# Optimization of the Cutting Parameters by Vibration Analysis of Cutting Tool

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**Abstract - Surface quality is an important factor to decide the performance of a manufactured product. Controlling vibration magnitude in cutting tool of machine is one of the approaches to enhance the surface finish. In the present study, the experimentation was carried out to investigate the effect of various controlling process parameters such as speed of work piece, depth of cut on the vibrations of cutting tool during manufacturing. The increase in vibration magnitude will represents the deterioration in surface finish of the product. For the experimentation in plain turning operation in Lathe, three materials (Aluminum, Mild steel and PVC), three cutting speed (200, 350 and 500 rpm), three values of depth of cut (0.2, 0.4 and 0.6 mm) were selected for the study. The vibration magnitudes of cutting tool in three orthogonal directions were measured using accelerometer, data acquisition system(DAS) and Labview software. The result shows that the depth of cut is independent of vibration magnitude for given range of speed and material. The effect of speed on vibration magnitude varies depends on the material. The study will be helpful to optimize the speed, feed and depth of cut to get minimum vibration, which in turn enhance the surface finish of the product.**

**Keywords – Vibration magnitude, DAS, Labview,**

## I. INTRODUCTION

Metal cutting technology is part and parcel of any mechanical manufacturing facility. It is also considered as the most commonly employed metal shaping process. The term metal cutting is defined as an operation in which a thin layer of metal or chip is removed from a larger body by using a wedge shaped tool. The turning operation is one of the most widely and commonly used cutting operation carried on a lathe machine.

*Machine Tool Problems*

During a metal-cutting operation, a machine tool experiences cutting forces generated due to its structural elements and machining operations. Due to the generation of these forces, a machine tool is likely to produce errors known as machine tool variables. The variables effecting accuracy of a machine tool are-

*A. Spindle Vibration*

The spindle‘s vibration can permeate throughout the structural loop of the machine tool, resulting in exciting the machine tool structure. Generally, frequency levels due to vibration of a machine tool spindle are relatively high. The spindle of the machine tool could excite vibration within the structure of the machine tool.

*B. Tool Vibration*

Tool Vibration can be defined as simply a motion that repeats itself after an interval of time. It is also known as oscillation. The swing of a pendulum and motion of a plucked string are typical examples of vibration. Anyone can have an experience of touching a machine tool to observe or feel if it is operating rightly.

## II. INSTRUMENTS AND MATERIALS USED FOR VIBRATION DETECTION AND ANALYSIS

**I.** Accelerometer, II. Data Acquisition System, III. Labview software, IV. Three work pieces
V. Single Point Cutting Tool.

*Accelerometers*

Accelerometer is an inertial measurement device that converts a mechanical movement into the electrical signal. By piezoelectric theory, the converted electrical signal is directly proportional to the amount of vibration acceleration. The accelerometer consists of a mass normally contained in a shielding case of metal and a piezoelectric crystal. The crystal produces a charge or signal directly proportional to its acceleration when the shielded mass puts a force on the crystal. A 3-Axis Accelerometer mounted in one small block using the appropriate data-collection hardware and software. The 3-Axis Accelerometer can be used for a wide variety of experiments and demonstrations, both inside the lab and outside. A 3-Axis Accelerometer was used to collect data during a bungee jump in x, y and z direction.

*Data Acquisition System*

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity.

*Lab VIEW Software*

Lab View (Short for Laboratory Virtual Instrumentation Engineering workbench) is a platform and development environment for a visual programming language from National Instruments. Labview is commonly used for data acquisition, instrumentation control and industrial automation on a verity of platforms including Microsoft Windows, various flavors of UNIX, Linux and Mac OSX. The latest version of lab VIEW is LabVIEW 2011.

*Work pieces for Experiment and Cutting Tool*

The three work pieces are used for this experiments are

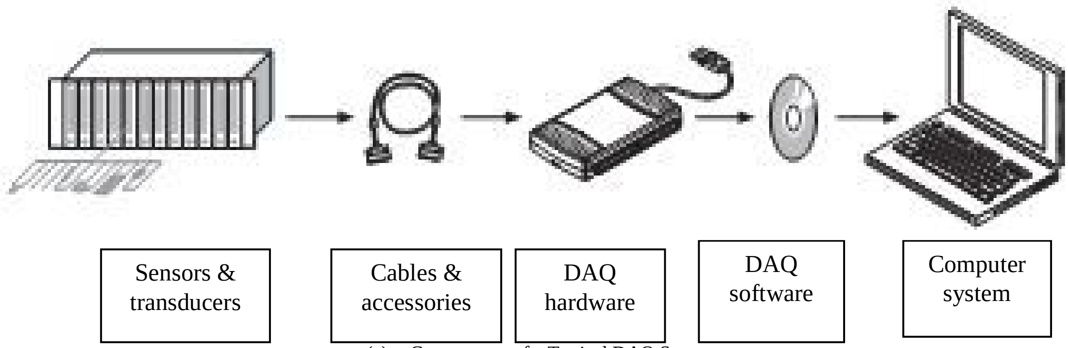
1. Mild steel- diameter-25 mm
2. Aluminium –diameter-25 mm
3. PVC- diameter- 25 mm

And a single point cutting tool (HSS) is used for experiment.

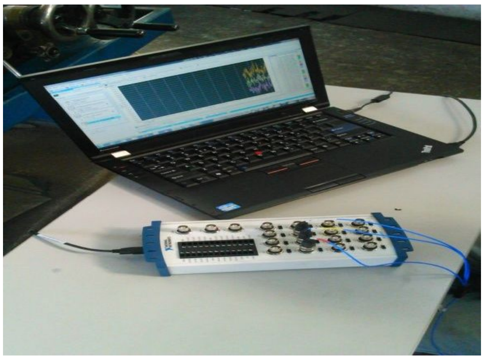
## III. METHODOLOGY

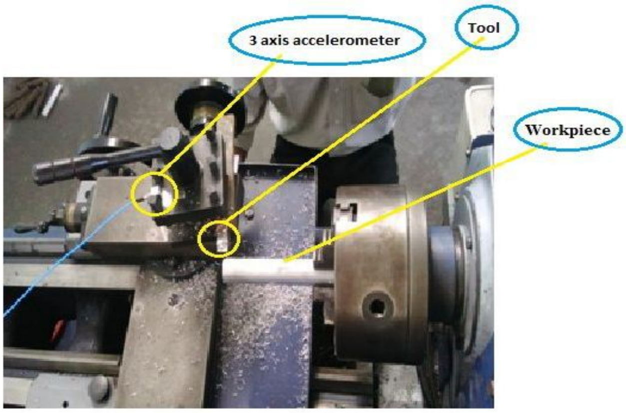
The most readily controlled parameters in cutting operations are cutting speed, depth of cut, feed rate. Literature reviewed shows that investigation of effect of vibration has been mainly carried out by taking into consideration the vibration generated during machining operations. In the current study, an attempt is made to relate the surface roughness with the vibration level of the machine tool. Machine tool's vibration amplitude measurements can be done by considering any one amongst displacement, velocity, and acceleration. To do this, one accelerometer can be placed near or at the tip of the cutting tool. It will help in collecting or recording enormous information by recording the difference of vibration levels. If the two signals collected are in phase and are of the same amplitude, there would be definitely rigid body motion and no relative motion happening between the cutting tool and work piece. Therefore as a first order approximation, this is a required condition for correcting this problem in the machine tool. If however, there are big differences in the vibration phase and or amplitude of the motions, there would definitely be larger levels of errors in the cutting operation. The spindle speed of the turning centre selected for the present study was around 200rpm, 350rpm and 500 rpm. Machining operation, straight turning, is selected for this study. In a straight turning machine operation, a single point cutting tool takes away material in the form of chips from the outer surface of a rotating cylindrical bar. The experimentation was, carried out by measuring acceleration amplitude.

Three different materials i.e. aluminium, mild steel and PVC was chosen. Three different speed i.e. 200, 350 and 500 was taken and at each speed three different depth of cut were considered during the experiment. The accelerometer was mounted on the tool post and was connected to DAS through BNC cables.




(a) Components of a Typical DAQ System






B. Monitoring System Connected with DAQ System C. Showing accelerometer, tool and work piece attached to machine

*Using Formula for Mean Vibration and Standard deviation*

The readings at different rpm and different depth of cut were taken and the mean vibration and standard deviation was calculated using the formula given below:

$$\overline{X} = \frac{\sum X}{N}$$

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Where N= number of readings

X= random values from a finite data set $x_1, x_2, \ldots x_N$

S= Standard deviation

*Measurement of Vibration at Different Conditions*

The various readings at different speed and depth of cut have been tabulated in Table 5.1. The readings were taken at three different depth of cut each corresponding to three different spindle speed. The feed rate was kept constant. The mean vibration on each axis was calculated from the readings that were obtained through accelerometer. The readings were taken in dry running condition. Here,

'x' represents longitudinal axis

'y' represents transverse axis

'Z' represents cutting force direction

## IV. Observation and Calculation

Observation Table - for finding the Vibration on Cutting tool at Various Speed

*Aluminium-*

| **Sl.** | **Name of Materials** | **Speed in rpm** | **Feed (mm)** | **Depth of Cut mm)** | **Mean Vibration in m/s$^2$** | | | **Std. Deviation** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **X-axis** | **Y-axis** | **Z-axis** | **X-axis** | **Y-axis** | **Z-axis** |
| **1** | **Aluminium** | **200** | **0.2** | **0.2** | **0.4305** | **0.3260** | **0.5201** | **0.0309** | **0.0295** | **0.0327** |
| **2** | | **200** | **0.2** | **0.4** | **0.4509** | **0.3456** | **0.5451** | **0.0312** | **0.0310** | **0.0343** |
| **3** | | **200** | **0.2** | **0.6** | **0.4495** | **0.3422** | **0.5420** | **0.0314** | **0.0290** | **0.0314** |
| **4** | | **350** | **0.2** | **0.2** | **0.4542** | **0.3490** | **0.5469** | **0.0318** | **0.0297** | **0.0324** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | (Dia-25mm) | 350 | 0.2 | 0.4 | 0.4508 | 0.3457 | 0.5430 | 0.0314 | 0.0300 | 0.0322 |
| 6 | | 350 | 0.2 | 0.6 | 0.4593 | 0.3537 | 0.5519 | 0.0327 | 0.0317 | 0.0334 |
| 7 | | 500 | 0.2 | 0.2 | 0.4722 | 0.3614 | 0.5647 | 0.0324 | 0.0302 | 0.0305 |
| 8 | | 500 | 0.2 | 0.4 | 0.4722 | 0.3638 | 0.5723 | 0.0311 | 0.0306 | 0.0318 |
| 9 | | 500 | 0.2 | 0.6 | 0.4719 | 0.3610 | 0.5676 | 0.0307 | 0.0290 | 0.0306 |

*Mild Steel*

| Sl. | Name of Materials | Speed in rpm | Feed (mm) | Depth of Cut mm) | Mean Vibration in m/s$^2$ | | | Std. Deviation | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | X-axis | Y-axis | Z-axis | X-axis | Y-axis | Z-axis |
| 1 | Mild Steel (Dia-25mm) | 200 | 0.2 | 0.2 | 0.4884 | 0.3755 | 0.5816 | 0.0320 | 0.0303 | 0.0323 |
| 2 | | 200 | 0.2 | 0.4 | 0.5003 | 0.3873 | 0.5970 | 0.0309 | 0.0292 | 0.0323 |
| 3 | | 200 | 0.2 | 0.6 | 0.5105 | 0.3689 | 0.6058 | 0.0305 | 0.0288 | 0.0308 |
| 4 | | 350 | 0.2 | 0.2 | 0.6209 | 0.5018 | 0.7251 | 0.0302 | 0.0209 | 0.0331 |
| 5 | | 350 | 0.2 | 0.4 | 0.5673 | 0.4464 | 0.6635 | 0.0300 | 0.0296 | 0.0299 |
| 6 | | 350 | 0.2 | 0.6 | 0.5708 | 0.4508 | 0.6697 | 0.0302 | 0.0309 | 0.0316 |
| 7 | | 500 | 0.2 | 0.2 | 0.5060 | 0.3892 | 0.6034 | 0.0305 | 0.0285 | 0.0303 |
| 8 | | 500 | 0.2 | 0.4 | 0.5215 | 0.4005 | 0.6209 | 0.0304 | 0.0286 | 0.0315 |
| 9 | | 500 | 0.2 | 0.6 | 0.5047 | 0.3868 | 0.6047 | 0.0315 | 0.0307 | 0.0317 |

*PVC*

| Sl. | Name of Materials | Speed in rpm | Feed (mm) | Depth of Cut mm) | Mean Vibration in m/s$^2$ | | | Std. Deviation | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | X-axis | Y-axis | Z-axis | X-axis | Y-axis | Z-axis |
| 1 | PVC (Dia-25mm) | 200 | 0.2 | 0.2 | 0.4876 | 0.3691 | 0.5840 | 0.0299 | 0.0272 | 0.0313 |
| 2 | | 200 | 0.2 | 0.4 | 0.4777 | 0.3707 | 0.5889 | 0.0297 | 0.0299 | 0.0296 |
| 3 | | 200 | 0.2 | 0.6 | 0.4787 | 0.3631 | 0.5747 | 0.0290 | 0.0301 | 0.0303 |
| 4 | | 350 | 0.2 | 0.2 | 0.4810 | 0.3665 | 0.5286 | 0.0310 | 0.0288 | 0.0321 |
| 5 | | 350 | 0.2 | 0.4 | 0.4772 | 0.3622 | 0.5750 | 0.0295 | 0.0285 | 0.0301 |
| 6 | | 350 | 0.2 | 0.6 | 0.4890 | 0.3696 | 0.5860 | 0.0292 | 0.0277 | 0.0298 |
| 7 | | 500 | 0.2 | 0.2 | 0.4945 | 0.3767 | 0.5896 | 0.0303 | 0.0303 | 0.0286 |
| 8 | | 500 | 0.2 | 0.4 | 0.4887 | 0.3695 | 0.5863 | 0.0308 | 0.0315 | 0.0313 |
| 9 | | 500 | 0.2 | 0.6 | 0.4939 | 0.3801 | 0.5934 | 0.0293 | 0.0310 | 0.0293 |

*Calculation*

From the above table, it can be calculated that keeping the speed, feed, depth of cut constant, and the maximum vibration took place in the direction of cutting force. Therefore it becomes necessary to reduce the cutting force so as to decrease the vibration and thereby increasing the surface finish. It can also be done by application of cutting fluid at the appropriate place and appropriate time. The conditions for finding the optimum surface finish for different materials were obtained which are given below:

- For Mild Steel :-

  Feed rate = 0.2 mm/rev

Speed = 200 rpm
Depth of cut = 0.2 mm

- For Aluminium :-
  Feed rate = 0.2 mm/rev
  Speed = 200 rpm
  Depth of cut = 0.2 mm
- For PVC :-
  Feed rate = 0.2mm/rev
  Speed = 350 rpm
  Depth of cut = 0.2 mm

It was also seen that mean vibration in all the three direction were greater in mild steel and least in aluminium. The yield strength of aluminium is 7-11 MPa, whereas for PVC yield strength varies from 30 MPa-60MPa. And for mild steel it is 248 MPa. Therefore it can be said that as the yield strength decreases the vibration also decreases.
Now we conclude that the vibration was least in transverse direction (i.e. in y-direction) and most in cutting force direction (i.e. in z-direction). Hence it can be said that the depth of cut has minimum affect of vibration followed by feed and the cutting force has maximum affect on vibration and surface finish. Thus by controlling the feed and by proper lubrication for reducing cutting forces, the vibration and thus surface finish can be controlled.

## V. Result

Now we found that the vibration was least in transverse direction (i.e. in y-direction) and most in cutting force direction (i.e. in z-direction). Hence it can be said that the depth of cut has minimum affect of vibration followed by feed and the cutting force has maximum affect on vibration and surface finish. Thus by controlling the feed and by proper lubrication for reducing cutting forces, the vibration can be controlled and thus surface finish can be improved.

## VI. Conclusion

This project reports the vibration amplitude of different materials at different speed and depth of cut keeping feed rate constant.

- The vibration amplitude measured in longitudinal axis, transverse axis and cutting force direction suggests using 3-axis accelerometer suggests that maximum vibration takes place in z-direction or cutting force direction for the same speed and depth of cut.
- The results also showed that as the material having higher yield strength have more vibration as compared to materials having lower yield strength. This can be seen from the vibration values obtained for different materials in x, y, z directions.
- It was also found that the vibration amplitude is mainly affected by cutting forces, followed by the feed and the depth of cut has the least affect of all the three.

## VII. Future Scope

The further research in this area could be the following:

- The experiments have been conducted on a small size lathe machine and further study could be carried on different size lathe machines to develop vibration levels in acceptable range according to the size/speed ratio for optimum values of surface roughness.
- Further study could be carried out by considering more parameters along with machine tool's vibration amplitude (e.g., materials/hardness, lubricants, chip breakers, etc.) to predict the optimal setting of levels for minimization of the surface roughness.
- In this study, machine tool's vibration amplitude is taken as input parameter. It may be treated as a noise factor in further research.
- Also for this study speed and depth of cut was varied. Furthermore experiments can be done by varying depth of cut, nose radius etc.
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