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Effect of Cutting Parameters of Turning Process on Cutting Tool vibrations and surface roughness of stainless steel using Taguchi Method

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Abstract

In actual cutting conditions various forces and unseen factors arise which cause vibrations. If vibrations occur between the tool and the job, then naturally the dimensional accuracy cannot be maintained and the performance of the machine tool will not be satisfactory. Also the machine tool vibration has detrimental effect on tool life and thus the cost of the production is increased and productivity lowered.

In any machining operation, minimizing the vibration of the tool is a very important requirement for any turned work piece. 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 31 mm using ISO 6R 1212 as the cutting tool at different levels of speed (130, 180, 340rpm), feed (0.1, 0.20, 0.22mm/rev) and depth of cut (0.4, 0.5, 0.6mm) 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.

This study highlights the use of Taguchi design to optimize the multi response in turning operation. For this purpose Taguchi design of experiment was carried out to collect the data for tool vibration and cutting forces. The result shows the optimum values of the input parameters and a confirmatory test is held to confirm the result.

Although a high roughness value is often undesirable, it can be difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Roughness can be measured by manual comparison against a "surface roughness comparator", a sample of known surface roughness, but more generally a Surface profile measurement is made with a profile meter that can be contact (typically a diamond styles) or optical (e.g. a white light interferometer).

1. Introduction

In machine tools the accuracy and reliability of the job are very important features and to achieve them it is essential that dynamic rigidity of machines is given due consideration.

In actual cutting conditions various forces and unseen factors arise which cause vibrations. If vibrations occur between the tool and the job, then naturally the dimensional accuracy cannot be maintained and the performance of the machine tool will not be satisfactory. Also the machine tool vibration has detrimental effect on tool life and thus the cost of the production is increased and productivity lowered.

1.1 Effect of vibration

In machine tool attempts should be made either to eliminate the source of vibrations or to reduce them. To achieve this, it is essential that first the effect of vibrations on machine tool are studied.

The effect of vibrations can be considered on the machine tool, work-piece, tool life and the cutting conditions.

a. **Effect of vibrations on machine tool:** The machine tool is made of various parts and when vibrations are produced, they also start vibrating at same frequency. If the frequency approaches the natural frequency of vibrations of that part then amplitude of vibrations will be very excessive and that part may break even.
b. **Effect of vibrations on work-piece:** Due to presence of vibrations the surface finish obtained will be very poor and thus this aspect is very important for fine finishing operations.
c. **Effect of vibrations on tool life:** As the tool life is a function of the cutting variables only, the tool life is greatly affected by presence of vibrations in machine tools. It is found out that the tool life is decreased by

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about 70-80% of the normal value if vibrations are present.

d. **Effect of vibrations on cutting conditions:** By presence of vibrations in machine tools the chip thickness as removed by the cutting tool does not remain constant and due the cutting force also vary.

Also due to vibrations, vibratory displacements of the tool take place in the direction of motion of the job which results in the chatter of the tool.

1.2 Sources of the vibrations

a. Generations of vibrations from the cutting process (tool chatter). These type of vibrations are self induced and are supplied from the cutting process under some particular conditions.

b. In homogeneities in the material being machined and build up edges on the cutting tools. Due to sudden increment in hardness of the tool or job, impulsive force is generated which causes vibrations.

c. Transmission from the ground which is vibrating due to some other reasons. This can be minimized by isolating the machine tool from the ground.

1.3 Surface Roughness

Surface roughness, often shortened to roughness, is a component of surface texture. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion.

2. Experimental Details

Table: 1. Specification of the Cutting Tool (ISO 6R 1212)

Ordering Code	Tip	Dimensions (mm)								
		h	b	L_1	f_1	f_2	a_p	r_e	ɣ	ʎ
ISO 6R 1212	C10	12	12	100	17	7,5	10	0,4	12°	0°

2.1 Work-piece

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

Table: 2. Chemical Composition of SS304

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

3. Observations

Table: 3. Observation Table

S. No.	Depth (mm)	Feed(mm/rev)	Speed(rpm)	Peak Acc(m/sec^2)	Surface roughness
1	0.4	0.10	130	0.0500	3.56
2	0.4	0.10	180	0.0550	3.63
3	0.4	0.10	340	0.0730	3.75
4	0.4	0.20	130	0.0560	3.95
5	0.4	0.20	180	0.0600	3.87
6	0.4	0.20	340	0.0500	3.68
7	0.4	0.22	130	0.0740	8.78
8	0.4	0.22	180	0.0810	8.56
9	0.4	0.22	340	0.0600	8.43
10	0.5	0.10	130	0.0850	3.87
11	0.5	0.10	180	0.0910	3.96
12	0.5	0.10	340	0.1125	3.98
13	0.5	0.20	130	0.1070	4.21
14	0.5	0.20	180	0.0830	4.36
15	0.5	0.20	340	0.0970	4.75
16	0.5	0.22	130	0.1150	7.68
17	0.5	0.22	180	0.1080	7.76
18	0.5	0.22	340	0.1150	7.96
19	0.6	0.10	130	0.1000	3.25
20	0.6	0.10	180	0.0670	3.46
21	0.6	0.10	340	0.0760	3.64
22	0.6	0.20	130	0.0850	4.27
23	0.6	0.20	180	0.0950	4.38
24	0.6	0.20	340	0.1090	4.71
25	0.6	0.22	130	0.0920	7.81
26	0.6	0.22	180	0.1100	7.91
27	0.6	0.22	340	0.1020	7.97

3.1 Analysis

The peak acceleration data was analyzed using the taguchi analysis method of the Minitab 14 software. 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 analyzed and the following outputs were obtained.

Table: 4. 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				

3.2 Analysis

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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: 5. Response table for S/N Ratio (smaller is better)

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.

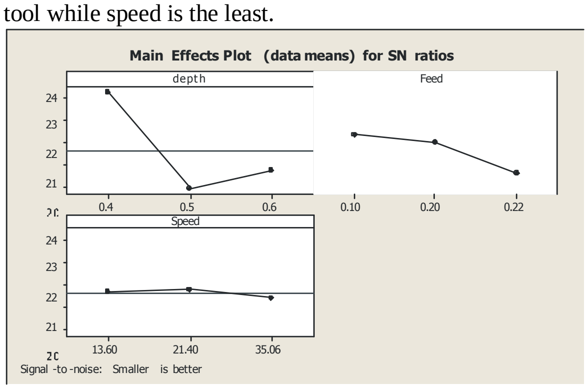

Fig: 1. Main Effects Plot for S/N Ratios

4. Conclusions and Recommendation

The following conclusions can be drawn after the experiment and study on turning of SS 304 with the ISO 6R 1212 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 analyzed using the Taguchi Design.

1. Taguchi method can be efficiently used in off-line quality control in that the experimental design is combined with the quality loss.
2. From the study it is found that the main factors affecting more the cutting force and tool vibration are principal cutting edge angle and depth of cut. Cutting speed and feed rate are less affecting as compared to the above two mentioned parameters. The two responses cutting force and tool vibration are combined together to one.
3. The optimal setting is found to be **A1B1C2D2**, and surface roughness is found to be **A3B1C1**. A confirmatory test is carried out after the optimal setting of input parameters is determined.

The optimal value of tool vibration in terms of peak to peak displacement is found to be 0.3um.

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