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Research Article

Experimental Analysis on the Influence of Spindle Vibrations of CNC Lathe on Surface Roughness using Taguchi Method

Vijay Mohan Shetty†*, Mahesh Pallapothu† and Vamshi Reddy Pothuganti†

†Department of Mechanical Engineering, JNTUH college of Engineering, Jagityal, Karimnagar District ,Telangana State, India

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Abstract

In today's manufacturing environment, many industries have attempted to introduce flexible manufacturing systems (FMS) as their strategy to adapt to the ever changing competitive market requirements. To ensure quality of machined products to reduce the machining costs and to increase the machining effectiveness, it is very important to select appropriate machining parameters when machine tools are selected for machining. In this work, after conducting an exhaustive literature review, several optimization techniques used in various manufacturing processes have been identified. The selection of optimal cutting parameters, like depth of cut, feed and speed is a very important issue for every machining process. Experiments have been designed using Taguchi technique and turning of Aluminium 6065 has been performed on Cnc Lathe shown in figure 1.5(c) Analysis using S/N and ANOVA were performed to find the optimum level and percentage of contribution of each parameter. By using S/N analysis the optimum machining parameters from the experimentation is obtained using MINITAB 17 software. The main objective of this study is dedicated to experimental vibration analysis of the spindle bearing assembly with self-exited vibration and the effect of vibrations on surface roughness is evaluated using ANOVA.

Keywords: *Taguchi method, ANOVA, Turning process, vibrations, surface roughness.*

1. Introduction

Turning is a widely used machining process in which a single-point cutting tool removes material from the surface a rotating cylindrical work piece. Three cutting parameters, i.e., feed rate, depth of cut, and insert radius must be determined in a turning operation. A common method of evaluating machining performance in a turning operation based on the surface roughness. Basically, surface roughness is strongly correlated with cutting parameters such as insert radius, feed rate, and depth of cut. Proper selection of the cutting parameters can obtain better surface roughness. Hence, optimization of the cutting parameters based on the parameter design of the Taguchi method adopted in this paper to improve surface roughness in a turning operation. Surface finish is an essential requirement in determining the surface quality of a product.

Surface roughness in metal cutting is defined as irregularities on any material resulting from a machining operation. Average roughness (Ra) is the arithmetic average of departure of the profile from the mean line along a sampling length. Surface finish has a great influence on the reliable functioning of two mating parts.

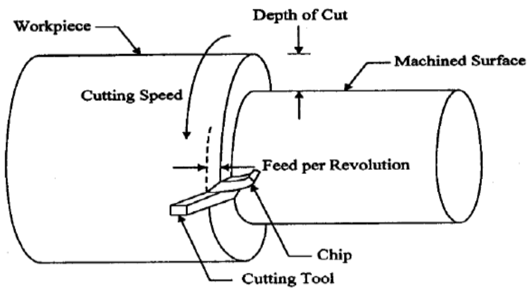

Fig.1 Turning process

2. Influence of vibrations on machining

Today's manufacturing industry demands higher productivity with preserved or even smaller tolerances. The demand on high productivity leads to increased material removal per unit time and higher spindle speeds, increased feed rate, and greater depth of cut. However, at certain combinations of machining parameters; process instabilities and vibrations can occur which result in decreased accuracy, poorer surface finish, reduced tool life time and in the worst case spindle failure.

Vibrations in Turning have been investigated by many researchers using cutting force sensors microphones and accelerometers. Although cutting

*Corresponding author Vijay Mohan Shetty is working as Lecturer; **Mahesh Pallapothu** and **Vamshi Reddy Pothuganti** are students.

force measurements may be addressed as the key information needed to be monitored, today's available force measuring platforms, dynamometers, are limited to relative small work pieces. Microphones are best suited for setting up thresholds based on experience or trials. The sound of a stable cutting process is usually calm and contains only frequencies originating from the spindle speed and the cutting teeth. However, microphones cannot give any information about deformations and forced vibrations. Since accelerometers easily be applied on the spindle bearing and measured the vibration level.

Deterioration in the operation of a machine component gives rise to increasing in vibration level, mixing of vibration signals does not cause any loss of individual's frequency information. Vibration signature taken from appropriate location in machine tool can reveal the following defects: imbalance, misalignment, imperfect foundation, rubs, bearing defects, fault in belt drive etc.

3. Taguchi Method

The taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization and this is a powerful tool for the design of high quality systems. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. This is an engineering methodology for obtaining product and process condition, which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs. Signal to noise ratio and orthogonal array are two major tools used in robust design.

The S/N ratio characteristics can be divided into three Categories when the characteristic is continuous

a) Nominal is the best
b) Smaller the better
c) Larger is better characteristics.

For the maximum material removal rate, the solution is "Larger is better" and S/N ratio is determined according to the following equation:

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

Where, S/N = Signal to Noise Ratio,
n = No. of Measurements,
y = Measured Value.

The influence of each control factor can be more clearly presented with response graphs. Optimal cutting conditions of control factors can be very easily determined from S/N response graphs, too. Parameters design is the key step in Taguchi method to achieve reliable results without increasing the experimental costs. The beauty of Taguchi method lies in the fact that it integrates statistical methods into the powerful engineering process.

4. Experimental work

Material: **AA 6065 T6** the mechanical properties are:

S.No	Material Properties	Range
1	Aluminium	94.4 - 98.2%
2	Magnesium	0.8 - 1.2%
3	Silicon	0.4 - 0.8%
4	Iron	0 - 0.7%
5	Copper	0.15 - 0.40%
6	Zinc	0 - 0.25%
7	Chromium	0 - 0.15%
8	Manganese	0 - 0.15%
9	Titanium	0-0.1%

5. Experimental Procedure

The experiments are conducted at THREE Levels and Three factors L_{27} orthogonal array as given below in table

Table 1.1 L_{27} orthogonal array

Cutting speed (m/min)	Depth of cut (mm)	Feed(mm/rev)
150	0.25	0.1
150	0.25	0.2
150	0.25	0.3
150	0.5	0.1
150	0.5	0.2
150	0.5	0.3
150	0.75	0.1
150	0.75	0.2
150	0.75	0.3
200	0.25	0.1
200	0.25	0.2
200	0.25	0.3
200	0.5	0.1
200	0.5	0.2
200	0.5	0.3
200	0.75	0.1
200	0.75	0.2
200	0.75	0.3
250	0.25	0.1
250	0.25	0.2
250	0.25	0.3
250	0.5	0.1
250	0.5	0.2
250	0.5	0.3
250	0.75	0.1
250	0.75	0.2
250	0.75	0.3

6. Experimental setup

The experiments are conducted on Cnc Lathe at different operating conditions on Aluminium 6065 and vibration analysis is done using an accelerometer mounted in spindle to collect the vibration signals these signals are acquired using lab view software and its signals are stored at different stages of machining.

Table 1.2 Experimental results for different cutting conditions and their corresponding S/N ratio's

CS (m /min)	Depth of cut (mm)	Feed (mm /rev)	SR (Ra)	Acc'N In (mm/s2)	SN RA1	SN RA2
150	0.25	0.1	1.875	1.42	-5.46	-3.05
150	0.25	0.2	3.675	1.58	-11.3	-3.97
150	0.25	0.3	9.899	1.824	-19.9	-5.22
150	0.5	0.1	2.325	1.12	-7.33	-0.98
150	0.5	0.2	3.648	1.29	-11.2	-2.21
150	0.5	0.3	10.69	1.926	-20.6	-5.69
150	0.75	0.1	3.269	1.564	-10.3	-3.88
150	0.75	0.2	6.925	1.409	-16.8	-2.98
150	0.75	0.3	9.724	1.834	-19.8	-5.27
200	0.25	0.1	1.825	1.224	-5.23	-1.76
200	0.25	0.2	3.356	1.968	-10.5	-5.88
200	0.25	0.3	7.215	1.724	-17.2	-4.73
200	0.5	0.1	2.303	1.601	-7.25	-4.09
200	0.5	0.2	4.548	1.78	-13.2	-5.01
200	0.5	0.3	10.46	1.824	-20.4	-5.22
200	0.75	0.1	2.547	1.6	-8.12	-4.08
200	0.75	0.2	4.248	1.864	-12.6	-5.41
200	0.75	0.3	8.845	1.89	-18.9	-5.53
250	0.25	0.1	1.925	1.189	-5.69	-1.5
250	0.25	0.2	3.578	1.984	-11.1	-5.95
250	0.25	0.3	8.09	1.475	-18.2	-3.38
250	0.5	0.1	2.214	1.586	-6.9	-4.01
250	0.5	0.2	4.325	2.625	-12.7	-8.38
250	0.5	0.3	8.125	3.124	-18.2	-9.89
250	0.75	0.1	2.869	1.619	-9.15	-4.18
250	0.75	0.2	4.125	2.125	-12.3	-6.55
250	0.75	0.3	9.21	2.652	-19.3	-8.47

Table 1.3 Response Table for Signal to Noise Ratios Smaller is better for surface Roughness

Level	Cutting speed	Depth of cut	Feed
1	-13.631	-11.612	-7.268
2	-12.591	-13.084	-12.41
3	-12.61	-14.136	-1.153
Delta	1.04	2.524	11.884
Rank	3	2	1

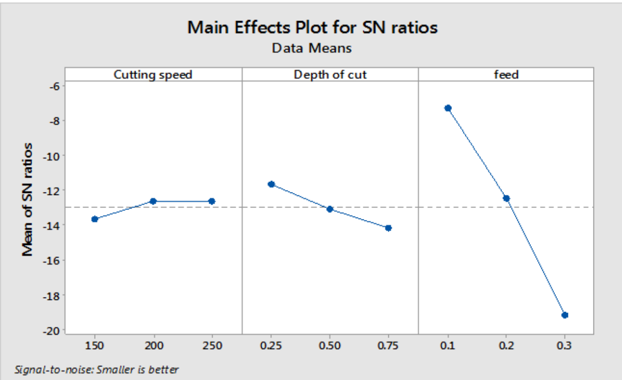

Figure 2 Effect of cutting parameters on surface roughness for S/N ratio's

Table 1.4 Response Table for Signal to Noise Ratios Smaller is better for acceleration

Level	Cutting speed	Depth of cut	Feed
1	-3.696	-3967	-3.059
2	-4.634	-5.054	-5.149
3	-5.813	-0.151	-5.934
Delta	2.117	1.213	2.874
Rank	2	3	1

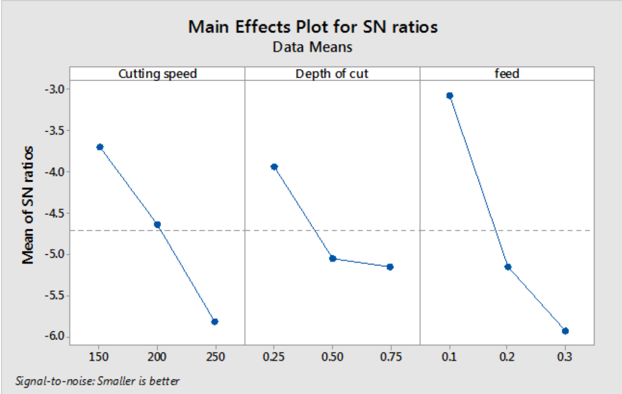

Figure 1.4 Effect of cutting parameters on acceleration for S/N ratio's

(a) (b)

(C)

Figure 1.5 (a) Specimens, (b) surface test SJ-210, (c) Cnc lathe

7. Anova Analysis of Variance Results

The purpose of ANOVA is to investigate which of the process parameters significantly affect the performance characteristics. This is accomplished by separating the total variability of the S/N ratios which is measured by the sum of the square deviations from the total mean of S/N ratios.

Table 1.5 Analysis of variance for surface roughness

Source	DF	Seq SS	% C	Adj SS	Adj MS	F- Value	P- Value
Cutting speed	2	3.805	1.57%	3.805	1.902	3.17	0.064
Depth of cut	2	6.228	2.57%	6.228	3.114	5.18	0.015
feed	2	220.476	90.91%	220.476	110.238	183.53	0.000
Error	20	12.013	4.95%	12.013	0.601		
Total	26	242.522	100.00%				

Table 1.6 Analysis of variance for Accelerometer

Source	DF	Seq SS	% C	Adj SS	Adj MS	F- Value	P- Value
Cutting speed	2	1.1175	20.57%	1.11175	0.5588	4.99	0.017
Depth of cut	2	0.073	7.49	0.4073	0.2036	1.82	0.188
feed	2	1.6683	30.70	1.6683	0.8341	7.44	0.004
Error	20	2.2410	41.24	2.2410	0.1120		
Total	26	5.4340	100				

Regression Equation for surface roughness:

Surface Roughness =

5.253+ 0.528 Cutting speed_150-
0.215 Cuttingspeed_200- 0.313 Cutting speed_250-
0.649 Depth of cut_0.25+ 0.151 Depth of cut_0.50+ 0.4
98 Depth of cut_0.75- 2.903 feed_0.1- 0.983 feed_0.2
+ 3.886 feed_0.3.

Regression Equation for acceleration:

Acceleration =

1.7711- 0.2193 Cutting speed_150-
0.0517 Cutting speed_200+ 0.2710 Cutting speed_250-
0.1725 Depth of cut_0.25+ 0.1040 Depth of cut_0.50+ 0
.0685 Depth of cut_0.75-
0.3353 feed_0.1+ 0.0761 feed_0.2 + 0.2592 feed_0.3

Conclusion

This paper has presented on application of parameter design of the Taguchi Method in optimization of turning operation. The following conclusions can be drawn based on turning operation on AA 6065 T6 material.

1. In turning the minimum surface roughness can be obtained by operating at medium cutting speed 200 m/min and lower feed 0.1 mm/rev and depth of cut 0.25 mm are recommended to obtain better surface finish for the specific test range.
2. From the ANOVA results it is observed that the feed is the only significant factor which contributes more to the surface roughness i.e., 90.91% contributed by feed on surface roughness.
3. Regarding the Vibrations of spindle, feed and speed has the most significant role i.e., 30% and 20% for feed and speed respectively.
4. The minimum surface roughness at the optimum cutting parameters is 1.825 μm.

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Author Profile

Vijay Mohan Shetty, Lecturer, Mechanical Engineering Department, JNTUH college of Engineering Jagtial. I **have** completed my B.Tech from Kakatiya institute of Technology and science, Warangal and M.Tech from JNTUH College of engineering, Kukatpally.

Mahesh Pallapothu, Student, Mechanical Engineering Department, JNTUH College of Engineering, Jagtial. He is interested in the area of Design and Advanced manufacturing systems.

Vamshi Reddy Pothuganti, Student, Mechanical Engineering Department, JNTUH College of Engineering, Jagtial. He is Interested in the area of Design and Advanced Manufacturing systems.