiment. [13] Stainless Steel 304 is an austenitic grade which offers excellent resistance to corrosion and can also be readily welded.

Table 2.2 Chemical Composition of SS304:

Grade	C(%)	Mn(%)	Si(%)	P(%)	S(%)	Cr(%)	Ni(%)	N(%)
SS 304	0.08max	2.0	0.75	0.045	0.030	18-20	8-10.5	0.1

reference: [14]

Table 2.3. Mechanical Properties of SS 304:

Grade	Tensile strength(MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Rockwell B (HR B) max	Brinell (HB) max
SS 304	515	205	40	92	201

reference: [14]

2.1.3 Vibrometer

TV300 vibration tester:

[15], TV300 uses piezoelectric acceleration transducer and converts the vibration signal into electric signal. It then analyses the input signal and gives the result which includes peak values of acceleration, peak-peak values of displacement and the rms of velocity values. It can be used not only to test the acceleration, velocity and displacement of vibration but also the inherent frequency and can also perform simple failure diagnosis. It measures peak acceleration (0.1-392m/s^2), rms velocity (0.01-80cm/s) and peak-peak displacement (0.001-10mm).

The vibrometer was checked for some trial runs with mild steel rod. The suitable values of cutting speed, feed & depth of cut were taken. The workpiece was given with an initial roughing pass and 27 markings of equal length were made on the workpiece. The number of markings were 27 as each of the cutting parameters were varied three times. So taking the different set of cutting parameters, 27 observations were taken for analysis. Using the TV300 vibrometer the vibration of the cutting tool was measured in the form of the peak acceleration of the cutting tool.

TV300 Vibration Tester **Workpiece**

Fig 2.2 <u>Experimental Setup</u>

Fig 2.3 <u>Machined Workpiece</u>

2.2 Taguchi method of Analysis

According to Taguchi [11], “ Quality is the loss imparted to society from the time a product is shipped.” Taguchi concept attempts to reduce the impact of noise rather than eliminate it. Taguchi also proposes a three-stage design operation to determine the tolerances and target values for relevant parameters in the product and the process which are the system design, parameter design and the tolerance design. In system design, scientific and engineering principles and experience are used to create a prototype of the product that will meet functional requirements. Parameter design aims to minimize the performance variability by finding out the optimal settings of the product and process parameters. And in tolerance design, tolerances are set around the target values of the control parameters identified in the parameter design phase and is done only when the performance variation achieved by the settings identified in the parameter design stage is not acceptable. Taguchi also defined a performance measure known as the signal to noise ratio (S/N) and aims to maximize it by properly selecting the parameter levels. Signal here, represents the square of the mean value of the quality characteristic whereas noise is a measure of the variability of the characteristic, or the uncontrollable factors. Usually there are three categories of quality characteristic in the analysis of the S/N ratio, i.e; the lower is better, the higher is better and the nominal is better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. But irrespective of the quality characteristic, a greater S/N ratio corresponds to better quality characteristic.

For this concerned project, which aims at optimizing the turning parameters for reduced vibration, the smaller is better technique is used.

Smaller is Better

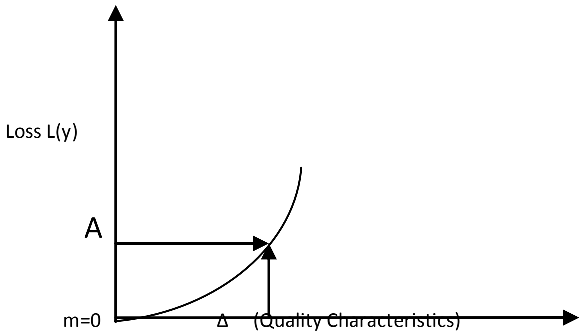

Fig 2.3 Loss Function for Smaller is Better

The loss function for smaller is better is given by,

$L(y) = ky^2$

If the loss caused by exceeding the customer's tolerance level Δ is A, the value of the proportionality constant k is then, $k = A/\Delta^2$

The expected loss over the items produced is given by,

$E[L(y)] = KE(y^2)$

$= (A/\Delta^2)E(y^2)$

$= (A/\Delta^2)[Var(y) + \mu^2]$

$= (A/\Delta^2)MSD$

Where MSD represents the mean square deviation and is represented as $(\Sigma^n_{i=1} y_i * y_i)/n$

and, Var(y) signifies the variance of y.

3. Results and Discussion

3.1 Observations

Table 3.1: Obsearvation Table

Sl no.	Depth (mm)	Feed (mm/rev)	Speed (rpm)	Peak acc (m/s^2
1	0.5	0.1	140	0.0500
2	0.5	0.1	220	0.0550
3	0.5	0.1	360	0.0730
4	0.5	0.16	140	0.0560
5	0.5	0.16	220	0.0600
6	0.5	0.16	360	0.0500
7	0.5	0.25	140	0.0740
8	0.5	0.25	220	0.0810
9	0.5	0.25	360	0.0600
10	0.6	0.1	140	0.0850
11	0.6	0.1	220	0.0910
12	0.6	0.1	360	0.1125
13	0.6	0.16	140	0.1070
14	0.6	0.16	220	0.0830
15	0.6	0.16	360	0.0970
16	0.6	0.25	140	0.1150
17	0.6	0.25	220	0.1080
18	0.6	0.25	360	0.1150
19	0.7	0.1	140	0.1000
20	0.7	0.1	220	0.0670
21	0.7	0.1	360	0.0760
22	0.7	0.16	140	0.0850
23	0.7	0.16	220	0.0950
24	0.7	0.16	360	0.1090
25	0.7	0.25	140	0.0920
26	0.7	0.25	220	0.1100
27	0.7	0.25	360	0.1020

3.2 Analysis

The peak acceleration data was analysed using the taguchi analysis method of the Minitab 14 software. [10] Minitab 14 software was used as it provides an effortless method to create, edit and update graphs. Also it provides a dynamic link between a graph and its worksheet that helps in updating the graph automatically whenever the data is changed. Its appearance and easy to use enhancements further add to its advantages.

The type of design was specified as a 3-Level Design and the input parameters i.e; speed, feed & depth of cut were taken as the factors and the peak acceleration was taken as the response. The created Taguchi design was analysed and the following outputs were obtained.

Table 3.2: Analysis of Variance for S/N Ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Depth	2	95.110	95.1099	47.5549	31.90	**0.000**
Feed	2	14.949	14.9486	7.4743	5.01	**0.017**
Speed	2	0.799	0.7994	0.3997	0.27	0.768
Residual error	20	20.817	29.8174	1.4909		
Total	26	140.675				

The analysis of variances for the factors is shown in above table which clearly indicates that the cutting tool speed is not of much importance in influencing the tool vibration and depth & feed are the most influencing factors for tool vibration (shown in bold).

Table 3.3: **<u>Response table for S/N ratio (smaller is better)</u>**

Level	Depth	feed	Speed
1	24.26	22.34	21.71
2	19.93	21.99	21.81
3	20.74	20.61	21.41
Delta	4.32	1.72	0.40
Rank	1	2	3

As the above table itself gives the rank to the factors: depth, feed and speed, it is clear that depth of cut is the most important factor in controlling the vibration of the cutting tool while speed is the least.

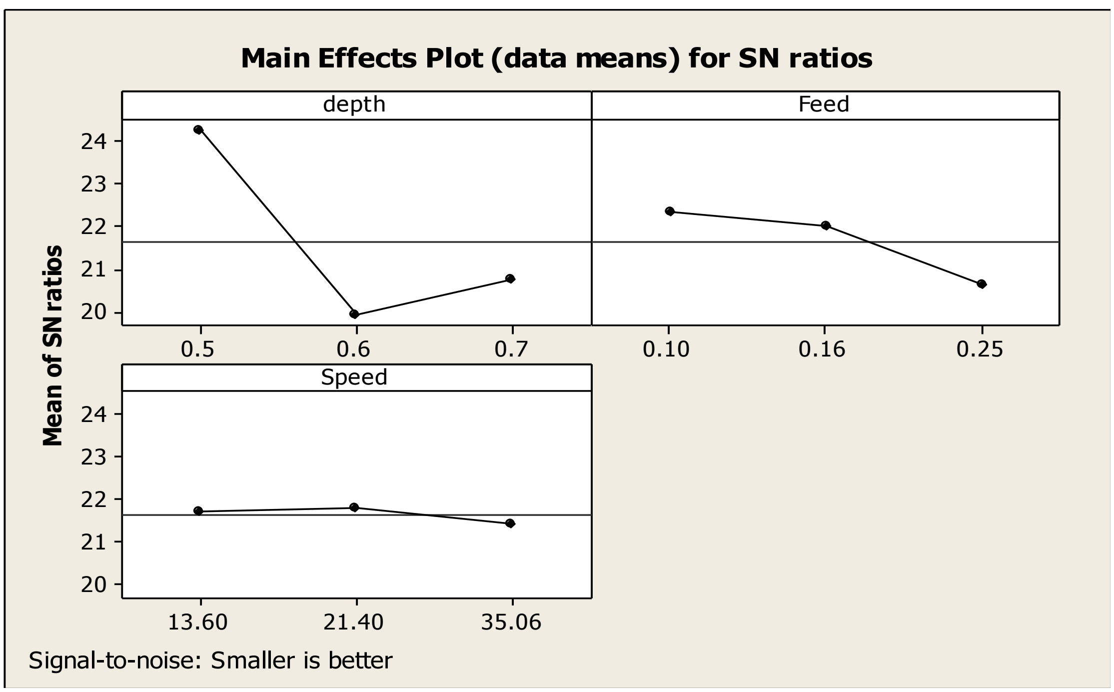

Fig 3.1: **Main Effects Plot for S/N Ratios**

The influence of the input variables i.e; the speed, feed and depth of cut is observed on the vibration of the cutting tool, as shown above in the main effect plot for S/N ratios. The depth of cut here has the most dominant effect on the tool vibration while speed does not effect the tool vibration in a large manner. The S/N ratio first decreased when the depth of cut was increased from 0.5 to 0.6mm but then increased when the depth of cut was increased from 0.6 to 0.7mm. Also when the feed increased from 0.1 to 0.16mm/rev the S/N ratio was found to decrease and the the S/N ratio further decreased with a larger rate when the feed was increased from 0.16 to 0.25mm/rev. Overall, it can be that as the speed, feed & the depth of cut are increased the tool vibration increases.

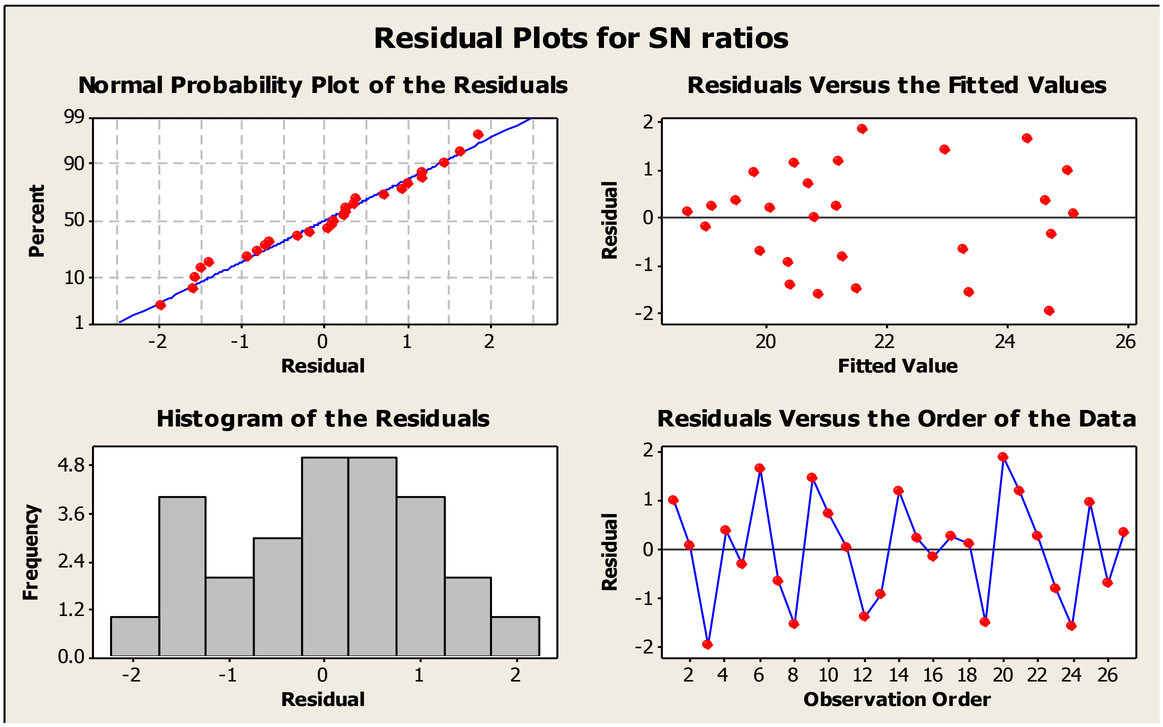

Fig 3.2: <u>Residual Plots for S/N Ratios</u>

The residual plot of S/N ratios is shown in the above figure. This layout is useful to determine whether the model meets the assumptions of the analysis. The residual plots in the graph and the interpretation of each residual plot are:

a. Normal probability plot helps in detecting non-normality. An approximately straight line indicates that the residuals are normally distributed.

   The above Normal probability plot indicates that the data are normally distributed and the variables are influencing the response. Outliers do not exist in the data, as the standardized residues are between -2 and 2.

b. The plot of residual versus the fitted values helps in detecting non constant variance, missing higher-order terms and the outliers. The residuals should be scattered randomly around zero.

   The above residuals versus fitted values plot indicate a constant variance as well as absence of the outliers in the data.

c. The plot of histogram of the residuals helps in detecting multiple peaks, outliers, and non-normality. The histogram should be approximately symmetric and bell-shaped.

   The above plot of histogram of the residuals points towards the presence of multiple peaks and also shows that the histogram is approximately symmetric and bell-shaped.

d. The plot of residuals versus order helps in detecting the time-dependence of residuals. The residuals should exhibit no clear pattern.

   The above Residuals versus order plot indicates towards the random pattern of the residuals.

   .

Chapter 4

4. Conclusion

In the present study the behavior of vibration of the cutting tool was observed by changing cutting parameters i.e; the speed, feed and the depth of cut. SS 304 was taken as the workpiece material, the cutting tool was ISO 6R 1212 and also the vibration was represented by the peak acceleration of the cutting tool. As there were 3 factors each having three levels so a total of 27 experiments were done by varying the factors and the data thus obtained were analysed using the Taguchi Design which was performed on the MINITAB14 software.

From the experimental results it can be concluded that the depth of cut is the most important factor in controlling the vibration of the cutting tool while speed is the least dominant factor in controlling the same vibration and the effect of the feed lies in between that of depth of cut and the cutting speed.

References

[1] – On-line control of machine tool vibration during turning operation, S.K. Choudhury[a], M.S. Sharath[b], [a]Mechanical Engineering Department, I.I.T. Kanpur, PO I.I.T., Kanpur 208016, India, [b] [b]Metal Cutting Division, Hindustan Machine Tools, Bangalore, India, (Received June 11, 1993)

[2] – Effect of tool vibrations on surface roughness during lathe dry turning process, Thomas M., Beauchamp Y., Youssef A.Y., Masounave J. Professor, Mechanical Engineering Department École de technologie supérieure 4750, ave Henri-Julien, Montréal, Canada, H2T2C8

[3] – Design of dynamic vibration absorber against vibrations in turning operations, E.C. Lee[a], C.Y. Nian[b], Y.S. Tarng[a,*], [a]Department of Mechanical Engineering, National Taiwan University of Science & Technology, Taipei 106, Taiwan, ROC, [b]Department of Automatic Engineering, Fushin Institute of Technology, Touchen, I-Lan261, Taiwan, ROC, Received 6 April 1999

[4] – On-Line Control of Machine Tool Vibration in Turning, S.K. Choudhury, N.N. Goudimenko and V.A. Kudinov, (Received 11 august 1995; in final form 13 february 1996)

[5] – Tool vibration and its influence on surface roughness in turning, M. S. Selvam, Department of Mechanical Engineering, College of Engineering, Guindy, Madras-600025(India), (Received October 16, 1974; in final form March 7, 1975)

[6] – Surface roughness prediction based on cutting parameters and tool vibrations in turning operations, O.B. Abouelatta[*], J. Mádl, Faculty of Mechanical Engineering, Mechanical Technology Department, Technická 4, CTU, 166 07 Praha 4, Czech Republic

[7] - Prediction of surface roughness and dimensional deviation by measuring cutting forces and vibrations in turning process, K.A. Risbood, U.S. Dixit*, A.D. Sahasrabudhe, Department of Mechanical Engineering, Indian Institute of Technology, Guwahati 781 039, India, Received 26 March 2002; received in revised form 13 August 2002; accepted 9 September 2002

[8] - Design optimization of cutting parameters for turning operations based on the Taguchi method, W.H. Yang, Y.S. Tarng *, Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taipei 106, Taiwan, Received 21 May 1997

[9] - Statistical investigation of modal parameters of cutting tools in dry turning, M. Thomas *, Y. Beauchamp, Department of Mechanical Engineering, E´ cole de technologie supe´rieure, 1100 Notre Dame West, Montreal, Quebec H3C 1K3, Canada, Received 4 May 2000; received in revised form 30 April 2003; accepted 7 May 2003

[10] – www.gtpcc.org/gtpcc/minitab14.htm

[11] – Fundamentals of Quality Control and Improvement, second edition, Amitava Mitra,PHI Learning Private Limited, New Delhi-110001, 2008, page (595 to 637)

[12] - http://www2.coromant.sandvik.com/coromant/pdf/Metalworking_Products_051/turn_h.pdf

[13] - http://www.engineersedge.com/stainless_steel.htm

[14] - http://www.azom.com/article.aspx?articleid=965

[15] - TV300 Vibration Tester, User’s Manual (V090304), Beijing TIME High Technology Limited