INVESTIGATION OF VIBRATION OF A CUTTING TOOL DURING TURNING AND ITS MINIMIZATION

By

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A thesis submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, in partial fulfillment of the requirements for the degree of **Master of Engineering in Industrial and Production Engineering.**

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নং 107388
তাং 31.10.09
লাইব্রেরী, ঢাকা

DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DHAKA

OCTOBER 2009

CERTIFICATE OF APPROVAL

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I hereby declare that no part of this thesis has been submitted elsewhere for the award of any degree or diploma.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

Abbreviations

CPM	Cycles per Minute
A	Amplitude
RMS	Root Mean Square
FFT	Fast Fourier Transform
γ	Rake angle
Fc	Tangential force
F_a	Axial force
F_r	Radial force
R_a	Surface Roughness
CLA	Center Line Average
F_0	External Force
ω	Forced Frequency
ω_n	Natural Frequency
t	Time
X	Displacement
Φ	Phase Angle
M	System's Mass
g_c	Acceleration of gravity
K	Spring Stiffness
c	Damping Coefficient
c_c	Critical Damping
q	Damped Natural Frequency
d	Depth of Cut
V	Cutting Speed
s	Feed

ACKNOWLEDGEMENT

I would like to thank first the Bangladesh University of Engineering and Technology for providing funding which gave me an opportunity to further my education and obtain me Master degree. I would like to express my sincere gratitude and appreciation to the Department of Industrial and Production Engineering for allowing me this opportunity to purse M. Engineering degree in the department.

I would like to wish to express heartiest gratitude and profound indebtedness to his supervision of Dr. A.K.M. Masud, Associate Professor, Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka for his generous help, invaluable suggestions, continuous encouragement, generous help and unfailing enthusiasm at every stage of this study. The valuable advice and guidance of Dr.Zahid Hossain, Assistant Professor, MCE, Islamic University of Technology is gratefully acknowledged. His active interest in this topic and valuable advice was the source of inspiration.

I would like to thank Executive Director all Engineers and Staffs of Training Institute for Chemical Industries (TICI) especially Engr.Md.Lutfar Rahman, Engr.Arup Kumar Pramanik, Engr.Mostofa Abdul Mazid, for giving me opportunity to use their Machine and Instruments and invaluable cooperation at every stage.

I would like to thank Md.Kamruzzaman, Assistant Professor, ME, Dhaka University of Engineering and Technology, Gazipur, for his kind cooperation and valuable advice. I would like to thank all of the staffs of Machine tool laboratory of IPE Department for their kind cooperation. I would like to thanks Md.Kamal Miah who advised me to do my thesis in TICI.I would like to thanks all of my friends especially Shama Farabi Barna who have helped me in various way.

Beyond the education and technical guidance, my deepest thanks must go to my parents and brother who made my undergraduate and graduate education possible.

And finally, I would like to thank all the people who are not listed here but have contributed any way, being my side and other senses.

ABSTRACT

Improving surface quality of work-piece and reducing vibration of machine tool is the main concern of manufacturing industries. Vibration problem in machine tool is a considerable obstacle for machining industries. Effect of vibration on a machine tool can be much too disastrous leading to the failure of tools and certain executive organs. Quality of the job will suffer, thereby lowering the productive capacity.

In order to prevent these vibration or to minimize the transmission of forces to the tool holder there need high damping coefficient of the system also to have larger stiffness of the tool.

The machining industry has an increasing need for improved characterization of cutting tools and for controlling vibration and chatter during the turning process.

In this thesis, a study has been carried out to find out the effect of vibration on machine tool in turning and to develop a system to minimize the vibration based on the analysis of both vibration and roughness result applying various operating condition.

During the investigation attention is concentrated on how supporting materials influences the amplitude of vibration and surface roughness and way to develop a system for better performance.

It has been found that using aluminum support under tool holder surface quality of work piece has been improved and vibration reduced to a remarkable label.

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Vibrations an oscillation, or moving back and forth of an object. A particle is vibrating means it is traveling a distance back and forth at a particular frequency. Some force- external or internal is necessary to generate vibration. When a machine runs it vibrates due to residual unbalance force acting on moving parts.

Vibration is produced by cyclic variations in the dynamic components of the cutting forces, resulting from periodic wave motions. The nature of vibration signals arising from the metal cutting process incorpornes free, forced, periodic, and random type of vibration .Direct measurement of vibration is difficult to achieve because vibration mode is frequency dependent.

In turning operations the relative dynamic motion between cutting tool and work piece, or vibration is a frequent problem. This affects the results of the machining, and in particular, the surface finish. Tool life is also influenced by vibration. Noise in the working environment frequently occurs as a result of dynamic motion between cutting tool and the work piece. With proper machine design, i.e. improved stiffness of the machine structure, the problem of relative dynamic motion between cutting tool and work piece may be partially solved.

High frequency vibration in turning operations can be minimized improving stiffness as well as damping of cutting tool. Supporting materials can be used for this. Leading to a stiffer structure of tool post the vibration problem may be solved in part.

1.2 BACKGROUND AND PRESENT STATE OF THE PROBLEM

Vibrations in machining are important considerations of work piece dimensional accuracy, surface finish and tool life. Due to the elastic-plastic deformation during turning, work piece provides excitation to the cutting tool. It enhances the vibration in cutting tool which effects the surface finish and tool life. This vibration of a cutting tool depends on feed, depth of cut, spindle speed, etc. Including these factors, motion of tool is also hampered by the vibration of the machine itself, gear box, rotary machineries, etc, which provides more excitation vibration as a disturbance to the tool.

It has been shown in some literatures that cutting variables are affected by vibration, as such is expected that tool life will also be affected by the tool vibration, because tool life is a function of the cutting variables only [1].

If there be any relative vibratory motion present between the cutting tool and the job, it is obvious that the performance of the machine tool will not be satisfactory. Stiffness and damping capacity of machine tools are important factors in controlling vibration. Low stiffness affects the magnitude of vibration and chatters in tools and machines, and can have adverse effects on product quality. The amplitude of vibration can be reduced by increasing the stiffness or by damping the system [2].

Following calculations can be made with the purpose of preventing regenerative vibration

1. To have high damping coefficient of the system
2. To have large stiffness of the tool; and
3. Damping material in the tool holder also is a necessity.

Self excited vibration in a machine tool may result from the dynamic instability of the machine parts or of the tool used in cutting. Sometimes both may be the causes of self excited vibration. Under the dynamic condition, that is, under the working condition, the frequency of the vibration of the tool is much more than that of the various parts, of the machine tools.

Several models have been proposed by various research workers for analyzing self excited vibration in machine tools.

With Proper machine design, i.e., improved stiffness of the machine structure, the problem of relative dynamic motion between the cutting tool and work piece may be partially solved. However, by use of active control of the dynamic motion between the cutting tool and work piece can be achieved [3].

A study describes a tool-wear monitoring procedure in a metal turning operation using vibration features. The measured tool-wear forms were correlated to features in the vibration signals in the time and frequency domain. Analyses of the results suggested that the vibration signal features were effective for use in cutting tool-wear monitoring and wear qualification [4].

Some researchers mentioned techniques for suppression of vibration in cutting tools can save old machines and enhance design flexibility in new manufacturing systems. Structural stiffness interaction, with the use of smart materials, in an intelligent tool post is investigated using the finite element method [5].

Analytical and experimental vibration analyses are conducted for a lathe system to detect the possibility of faults and do develop and accurate cutting process. The best possible operating conditions for a specific turning process were determined using vibration analysis [6].

Recently a researcher mentioned in a work, an optimal control strategy is utilized for isolating the cutter from the vibration of the machine-tool in both the radial and feed directions. A random model with Gaussian distribution for the cutting process is constructed [7].

The purpose of this study is to develop a model of a machine tool with considering constant excitation force and analysis will be done by experiments. Then further investigation will be made to find the required spring-damper model to minimize the vibration. So, surface finish and tool life will be increased significantly.

1.3 OBJECTIVES AND POSSIBLE OUTCOME

This study is specially designed to address the following research objectives

1. Data analysis of cutting tool vibration.
2. Develop a new setup to reduce cutting tool vibration.
3. Data analysis of work piece surface roughness using modem sensor.
4. Develop a new setup to improve surface roughness.

The possible outcome of the proposed study

1. Develop a setup of cutting tool for reducing vibration
2. Develop a setup of cutting tool for improving surface roughness

In conclusion, Vibration monitoring and analysis are the primary diagnostic tools for most mechanical systems that are used to manufacture products. When used properly, vibration data provide the means to maintain optimum operating conditions and efficiency of critical plant systems. The present work involved to analyze and reduce the vibration by providing proper supporting materials.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

With the modern trend of machine tool development vibration has gained considerable importance for improving accuracy and reliability. The vibration of the cutting tool in a turning process is known to have detrimental effects on the surface finish of machined parts. The vibration of a machine tool is one of the major factors limiting its performance. Much attention has been focused on minimizing this problem, either by improving the dynamic compliance of the structure or by selecting the cutting conditions such that vibration does not occur. There are many thesis has been conducted to analysis the effect of vibration and found a promising result.

2.2 HISTORICAL BACKGROUND

In one study has been conducted to find the correlation of vibration signal features to cutting tool wear in a metal turning operation. The analysis and correlation of vibration signal features to cutting tool wear have been carried out. Time domain features were deemed to be more sensitive to cutting condition than tool wear, whereas frequency based features correlated well with the tool wear. Based on the measurements of cutting tool wear form and the analysis of the vibration signatures, it has been possible to identify the trend of the sensor signals as the insert wear length increased. The characteristics showed that the measured wear values correlated well with certain resonant peak frequencies. The sensor signals were also affected by the different wear modes. It has been possible to establish distinct differences in signal characteristics when cutting was performed with a new insert from that occurring with a detrimental level of wear [4].

By use of active control of the machine tool vibration, a further reduction of the dynamic motion between the cutting tool and work piece can be achieved. It was found that adaptive feedback control of the tool vibration in the cutting speed direction, based on the fil-tered-x LMS-algorithm, enables a reduction in vibration, by up to 40 dB at 1.5 kHz, and by approximately 40 dB at 3 kHz. It was also observed that the introduction of leakage in the fil-tered-x LMS-algorithm improved the stability properties of the feedback control system. A significant improvement in the work piece surface finish was observed and a substantial reduction in the noise level was obtained with adaptive control [3].

Another study describes a control system designed to improve the surface finish during turning by reducing the vibration of the machine tool. Vibration control is achieved by sensing the relative vibration between the tool and the work piece, generating a force which tends to neutralize the excitation. The control system has been tested experimentally during turning under various cutting conditions. The improvement in surface finish is verified by comparing two identical surfaces, one machine with and the other without the designed feedback-control device. Results indicate that the amplitude of vibration decreases by 33% whilst, the resulting improvement in the surface finish is about 22% [8].

In a recent study the best possible operating conditions for a specific turning process were determined using vibration analysis. Problem-causing components for several case studies (different speeds, feed rates, and tool lengths) were identified and guide lines for improving a typical manufacturing process were recommended. In these experiments it was shown that acceleration amplitudes were highest for the 5/8 inch tool length setting. The lowest vibration amplitudes were seen in the 3/8 inch tool length tests. This paper also recommended a pair of very stiff viscoelastic couplings made of graphite with high rigidity may help to reduce the effects of torsional and bending vibration from the feed rod, which are transmitted to the system [6].

Rigid fixing is required to minimize displacements of cutting tools from the nominal position during machining. However, the era of reconfigurable manufacturing needs fixtures consuming less space and having minimum weight [9].

Another study developed a tool post system for dynamic response control. In this work lead zirconate titanate (PZT) is employed as the intelligent material for the smart tool post actuator. The tool post model incorporates the actuator, tool carrier (holder), supporting diaphragm and the tool bit as a spring buffer between the tool carrier and the net axial actuating force at the tool tip (radial to the work-piece)[5].

High frequency vibrations of a boring bar cutting tip are minimized by use of a damping sandwich of plural layers of steel and plural alternate layers of viscoelastic solid material. This damping sandwich is placed at a joint in the machine tool between the cutting tip and a tool mounting area, and is shown as being provided between a mounting face of a tool mounting block and a mounting area. The damping sandwich permits greater depth of cut, with greater inches per revolution of chip removal without any chatter for improved metal removal [10].

From the above discussion, it is clear that there is no available, easy, less down time and cost effective system that provides capabilities needed for reducing vibration as well as improving surface finish. Its easily possible using proper supporting materials between tool holder and tool post by rigid fixing. Slice of supporting materials has been used. Spring mass damper model followed for this.

So by analyzing the spring mass damper model with proper supporting materials a suitable set up to reduce vibration as well as improving roughness developed here.

2.3 IMPORTANCE OF THE STUDY

Over the past several decades considerable improvements have been achieved in the performances of various machining process. Most of the current machine tools are designed for optimizing the process efficiency while maintaining the required surface quality of the finished parts. This often causes the machining process to operate very close to the stability limits. Unstable machine tool vibrations can cause inferior surface quality of the finished product as well as higher tool wear leading to tool breakage.

When a machine runs it vibrates due to residual unbalance force acting on moving parts. Design of a perfect machine which will not vibrate is practically impossible. But amplitudes of vibration can be reduced.

The need for selecting and implementing optimal machining conditions and the most suitable cutting tool has been felt over the last few decades. Today, minimization of tool vibration has become one of the greatest challenges of present time as it can lead to optimized product output through ensuring tool integrity, surface roughness and dimensional precisions.

In conclusion, Low cost system of improving surface finish and reducing vibration would be great practical value. The principle of the present work is to reduce the disturbing force by providing proper supporting materials under the tool holder to dissipate the disturbing force.

CHAPTER 3

FUNDAMENTAL THEORIES OF VIBRATION

3.1 INTRODUCTION

A body is said to vibrate if it has periodic motion. Mechanical vibration is the study of oscillatory motions of bodies. Vibrations are harmful for engineering systems. Some times vibrations can be useful. Excessive vibration causes discomfort to human beings, damage to machines and buildings and wear of machine parts such as bearings and gears.

To and Fro motion of rotating body is called vibration. This To and Fro motion may be for the rotating part of the machine or part of the stationary body, pipe line or the structure. Vibration can also expressed as the oscillation or moving back and forth of an object. Sometimes this vibration can be visible or audible and sometimes it can feel only. But this vibration is the measure of the condition of rotating machinery.

Vibration takes place using some input of energy through an applied force. In a machine, this input of energy to the vibration means that it is diverted from the process. This not only reduces the machines efficiency, but also may result in damage to the machines components or the machine as a whole.

3.2 CHARACTERISTICS OF VIBRATION

Vibration Amplitude and Vibration Frequency are the common characteristics. Sometimes a third characteristics, phase, becomes important when it is necessary to deal with several types of vibrations. The measurement of these characteristics, amplitude, frequency and phase, provides the source of all kinds of vibration.

The applied force to the system to make it vibrate directly affects the amplitude of the vibration. The more applied force, the greater the vibration amplitude. But the vibration amplitude limits by the mass, stiffness and damping factors of the system. These are three physical characteristics of all the system that acts against the input force to control the amplitude, frequency and phase of vibration. The system vibrates differently depending upon the applied force. If the system strikes once, then it will vibrate at its natural or resonance frequency. But normally for a rotating system, the vibration frequency is the same of the rotational frequency or any multiple of the rotational frequency. For a rotational system, the directions of vibration are in the radial or axial direction. But in some cases the system can vibrate torsionally.

3.3 EXAMPLES OF VIBRATION

1. Beating of heart
2. Lungs oscillate in the process of breathing
3. Walking- Oscillation of legs and hands
4. Shivering- Oscillation of body in extreme cold
5. Speaking - Ear receives Vibrations to transmit message to brain
6. Vibration of atoms
7. Mechanical Vibrations

3.4 CAUSES OF VIBRATION

There are many problems which can produce vibrations: few of these are-

-Unbalance

-Misalignment

-Worn, damaged gears

-Bad drive belts

-Bad bearings

-Aerodynamic/Hydraulic forces

-Rubbing/Resonance

The cause of vibration must be a force, which charges its direction or amount. The force causing vibration and its characteristics will be determined by the manner in which the forces are generated. This is the reason that each cause of vibration has its individual characteristics.

3.5 VIBRATION SOURCES

All machinery with moving parts generates mechanical forces during normal operation. As the mechanical condition of the machine changes due to wear, changes in the operating environment, load variations, etc., so do these forces. Understanding machinery dynamics and how forces create unique vibration frequency components is the key to understanding vibration sources.

Vibration does not just happen. There is a physical cause, referred to as a forcing function, and each component of a vibration signature has its own forcing function. The components that make up a signature are reflected as discrete peaks in the FFT or frequency-domain plot.

The vibration profile that results from motion is the result of a force imbalance. By definition, balance occurs in moving systems when all forces generated by, and acting on, the machine are in a state of equilibrium. In real-world applications, however, there is always some level of imbalance and all machines vibrate to some extent.

3.6 CLASSIFICATION OF VIBRATIONS

One method of classifying mechanical vibrations is based on degrees of freedom. The number of degrees of freedom for a system is the number of kinematically independent variables necessary to completely describe the motion of every particle in the system. Based on degrees of freedom, we can classify mechanical vibrations as follows:

1. Single Degree of freedom Systems
2. Two Degrees of freedom Systems
3. Multidegree of freedom Systems
4. Continuous Systems or systems with infinite degrees of freedom

Another broad classification of vibrations is:

1. Free and forced vibrations
2. Damped and un-damped vibrations.

Sometime vibration problems are classified as:

1. Linear vibrations
2. Non-linear vibrations
3. Random vibrations
4. Transient vibrations

A system is linear if its motion is governed by linear differential equations. A system is nonlinear if its motion is governed by nonlinear differential equations. If the excitation force is known at all times, the excitation is said to be deterministic. If the excitation force is unknown, but averages and standard derivations are known, the excitation is said to be random. In this case the resulting vibrations are also random. Some times systems are subjected to short duration non-periodic forces. The resulting vibrations are called transient vibrations. One example of a non-periodic short duration excitation is the ground motion in an earthquake.

3.7 MEASUREMENT OF VIBRATION

Vibration amplitude can be measured in Vibration Displacement, Vibration Velocity or Vibration Acceleration. All the characteristics are related. In fact these can be converted by using electronic integrator.

Electronic instruments for measuring machinery vibration are classified as Meters, Monitors or Analyzers. The main part of the measuring system is "transducer" or pickup. A transducer is sensing device which converts one form of energy into another form of energy, or we can say it converts mechanical vibration into an electrical signal. These pickups include velocity pickup, accelerometer and non contact (Proximity) probes.

3.7.1 Vibration Displacement

Displacement of a vibrating body from its stationary position in both directions is called the vibration displacement. The unit is expressed as the unit of length. Normally the vibration displacement is not so high. So it is expressed in smaller unit.

In FPS system it is expressed in MILS (1 mils = 0.001 inch)
In CGS system it is expressed in MICRON (1 micron = 0.001 mm)

Displacement can be measured using proximity transducer system.

3.7.2 Vibration Velocity

The time of rate of change of displacement is the velocity. For a vibrating body, velocity is not constant all over the displacement path. In case of simple pendulum the bob starts from one end and when crosses its stationary position then its velocity is maximum and minimum at the ends.

Vibration velocity can be expressed as:

Vibration velocity = (Vibration displacement) X (Vibration frequency)

For a low speed machine with low vibration displacement the machine may be good. But for high speed machine with the same vibration displacement the machine may not good.

So for vibration analysis of high speed machines sometime vibration velocity becomes very important, because it contains both vibration displacement and vibration frequency. The vibration velocity measured in zero-to --peak amplitude. The unit is expressed as the unit of velocity.

In FPS system it is expressed in inch/sec
In CGS system it is expressed in mm/sec

Vibration velocity can be measured using velocity transducer system. Velocity signal can be converted to displacement signal using electronic integrator. Velocity leads displacement by 90 degrees in time.

3.7.3 Vibration Acceleration

The time rate of change of velocity is the acceleration. For a vibrating body velocity is not constant all over the displacement path. Velocity is zero at two ends and maximum at the center. When the bob changes its velocity at the end points, then acceleration on the bob is maximum.

Vibration acceleration can be expressed as:

Vibration acceleration = (Vibration displacement) X $(\text{Vibration frequency})^2$

In case of vibration acceleration measurement, it increases as square of frequency of the vibrating body. So for a very high speed machine with small vibration displacement the machine condition may not be good.

The unit is expressed as the unit of acceleration due to gravity and denoted by G
In FPS system G = 32.3 ft/sec^2
In MKS system G = 9.8 meter/sec^2

Vibration acceleration can be measured using accelerometer. Acceleration signal can be converted to displacement signal using electronic integrator twice. Acceleration leads velocity by 90 degrees and leads displacement by 180 degrees in time.

3.8 VIBRATION FREQUENCY

It is defined as number of cycles in a given interval of time. In vibrations we take frequency as cycles per minute, CPM. Frequency of vibration is important because it indicates the cause of vibration. So, by knowing frequency we can identify the faulty part and the problem causing vibration. The forces which cause vibration are generated from the rotating motion of the machines parts. So, these forces change in amount and direction as the rotating part changes its position with rest of the machine. As a result vibration produced will have a frequency depending upon the rotating speed of the troubled part.

It is also important to note that different machinery troubles cause different frequencies of vibration, due to which we are able to identify the nature of the problem.
So vibration frequency is very important in analyzing the problems.

3.9 AMPLITUDE

Amplitude refers to the maximum value of a motion or vibration. This value can be represented in terms of displacement (mils), velocity (inches per second), or acceleration (inches per second squared). Amplitude can be measured as the sum of all the forces causing vibrations within a piece of machinery (broadband), as discrete measurements for the individual forces (component), or for individual user-selected forces (narrowband).

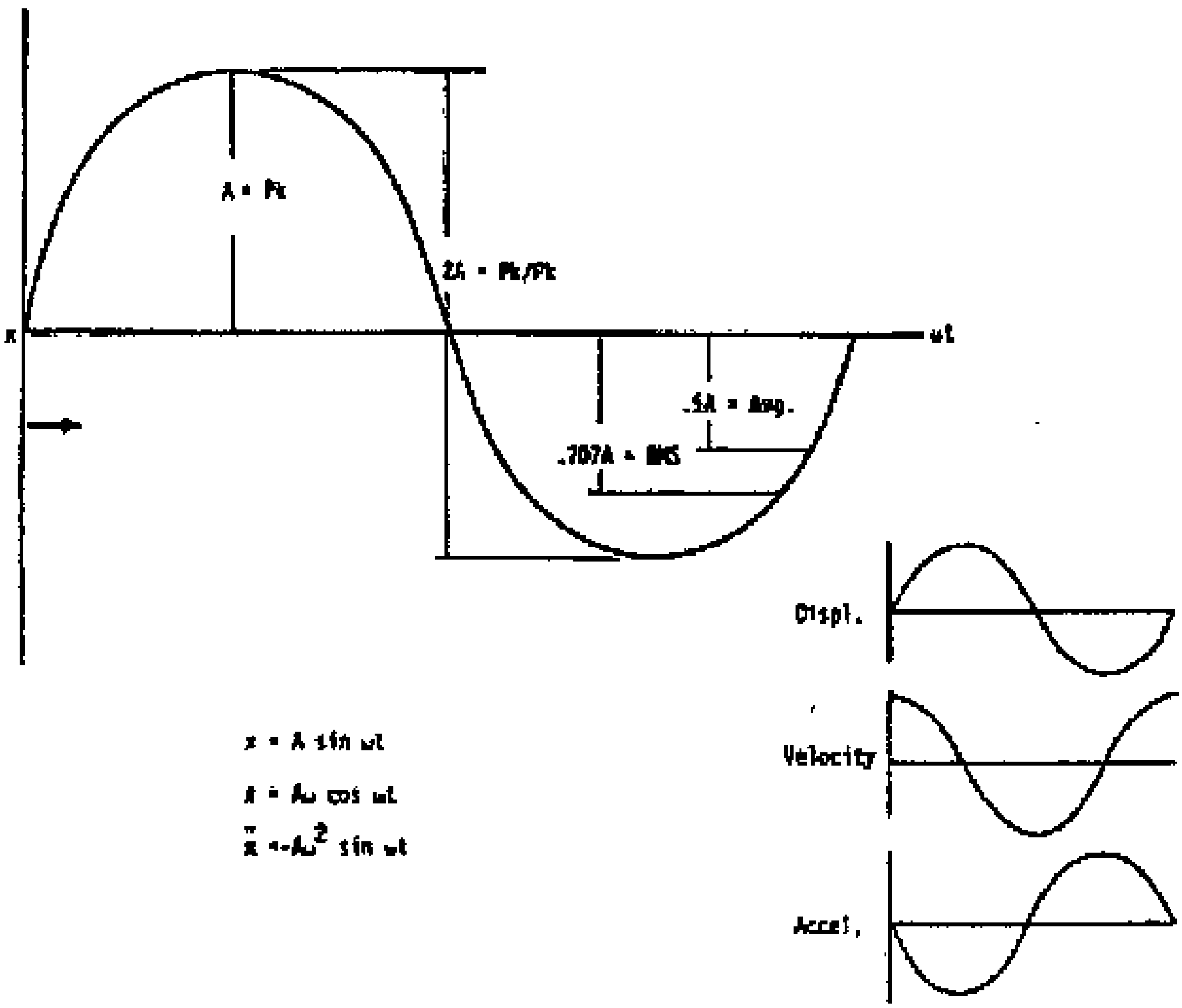

Figure: 3.1. Relationship of vibration amplitude

3.9.1 Peak-to-Peak

As illustrated in Figure 3.1, the peak-to-peak amplitude (2A, where A is the zero-to-peak) reflects the total amplitude generated by a machine, a group of components, or one of its components. This depends on whether the data gathered are broadband, narrowband, or component. The unit of measurement is useful when the analyst needs to know the total displacement or maximum energy produced by the machine's vibration profile.

Technically, peak-to-peak values should be used in conjunction with actual shaft-displacement data, which are measured with a proximity or displacement transducer. Peak-to-peak terms should not be used for vibration data acquired using either relative vibration data from bearing caps or when using a velocity or acceleration transducer. The only exception is when vibration levels must be compared to vibration-severity charts based on peak-to-peak values.

3.9.2 Zero-to-Peak

Zero-to-peak (A), or simply peak, values are equal to one-half of the peak-to-peak value. In general, relative vibration data acquired using a velocity transducer are expressed in terms of peak.

3.9.3 Root-Mean-Square

Root-mean-square (RMS) is the statistical average value of the amplitude generated by a machine, one of its components, or a group of components. Referring to Figure 3.1, RMS is equal to 0.707 of the zero-to-peak value, A. Normally, RMS data are used in conjunction with relative vibration data acquired using an accelerometer or expressed in terms of acceleration.

3.10 CHOICE BETWEEN DISPLACEMENT VELOCITY AND ACCELERATION

The amplitude of vibration can be measured in any one of the three parameters As all these parameters are directly related and can be used to check the condition of machine, but we have to select the most suitable one.

As we know vibration severity is a function of displacement and frequency, where as velocity is function of displacement and frequency. So we can say measure of vibration velocity is direct measure of vibration severity. By experience, this conclusion become true that vibration velocity is the best overall indication of machinery condition. Acceleration measure is also helpful where frequency range covers high frequencies.

3.11 EFFECTS OF VIBRATION

The effects of vibrations are as follows:

1. Unwanted noise
2. Early failure due to cyclical stress (fatigue failure)
3. Increased wear
4. Poor quality product
5. Difficult to sell a product
6. Vibrations in machine tools can lead to improper machining of parts

In conclusion, the fundamental of vibration is important for predictive maintenance, diagnostics, and many other uses. All mechanical equipment in motion generates a vibration profile, or signature, that reflects its operating condition.

CHAPTER 4
VIBRATION IN MACHINING

4.1 INTRODUCTION

With the modern trend of machine tool development, accuracy and reliability are gradually becoming more prominent features. To achieve higher accuracy and productivity is not enough to design the machine tools from static considerations without considering the dynamic instability of the machine tools. If there be any relative vibratory motion present between cutting tool and the job, it is obvious that the performance of the machine tool will not be satisfactory.

During operations machine tools are subjected to static or dynamic loads, the latter having periodic or impact characteristics. These loads are associated with the cutting process and/or movements of the machine tool members. These forces may act in either of the following manners:

(a)Dynamic behavior caused entirely by the load acting during the action of the load (forced vibrations),

(b)Dynamic behavior initiated by a load but persisting after load has caused to act (free vibrations),

(c)Dynamic behavior through an interaction between the structure and cutting process (self-excited vibrations).

While analyzing dynamic behavior of machine tools, rigidity and stability are two important characteristics to be considered.

Dynamic rigidity is defined as the ratio of amplitude of vibratory force considered harmonic to the vibratory displacement at a given frequency. It is the measure structure resistance to vibration. The system has its lowest rigidity at resonant frequency or frequencies. The pattern of deformation of a system for given frequency of vibration is referred to as a mode of vibration and in the case of a resonant frequency a principal mode of vibration at which it is assumed that all coupled masses are executing vibration at the same frequency. While dynamic rigidity refers to steady-state vibrations, stability corresponds to transient response characteristics.

Dynamic stability indicates that the masses of a distributed system oscillate with decreasing amplitudes towards the original state of equilibrium and constitute a dissipative system.

Dynamically unstable system oscillates with increasing amplitudes deviating more and more from the original position of equilibrium. The most common phenomena of dynamic instability in machine tools in one or more forms of self-excited vibrations frequency are described as chatter.

Lack of dynamic rigidity and occurrence of dynamic instability have adversely affected many designs of machine tools as regards their performance characteristics.

4.2 THE EFFECTS OF VIBRATION IN MACHINING

The effects of vibration can be considered on four main points:

(a) The effects of vibration on the machine tools

(b) The effects of vibration on the cutting condition

(c) The effects of vibration on the work piece

(d) The effects of vibration on tool life

4.3 SOURCES OF VIBRATION IN MACHINING

Knowing the purpose of the machine, the tolerable limit of vibration can be fixed up. For controlling and elimination of vibration, the sources of vibration must be searched out.

There are six main sources of vibration

(a) In-homogeneities in the work piece material
(b) Build-up edge in cutting tools
(c) Unbalance and disturbances in the drives
(d) Intermitted cutting (like milling)
(e) Transmission of vibration from the ground which vibrates due to other reasons
(f) Generation of vibration from the cutting process itself, commonly known as machine tool chatter.

4.3.1 In-homogeneities in the work piece material

When a homogeneous material is machined, the cutting force which deflects the elastic and tool holder, remain more or less constant. But if there be any in-homogeneity present in the materials an impulsive force will be generated due to the sudden increment of the hardness of the work piece material. As an effect of this impulse a free vibration is set up in the cutting tool and also in the machine tool body. Build-up edge has got also similar effect but that is not actually due to the work piece material. If the system is dynamically stable then the vibration initiated by the impulsive force will die out but if the system is unstable then the effect may be considerable.

4.3.2 Vibration due to Build-up Edges

There are some cases of vibrations which are neither forced nor self-excited. One such is due to build-up edges which change the instantaneous rake angle γ by an amount $\Delta\gamma$.

4.3.3 Disturbances in the Drives

Disturbance in the drives may be of two types: First one is due to disturbance in rotating, driving members of the machine tool. This type of disturbances may be generated due to many reasons. Some of the reasons are:

(i) Rotating unbalanced mass
(ii) Faulty arrangement of drive
(iii) Fault in the supporting bearing

4.3.4 Vibration due to Intermittent Cutting

When the cutting process itself is intermittent or periodically discontinuous then cutting force becomes fluctuating with a definite period. Due to this fluctuating or dynamic cutting force which is transmitted to the machine tool via the cutting tool and job, it is quite likely that a forced vibration will be generated due to the elastic nature of the system. Now if the frequency of the force fluctuation falls in the range of any natural frequency of the machine, the vibration may be severe.

4.3.5 Transmission of Vibration from Vibrating Foundation

In any machine shop floor there will be various machines and if any where dynamic force through vibration is transmitted to the ground, the machine shop floor will vibrate. Now this vibration may be transmitted to a precision machine through its foundation and spoil the job.

4.3.6 Machine Tool Chatter

Machine tool can vibrate due to the cutting process itself under some particular conditions. In these cases, exciting force is not coming from an outside element; it is supplied by the cutting process itself. These types of vibration are self-induced and commonly known as machine tool chatter.

4.4 FORCE SYSTEM IN TURNING

The cutting forces are largely affects the result of chip separation, its removal and chip-breaking actions, with the immense pressure and friction in this process producing forces acting in various directions. Figure 4.1 can be seen a model of the three-dimensional cutting force components in an oblique turning operation, when the principal cutting edge is at an angle to the main work-piece axis (i.e. Z-axis). These component forces can be separated into the:

Tangential force (Fc) – which is greatly influenced by the contact and friction between the work-piece and tool, as well as the contact conditions between the chip and the rake face of the cutting edge. The magnitude of the tangential cutting force is the greatest of these three component forces and contributes to the torque, which in turn, influences the power requirement for cutting. Fundamentally, the product of the tangential force and the cutting speed represent the power required for machining. The specific cutting force is a unit expression for the tangential cutting force, being closely related to the material's undeformed chip thickness and selected feed rate.

Axial force (F_a) – the magnitude of this force will *vary* depending on the selected feed rate and the chosen tool geometry and in particular, the 'plan approach angle' , or 'entering angle'. Its direction is from the feeding of the tool, along the direction of work-piece machining.

Radial force (F_r) – is directed at right angles to the tangential force from the cutting point. The 'plan approach angle' and the size of the nose radius will influence this force.

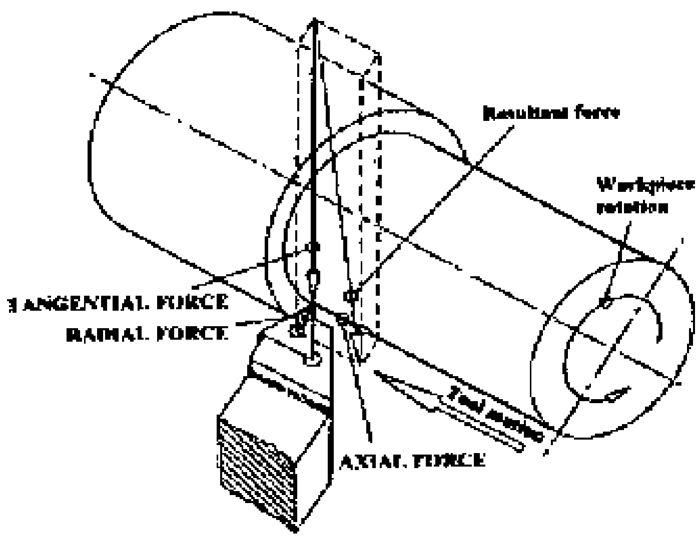

Figure 4.1 Cutting forces involved in turning operation

4.5 SURFACE ROUGHNESS IN MACHINING

Outermost layers of all machined surface display a great number of both macro-geometrical and micro-geometrical deviations from the ideal geometrical surface. Deviations of the first order include errors of form and are macro-geometrical. Deviations of the second order are waves while the deviations of third and higher orders refer to surface roughness. The principal elements of surfaces are defined below:

Surface: The surface of an object is the boundary which separates that object from another substance. Its shape and extent are usually defined by a drawing or descriptive specifications.

Profile: The contour of any specified section through a surface.

Roughness (Primary texture): Relatively fine-spaced surface irregularities. On surface produced by machining and abrasive operations, the irregularities produced by the cutting action of tool edge and abrasive grains and by the feed of the machine tool are roughness. Roughness may be considered as being super posed on a wavy surface. Roughness is expressed in terms of its height, its width, and its distance on the surface along which it is measured.

Roughness is generally described using two methods.

1. The arithmetic mean value (**R_a**, formerly identified as AA for arithmetic average or CLA for centerline average)
2. The root-mean- square average (**R_q**, formerly identified as RMS)

Waviness (Secondary texture): The surface irregularities which are of greater spacing than the roughness. On machined surfaces such irregularities may result from machine and work deflections, **vibrations**, etc.

Flaws: Irregularities which occur at one place or at relatively infrequent intervals in the surface, e.g., a scratches, ridge, holes, cracks, seams, tears etc.

Lay: The direction of predominant surface pattern and usually visible to the naked eye.

4.6 MESUREMENT OF SURFACE ROUGHNESS

Measurements of roughness are made in two general ways. One is by comparison of surfaces to standard reference surfaces. The other is by the use of instruments that make direct measurements.

I. Method of Comparison

Surfaces are observed through a magnifying glass or microscope for visual comparisons. Magnified surfaces are often photographed. However caution must be exercised in examine photographs. Often sight-and-touch is the best method of comparison. Photographs are so dependent on illumination or focus that they may not reveal true depth pattern. Most comparative methods require skill and judgment.

II. Stylus Type Profilometers

For actual quantitative measurements of surface roughness often stylus type profilometers are used. A sharp diamond stylus or pointer on the end of an arm is dragged back and forth across a surface at a given rate. The stroke length is adjustable and provides the sampling length.

As the stylus passes over the surface it rises and falls by amounts proportional to surface roughness. These rises and falls generate optical or electrical responses 'which are amplified and recorded.

4.7 FACTORS EFFECTING SURFACE QUALITY

There are seven major factors influencing surface quality in machining operations:

(a)Machine tool rigidity and bearing accuracies

(b)Finish-ability of work material

(c)Type and condition of cutting tool

(d)Application of cutting fluid

(e)Method of chip removal

(f)Geometry of cutting tool

(g)The variables: feed depth of cut and cutting speed.

Waviness of the surface may be due to vibrations which in due to

(1)External sources of shock and vibrations
(2)Defects in the drive in machine elements
(3)Defects in the drive in machine tool
(4)Self-excited vibrations

4.8 JOINTS IN MACHINE TOOL STRUCTURES

Although they are less significant than internal damping, bolted joints in the structure of a machine tool are also a source of damping; their effectiveness depends on size, position and the number of joints. Because friction dissipates energy, small relative movements along dry (unlubricated) joints dissipate energy and help to improve damping. In joints where oil or adhesive polymers are present, the internal friction at the joint dissipates energy, which also contributes to damping.

All machine tools consist of a number of large and small components, assembled into a structure by various means. Consequently, this type of damping is cumulative due to the presence of a number of joints in the machine tool.

The more joints, therefore, the greater the amount of energy dissipated and the higher the damping. However, overall system stiffness is usually reduced as the number of joints increases.

4.9 GUIDELINES FOR REDUCING VIBRATION

The basic guidelines may be summarized as follows:

a. Minimize tool overhang
b. Support work piece rigidly
c. Modify tool and cutter geometry
d. Change process parameters, such as cutting speed, feed, depth of cut, and cutting fluids.

e. Increase the stiffness of the machine tool and its components by improving design, using larger cross-sections, and using materials with higher elastic modulus.
f. Improve the damping capacity of the machine tool

In conclusion, it is important to know the effects of vibration in machining to save the machine from damage. Machine tool vibration has detrimental effect on tool life which, in turn, lowers down the productivity and increases cost of production.

CHAPTER 5

APPLICATION OF DAMPER IN DYNAMIC SYSTEM

5.1 VIBRATION ANALYSIS OF DAMPING SYSTEM

The fundamentals of vibration analysis can be understood by studying the simple mass-spring-damper model. In this section forced vibration with damping has been discussed.

5.2 Free Vibration

Vibration under free or natural conditions. No disturbing forces. Free vibration occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and then letting go or hitting a tuning fork and letting it ring. The mechanical system will then vibrate at one or more of its natural frequencies and damp down to zero.

Example: - Simple Pendulum

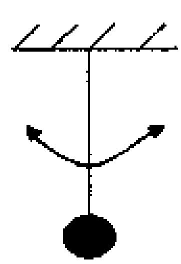

Figure: 5.1. Simple pendulum

5.2.1 Simple Harmonic Motion (S H M)

The oscillations of the mass shown in figure: 5.1. are described as simple harmonic motion. Simple harmonic motion is represented graphically in figure: 5.2.

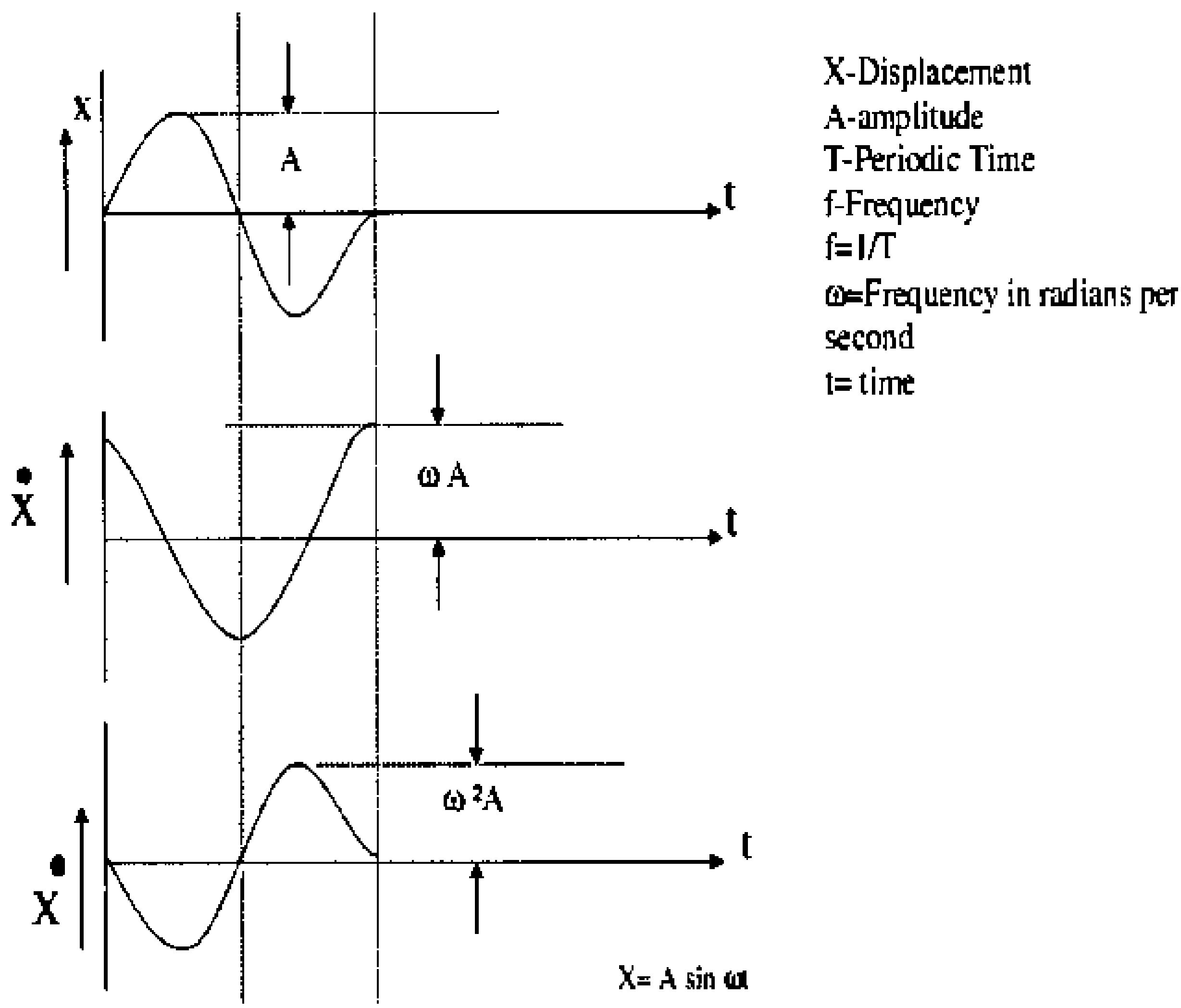

Figure: 5.2. Simple Harmonic Motion (SHM)

5.3 FORCED VIBRATION

Vibration due to impressed disturbing force. Forced vibration is when an alternating force or motion is applied to a mechanical system. Examples of this type of vibration include a shaking washing machining due to an imbalance, transportation vibration (caused by truck engine, springs, road, etc),or the vibration of a building during an earthquake. In forced vibration the frequency of the vibration is the frequency of the force or motion applied, but the magnitude of the vibration is stongly dependent on the mechanical system itself. Examples

1. Electric bell-clipper oscillation under electromagnetic force.
2. I.C Engines-vibrations due to unbalanced inertia forces

5.3.1 Forced Vibration-Damped

In a damped forced vibration system such as the one shown in Figure 5.3, the motion of the mass M has two parts: (1) the damped free vibration at the damped natural frequency and (2) the steady-state harmonic motions at the forcing frequency. The damped natural frequency component decays quickly, but the steady-state harmonic associated with the external force remains as long as the energy force is present.

With damped forced vibration, the only difference in its equation and the equation for damped free vibration is that it is equal to $F_0 \sin(\omega t)$ as shown below instead of being equal to zero.

$$\frac{M}{g_c}\frac{d^2X}{dt^2} + c\frac{dX}{dt} + KX = F_0 \sin(\omega t) \quad \text{.......Eqn.5.1}$$

With damped vibration, damping constant c is not equal to zero and the solution of the equation gets quite complex assuming the function, $X = X_0 \sin(\omega t - \Phi)$. In this equation, Φ is the phase angle, or the number of degrees that the external force, $F_0 \sin(\omega t)$, is ahead of the displacement, $X_0 \sin(\omega t - \Phi)$.

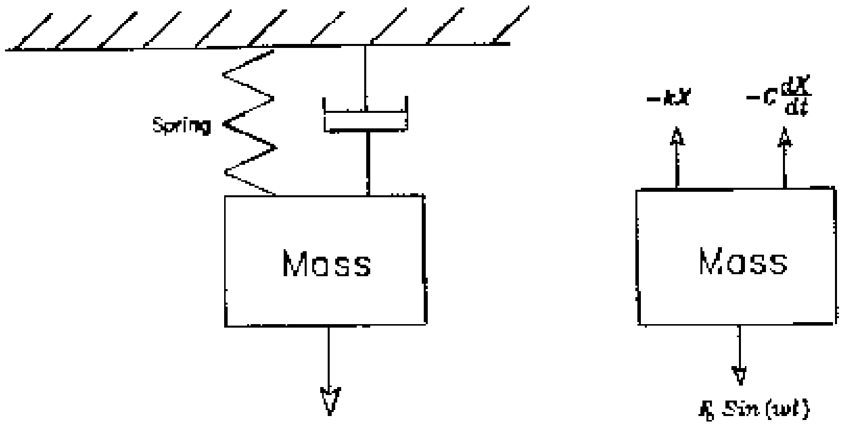

Figure: 5.3. Damped forced vibration system.

Using vector concepts, the following equations apply, which can be solved because there are two equations and two unknowns:

Vertical vector component:

$$KX_0 - \frac{M}{g_c}\omega^2 X_0 - F_0 \cos\phi = 0 \qquad \text{Eqn.5.2}$$

Horizontal vector component:

$$c\omega X_0 - F_0 \sin\phi = 0 \qquad \text{Eqn.5.3}$$

Solving these two equations for the unknowns X_0 and Φ:

$$X_0 = \frac{F_0}{\sqrt{(c\omega)^2 + \left(K - \frac{M}{g_c}\omega^2\right)^2}} = \frac{\frac{F_0}{K}}{\sqrt{\left(1 - \frac{\omega^2}{\omega_n^2}\right) + \left(2\frac{c}{c_c} \times \frac{\omega}{\omega_n}\right)^2}}$$ Eqn.5.4

$$\tan\phi = \frac{c\omega}{K - \frac{M}{g_c}\omega^2} = \frac{2\frac{c}{c_c} \times \frac{\omega}{\omega_n}}{1 - (\omega^2/\omega_n^2)}$$ Eqn.5.5

Where,

c = Damping constant

c_c = Critical damping =

$$2\frac{M}{g_c}\omega_n$$ Eqn.5.6

M = Mass of the system

g_c = Acceleration of gravity

c/ c_c = Damping ratio

F_0 = External force

F_0/K = Deflection of the spring under load, F_0 (also called static deflection, X_{st})

ω = Forced frequency

ω_n = Natural frequency of the oscillation

ω/ ω_n = Frequency ratio

For damped forced vibrations, three different frequencies have to be distinguished: the un-damped natural frequency,

$\omega_n = \sqrt{K g_c / M}$; Eqn.5.7

the damped natural frequency,

$$q = \sqrt{\frac{Kg_c}{M} - \left(\frac{cg_c}{2M}\right)^2}; \quad \text{Eqn.5.8}$$

and the frequency of maximum forced amplitude, sometimes referred to as the resonant frequency.

5.4 DYNAMIC SYSTEM REQUIREMENTS

Engineers commonly ask "how stiff should the structure be?" A minimum specified static stiffness is a useful but not sufficient specification. For example, the machine can be made to not deflect too much under its own weight or the weight of a part. Fortunately, it can be predicted with reasonable accuracy. To obtain good surface finish or dynamic performance, the dynamic stiffness needs to be specified.

The dynamic stiffness of a system is the stiffness measured using an excitation force with a frequency equal to the damped natural frequency of the structure. The dynamic stiffness of a system is also equal to the static stiffness divided by the amplification at dynamic resonance. It takes a large amount of damping to reduce the amplification factor to a low level.

If the damping is heavy, the system is said to be over-damped and if it is light, it is called under-damped and motion is oscillatory while is over-damped, the motion is a periodic.

5.5 EFFECTS OF CHANGING THE SYSTEM'S MASS

Decreasing the mass of the system will enhance the ability of the machine to respond to command signals. However, the trade-off is that the system will lose the ability to attenuate high frequency noise and vibration as shown in Figure: 5.4. A system with decreased mass offers a higher natural frequency, which means that higher speed controller signals can be used without compromising the accuracy of the system. A low mass system also shows improved damping, a result of the increased loss factor, but a low mass system shows less noise rejection at higher frequencies. This suggests that the machine will be less able to attenuate noise and vibration.

Considering all the issues, in conclusion, the mass should be minimized to reduce controller effort and improve the frequency response and loss factor (ζ).

Effects of changing system's mass, stiffness and damping shown by Figure 5.4,5.5 and 5.6

Where,

c = Damping coefficient N /sec /µm

m = Mass (Kg)

k = Stiffness N/µm

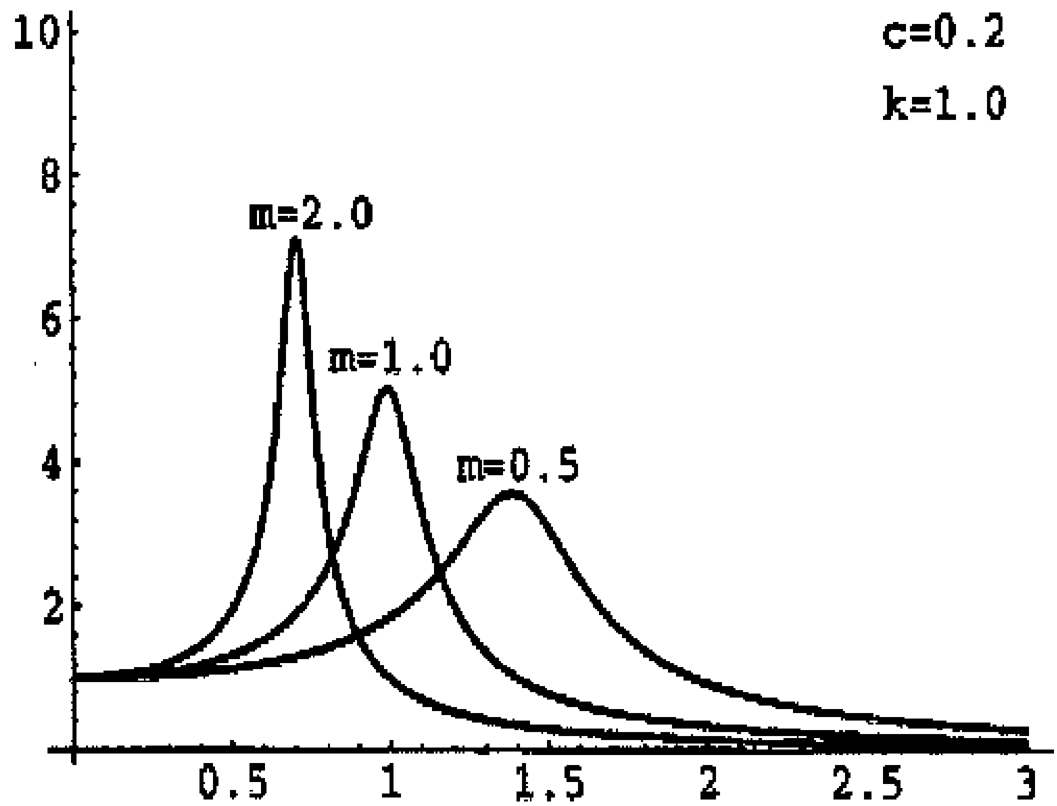

Figure: 5.4. Amplitude (μm) Vs Bandwidth (dB) changing system's mass

5.6 EFFECTS OF CHANGING THE SYSTEM'S STIFFNESS

A system with higher stiffness will give a flatter response at low frequencies and give smaller displacements for a given force input. More importantly, the compromise of decreased noise attenuation is not as dramatic as is the case with lowering the system mass. This is shown by the similar shapes in the three curves at high frequencies in Figure: 5.5. However, acoustical noise may be worsened by adding stiffness. In conclusion, the stiffness of the machine structure should be maximized to improve positioning accuracy.

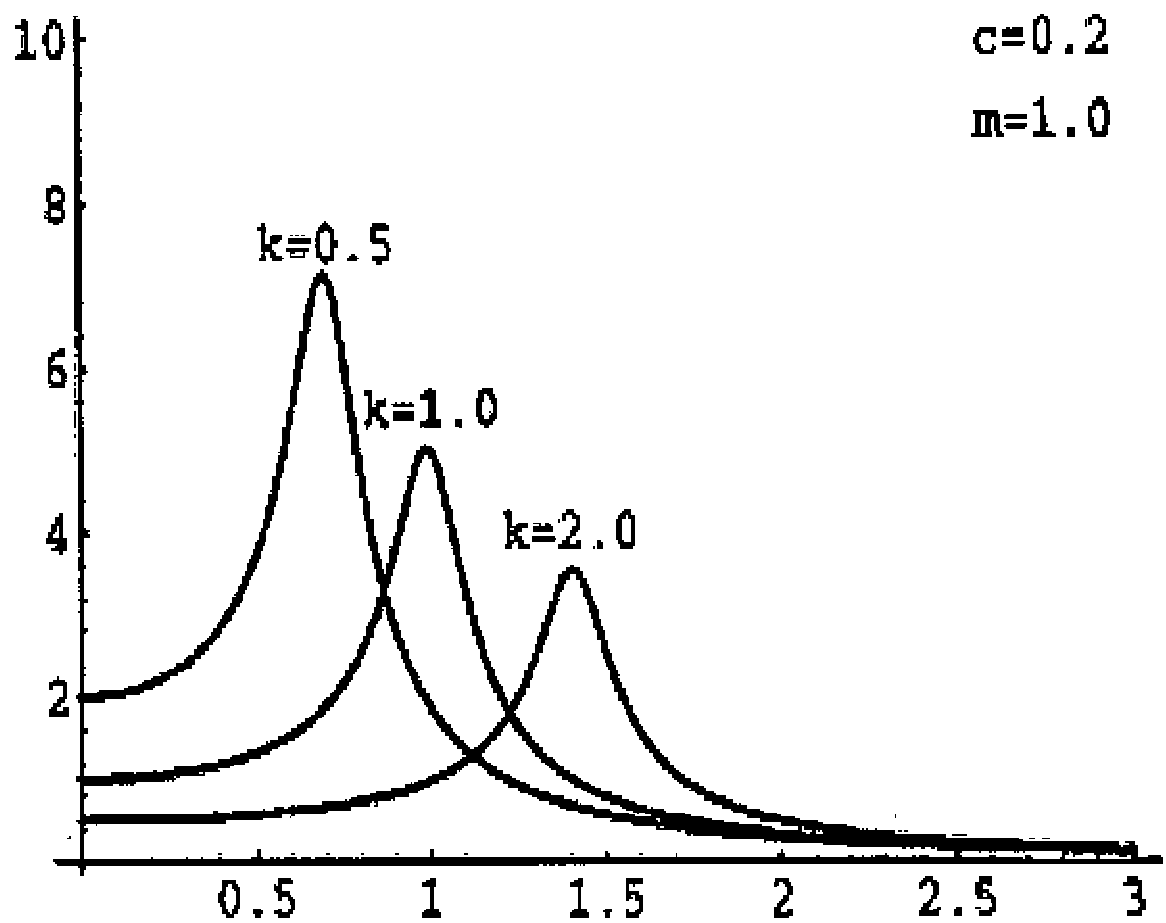

Figure: 5.5 Amplitude (μm) Vs Bandwidth (dB) changing system's stiffness

5.7 EFFECTS OF CHANGING THE SYSTEM'S DAMPING

Increasing the system's damping can make a dramatic improvement in the system's response. The trend is for decreasing amplification of the output at resonance with increasing damping, although a damping coefficient of 0.4 may be difficult to obtain in practice. Figure: 5.6. shows the dramatic improvement available by doubling the system's damping.

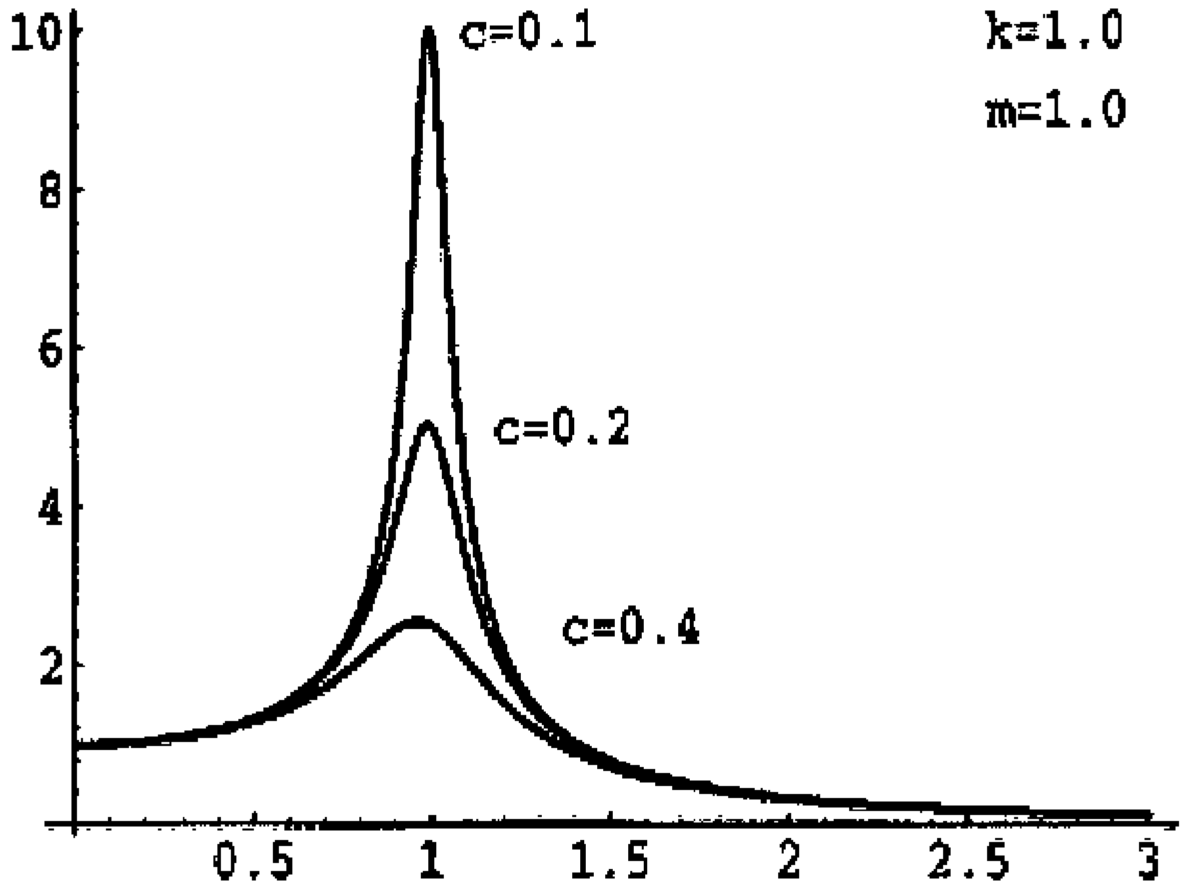

Figure: 5.6. Amplitude (μm) Vs Bandwidth (dB) changing system's damping

5.8 METHODS OF ACHIEVING DAMPING

Although it has been extensively studied, the mechanism of damping in a material is difficult to quantify, and one must generally rely on empirical results. In fact, damping is highly dependent on alloy composition, frequency, stress level and type, and temperature. Structural damping levels are often quite low, and frequently the dominant source of damping is the joints in an assembly. The amount of damping one obtains from a material is very low compared to the amount of damping that one can obtain with the addition of a damping mechanism.

CHAPTER 6

EXPERIMENTATION RESULT AND DISCUSSION

6.1 EXPERIMENTAL PROCEDURE

In this experiment, the system was subjected to various operating conditions to help better understand the sources of inaccuracy in the cutting process. By varying the system parameters and recording the signal from the system, the response in the amplitude of vibration and surface roughness was obtained for different operating conditions.
To complete the experimental results, 240 tests (120 for amplitude and 120 for roughness) were conducted.

Table-6.1 Specification of the test bed

Origin	Holland
Company	GEMCO
Model No.	S-90/260
Max Power	7.5 HP
Max Speed	1500 RPM
Max diameter of work piece	300 mm
Swing over the bed	530 mm
Bed length	8 feet

6.1.1 Measurement of Vibration

The test bed for this experiment was an Engine lathe with the specifications given in the Table-6.1.

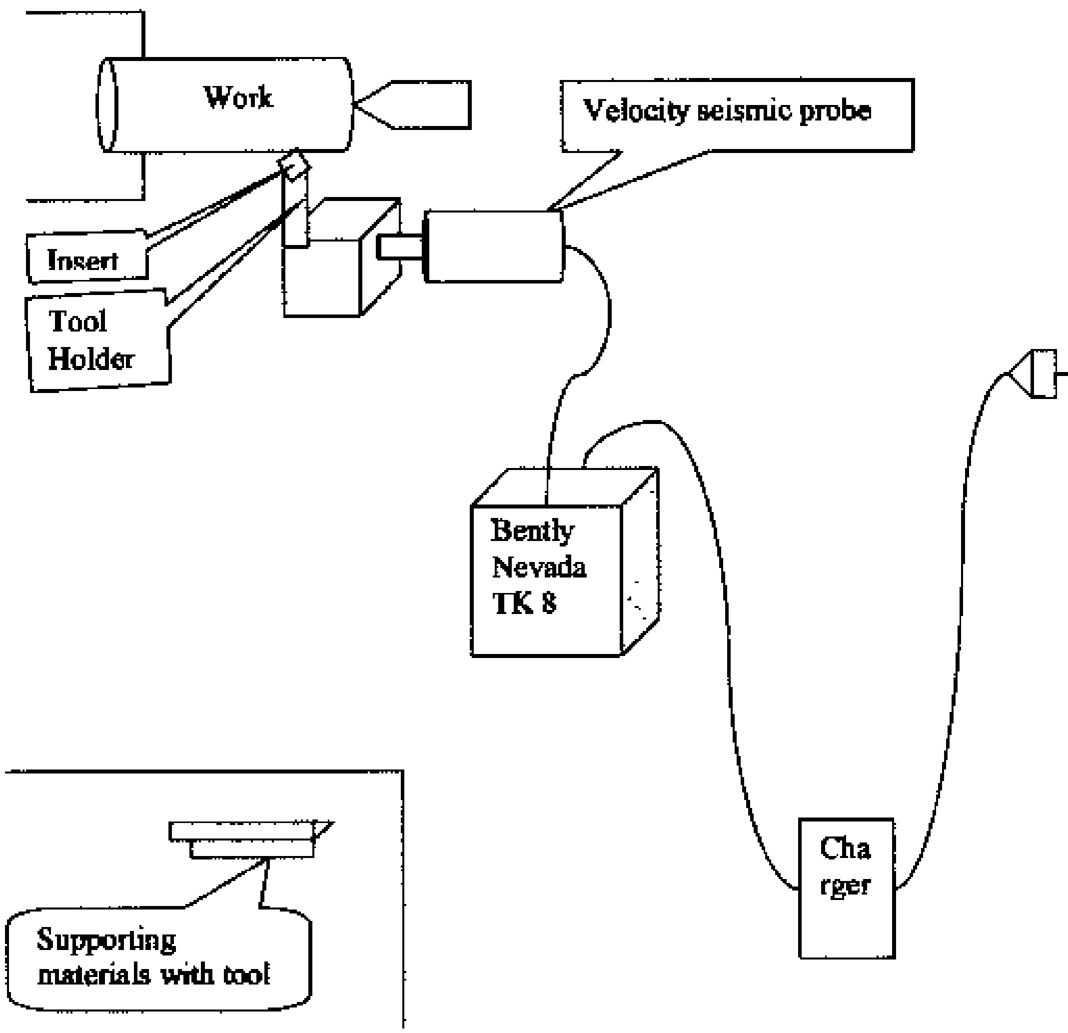

Figure: 6.1. Schematic diagram of experimental setup

A schematic diagram of the instrumentation setup is presented in Figure: 6.1 and details of the work-piece and tooling materials shown in Table-6.2

Table-6.2 Test material type and tool details

Work piece materials	Medium carbon steel
Tool holder	PSBNR 25 25 M12
Insert type	Coated carbide SNMG
Supporting materials	Steel, aluminum, plastic and rubber(heat proof) of each(100mmX25mmX2mm)
Cutting fluid used	None

The tests were conducted at the following cutting conditions for vibration given in Table-6.3

Table-6.3 Cutting conditions for vibration

Cutting speed, V(m/min)	29.37,45.39,61.42,93.46
Feed, s (mm/rev)	0.1,0.2
Depth of cut, d(mm)	0.5,1,1.5

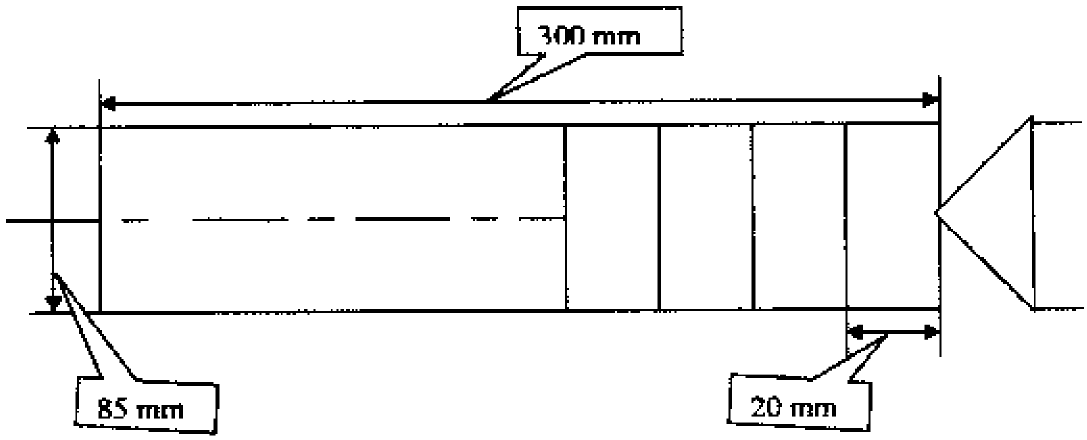

Figure: 6.2. Schematic diagram of work-piece used for vibration

According to Figure 6.1, one end of work piece is clamped rigidly by the 4-jaw chuck and centered accurately, other end clamped by tailstock. The work piece measurement given in the Figure: 6.2 and it was reset at the beginning of each trial. Carbide insert attached with the tool holder (without support).Tool holder rigidly fixed with tool post. Insert alignment checked properly with dead center and center of the work piece.

One velocity seismic probe was mounted beside the tool holder. Measurement of amplitude of vibration velocity were made using Bently Nevada TK 8 is a portable tunable filter vibration meter measures machine vibration using velocity/proximity probe. The meter contains manual tunable filter and can measured both composite and filtered vibration amplitude.

Amplitude of vibration velocity taken at feed(s) =0.1mm/rev and depth of cut (d) =0.5mm with varying cutting speed (V) 29.37, 45.39, 61.42 and 93.46m/min accordingly. Work piece machined 20mm distance along its length for taking result of each cutting conditions, work piece materials has changed as required. Interrupted machining was conducted for using a fresh tool for each depth of cut or the cutting edges severely worn.

Then amplitude of vibration velocity taken at feed(s) 0.1mm/rev depth of cut (d) changes to 1mm and 1.5mm varying cutting speed same as previous.

Again amplitude of vibration velocity taken with feed(s) changes to 0.2mm/rev and depth of cut(d) changes to 0.5mm, 1mm and 1.5mm varying cutting speed same as previous.

After taking all data of without support of each condition, supporting materials steel, aluminum, plastic and rubber (specification of each given in the Table-6.2) supported under the tool holder. For centering the insert tip tool holder materials removed 2mm from its bottom according to support thickness by machining. Tool holder reattached rigidly and all result taken again same as previous cutting conditions.

All the result of amplitudes presented in the Table6.5 to 6.10 based on cutting condition and supporting sequence.

6.1.2 Measurement of Roughness

For taking measurement of roughness wok piece has been machined following procedure of vibration measurement. Only little change introduced in depth of cut (given in the Table 6.4) and machining length of each condition given in the Figure 6.3.

The tests were conducted at the following cutting conditions for roughness given in table-6.4

Table-6.3 Cutting conditions for roughness

Cutting speed, V(m/min)	29.37,45.39,61.42,93.46
Feed, s(mm/rev)	0.1,0.2
Depth of cut, d(mm)	0.25,0.5,1

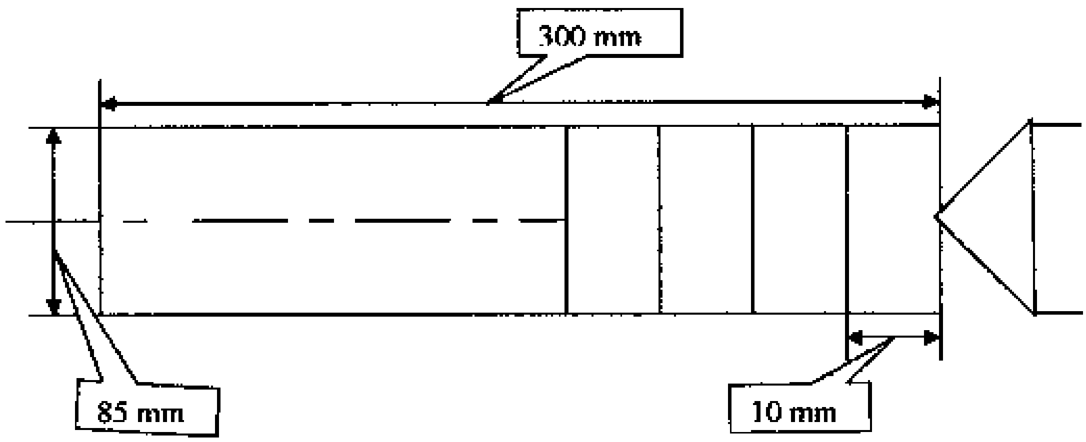

Figure: 6.3. Schematic diagram of work-piece used for roughness

Work piece machined 10mm distance along its length for taking result of each cutting conditions, work piece materials has changed as required. The work piece measurement given in the Figure: 6.3 and it was reset at the beginning of each trial.

Surface roughness of work piece taken at feed(s)=0.1mm/rev and depth of cut(d) 0.25mm with varying cutting speed (V) 29.37,45.39,61.42 and 93.46m/min accordingly.

Interrupted machining was conducted for using a fresh tool for each depth of cut or the cutting edges severely worn.

The values of average surface roughness for all cutting conditions, measured with the help of Taylor Hobson Surtronic 3+ roughness tester. In this system a sharp diamond stylus or pointer on the end of an arm is dragged back and forth across a surface at a given rate. The stroke length is adjustable and provides the sampling length. As the stylus passes over the surface it rises and falls by amounts proportional to surface roughness. These rises and falls generate optical or electrical responses `which are amplified and recorded.

Then surface roughness of work piece taken at feed(s) 0.1mm/rev and depth of cut(d) changes to 0.5mm and 1mm varying cutting speed(V) same as previous.

Again roughness of work piece taken with feed(s) changes to 0.2mm/rev and depth of cut(d) changes to 0.25mm, 0.5mm and 1mm varying cutting speed(V) same as previous.

After taking all roughness result of without support of each condition, supporting materials steel, aluminum, plastic and rubber (specification of each given in the Table-6.2) supported under the tool holder. After centering the insert tip all result taken again same as previous cutting conditions.

All the results of surface roughness are presented in the Table 6.11 to 6.16 based on cutting condition and supporting sequence.

Table 6.5 Vibration Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 0.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.025	0.035	0.0425	0.0475
Amplitude(in/sec) Using Steel Flat Bar	0.0125	0.020	0.0275	0.0325
Amplitude(in/sec) Using Aluminum Flat Bar	0.010	0.0175	0.020	0.025
Amplitude(in/sec) Using Rubber Sheet	0.015	0.0225	0.0325	0.0375
Amplitude(in/sec) Using Plastic Sheet	0.020	0.030	0.035	0.0425

Table 6.6 Vibration Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 1mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.030	0.0525	0.070	0.0775
Amplitude (in/sec) Using Steel Flat Bar	0.020	0.030	0.0375	0.040
Amplitude(in/sec) Using Aluminum Flat Bar	0.0125	0.0175	0.025	0.030
Amplitude (in/sec) Using Rubber Sheet	0.0225	0.0325	0.040	0.045
Amplitude(in/sec) Using Plastic Sheet	0.025	0.035	0.045	0.050

Table 6.7 Vibration Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 1.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.035	0.055	0.08	0 095
Amplitude (in/sec) Using Steel Flat Bar	0.025	0.035	0.040	0.0425
Amplitude(in/sec) Using Aluminum Flat Bar	0.0175	0.0275	0.030	0.0325
Amplitude(in/sec) Using Rubber Sheet	0.030	0.0375	0.0425	0.050
Amplitude(in/sec) Using Plastic Sheet	0.0325	0.0375	0.055	0.060

Table 6.8 Vibration Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 0.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.0275	0.045	0.060	0.065
Amplitude(in/sec) Using Steel Flat Bar	0.0125	0.015	0.0175	0.025
Amplitude(in/sec) Using Aluminum Flat Bar	0.010	0.0125	0.015	0.0225
Amplitude(in/sec) Using Rubber Sheet	0.015	0.0175	0.020	0.0325
Amplitude (in/sec) Using Plastic Sheet	0.0225	0.035	0.0425	0 045

Table 6.9 Vibration Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 1mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.045	0.055	0.0625	0.0675
Amplitude(in/sec) Using Steel Flat Bar	0.0225	0.0325	0.035	0.040
Amplitude(in/sec) Using Aluminum Flat Bar	0.020	0.0275	0.0325	0.0375
Amplitude(in/sec) Using Rubber Sheet	0.035	0.0375	0.040	0.045
Amplitude(in/sec) Using Plastic Sheet	0.0425	0.045	0.0475	0.0525

Table 6.10 Vibration Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 1.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Amplitude(in/sec) Without Support	0.055	0.0625	0.0675	0.070
Amplitude(in/sec)Using Steel Flat Bar	0.0375	0.040	0.045	0.0525
Amplitude(in/sec) Using Aluminum Flat Bar	0.030	0.0325	0.035	0.0425
Amplitude(in/sec) Using Rubber Sheet	0.0425	0.045	0.050	0.0575
Amplitude (in/sec) Using Plastic Sheet	0.045	0.0475	0.0525	0.060

Table 6.11. Roughness Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 0.25mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(μm) Without Support	6.00	4.84	4.42	3.02
Roughness(μm) Using Steel	4.50	3.86	3.08	1.92
Roughness(μm) Using Aluminum	3.26	3.10	2.70	1.84
Roughness(μm)Using Rubber	4.82	4.24	3.22	2.56
Roughness(μm) Using Plastic	5.06	4.76	3.82	2.70

Table 6.12. Roughness Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 0.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(μm) Without Support	6.62	5.58	5.32	3.38
Roughness(μm) Using Steel	4.78	4.06	3.62	2.62
Roughness(μm) Using Aluminum	3.50	3.22	2.82	1.86
Roughness(μm) Using Rubber	4.92	4.46	3.78	2.76
Roughness(μm) Using Plastic	5.82	4.84	4.18	2.92

Table 6.13. Roughness Result (at Feed, s = 0.1mm/rev, Depth of cut, d = 1mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(μm) Without Support	6.82	6.08	5.40	4.50
Roughness(μm) Using Steel	4.82	4.38	4.04	2.72
Roughness(μm) Using Aluminum	4.14	3.48	2.98	2.60
Roughness(μm) Using Rubber	4.98	4.66	4.30	3.48
Roughness(μm) Using Plastic	6.22	4.92	4.34	3.58

Table 6.14. Roughness Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 0.25mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(µm) Without Support	6.16	5.30	5.24	3.78
Roughness(µm) Using Steel	5.00	4.78	3.84	2.56
Roughness(µm) Using Aluminum	4.64	3.86	3.52	2.22
Roughness(µm) Using Rubber	5.52	5.00	4.26	2.98
Roughness(µm) Using Plastic	6.10	5.24	5.18	3.08

Table 6.15. Roughness Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 0.5mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(µm) Without Support	6.90	5.82	5.66	4.06
Roughness(µm) Using Steel	5.10	5.04	4.02	2.66
Roughness(µm) Using Aluminum	4.68	4.52	3.70	2.26
Roughness(µm) Using Rubber	5.62	5.26	4.38	3.10
Roughness(µm) Using Plastic	6.54	5.66	5.54	3.50

Table 6.16. Roughness Result (at Feed, s = 0.2mm/rev, Depth of cut, d = 1mm)

Cutting Speed, V(m/min)	**29.37**	**45.39**	**61.42**	**93.46**
Roughness(µm) Without Support	7.50	6.78	6.12	5.08
Roughness(µm) Using Steel	5.26	5.18	4.70	3.38
Roughness(µm) Using Aluminum	4.84	4.56	3.80	2.30
Roughness(µm) Using Rubber	6.00	5.46	5.14	3.40
Roughness(µm) Using Plastic	7.24	6.66	5.92	3.56

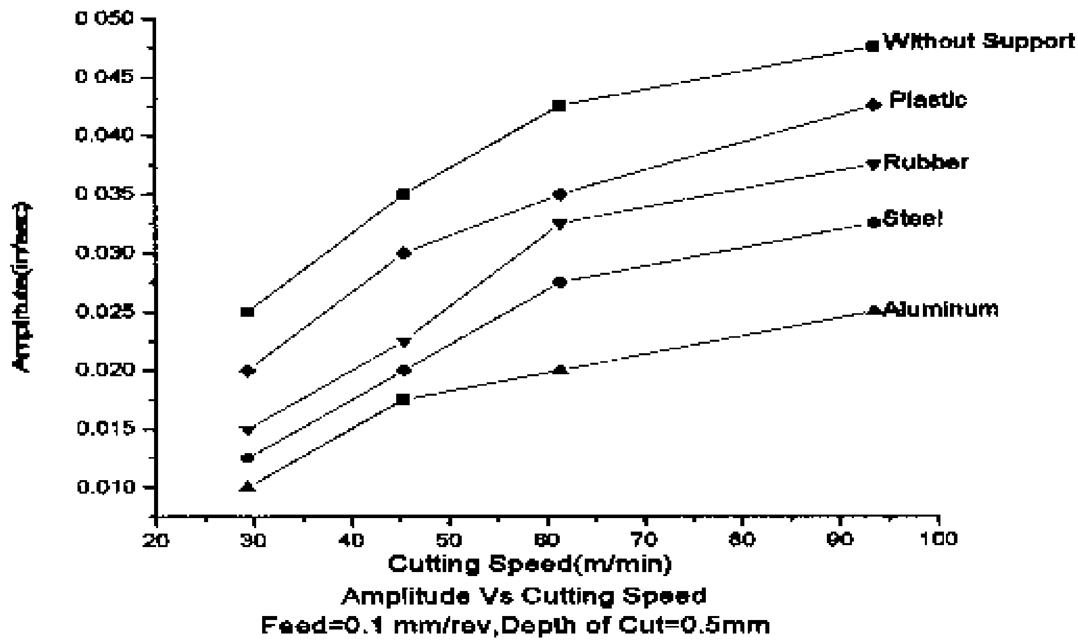

Figure: 6.4 Amplitude Vs Cutting Speed (Feed = 0.1mm/rev, Depth of cut = 0.5mm)

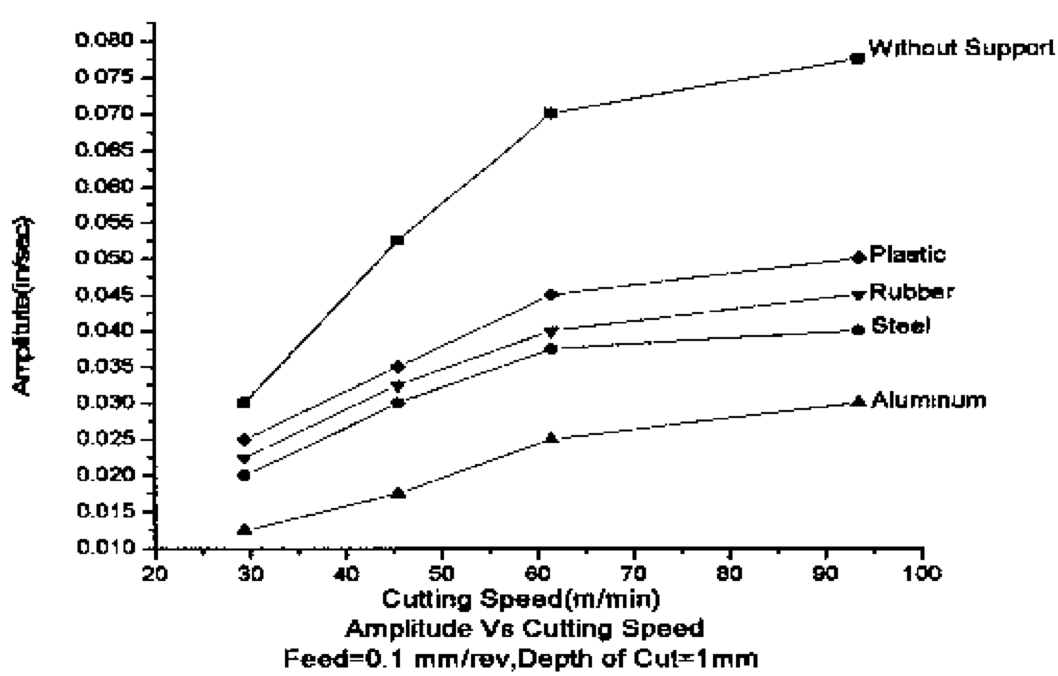

Figure: 6.5 Amplitude Vs Cutting Speed (Feed=0.1mm/rev, Depth of cut =1mm)

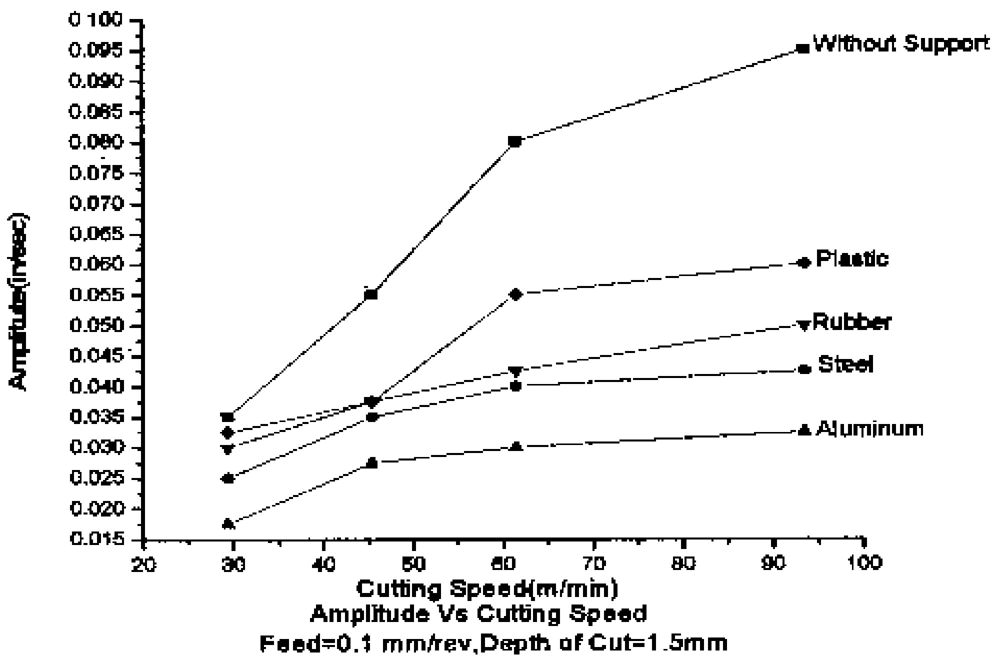

Figure: 6.6 Amplitude Vs Cutting Speed (Feed = 0.1mm/rev, Depth of cut = 1.5mm)

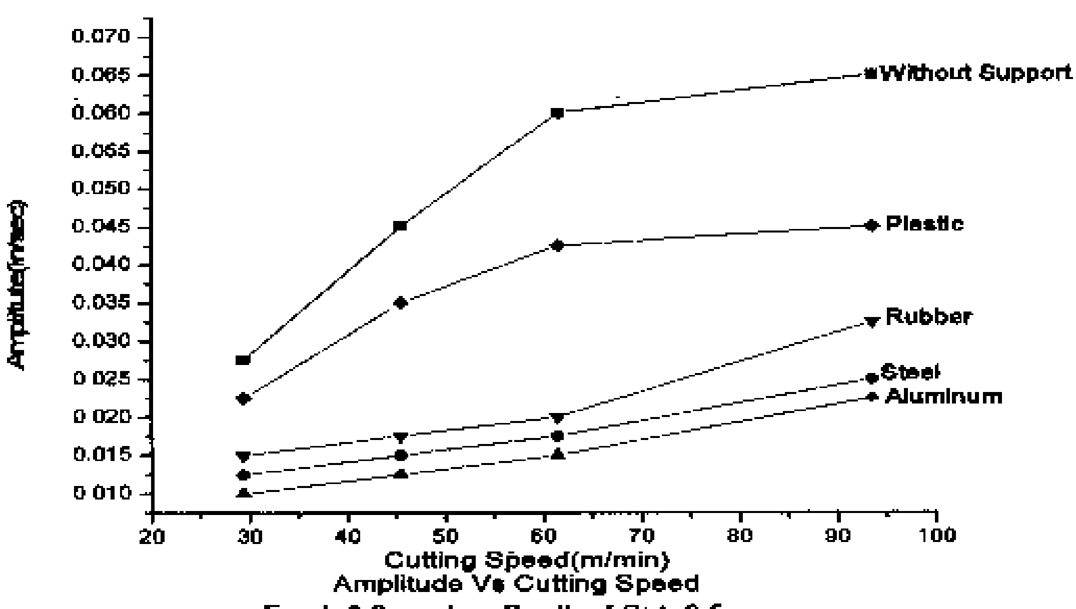

Figure: 6.7 Amplitude Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 0.5mm)

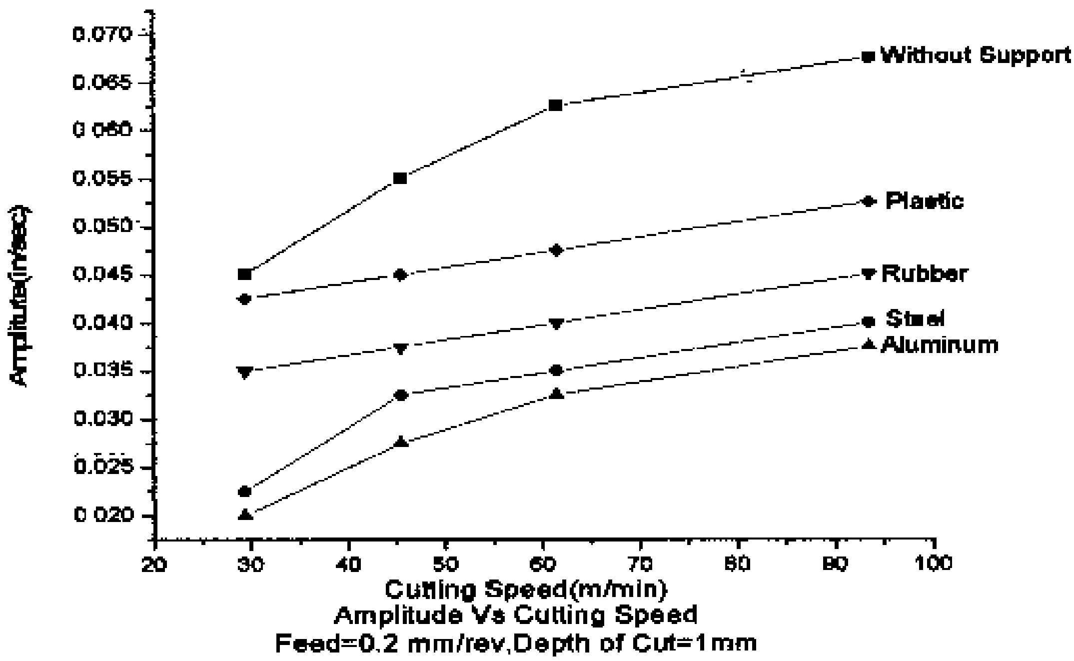

Figure: 6.8 Amplitude Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 1mm)

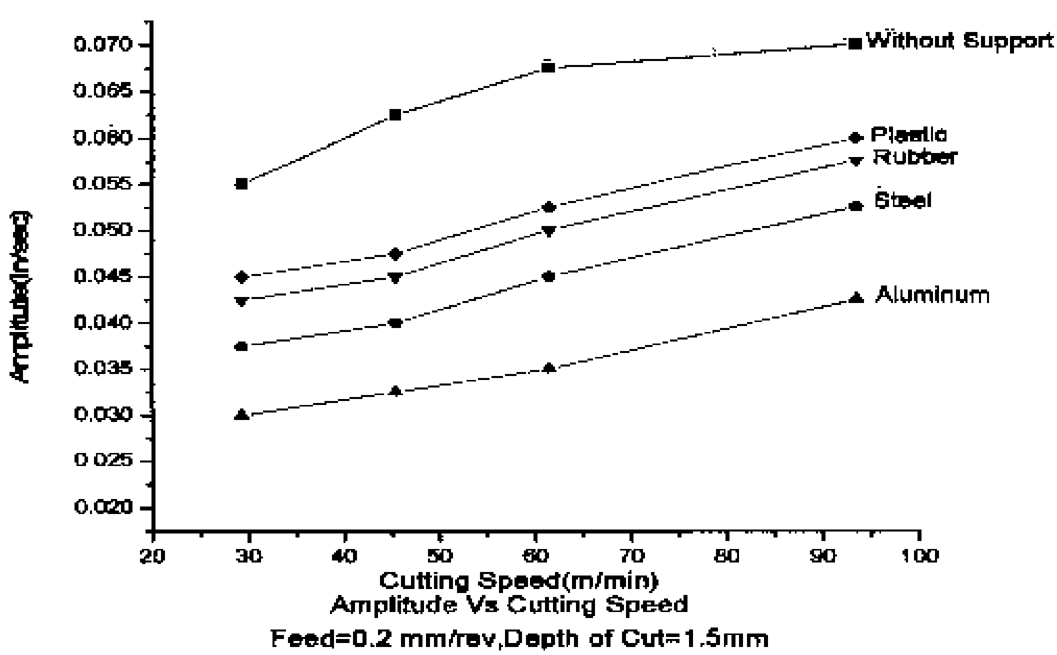

Figure: 6.9 Amplitude Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 1.5mm)

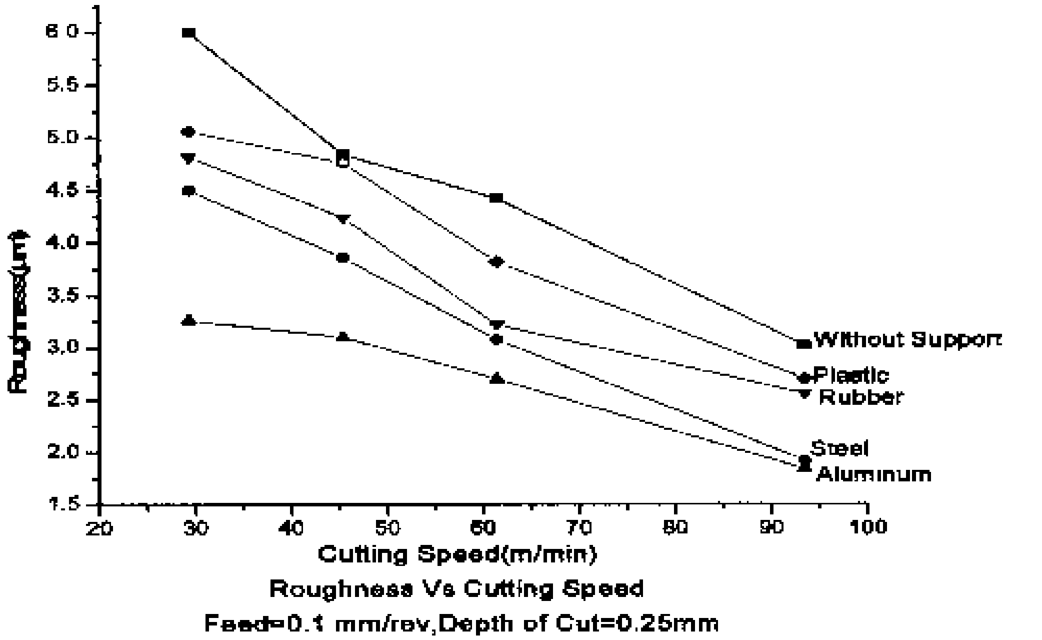

Figure: 6.10 Roughness Vs Cutting Speed (Feed = 0.1mm/rev, Depth of cut = 0.25mm)

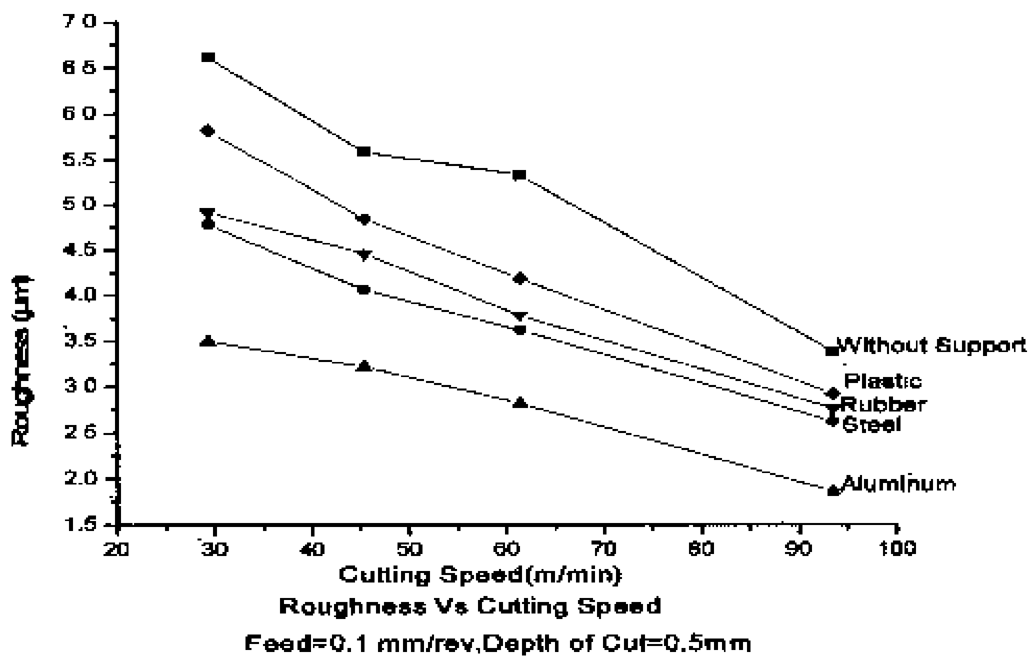

Figure: 6.11 Roughness Vs Cutting Speed (Feed = 0.1mm/rev, Depth of cu = 0.5mm)

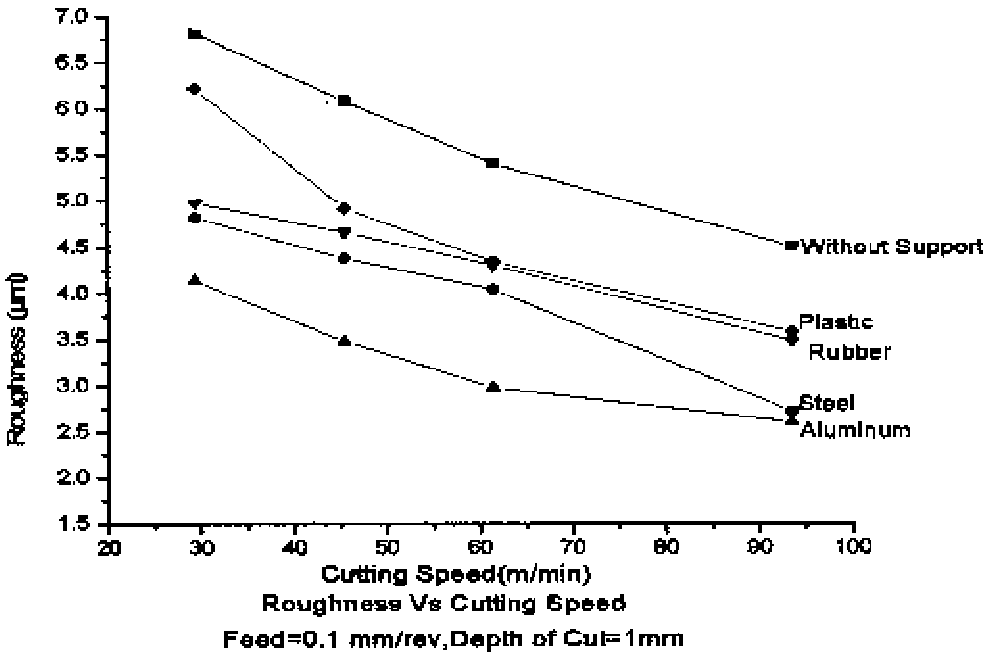

Figure: 6.12 Roughness Vs Cutting Speed (Feed = 0.1mm/rev, Depth of cut = 1mm)

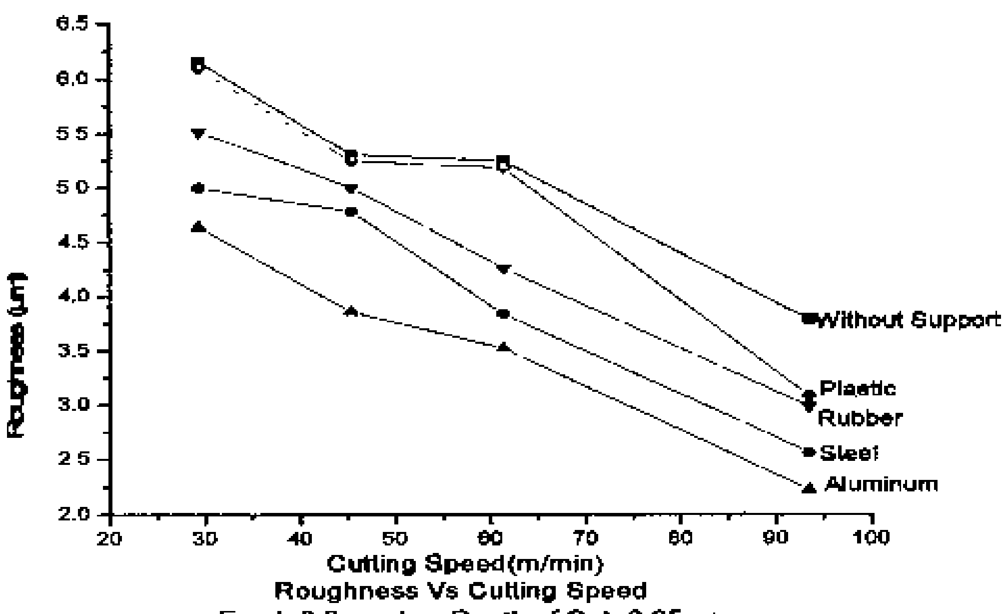

Figure: 6.13 Roughness Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 0.25mm)

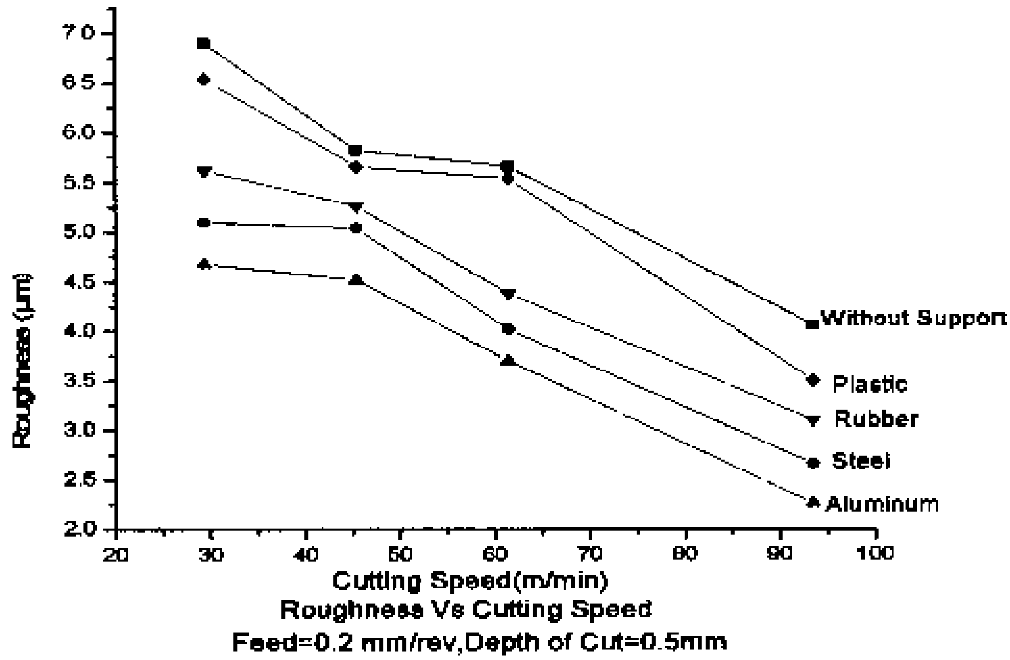

Figure: 6.14 Roughness Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 0.5mm)

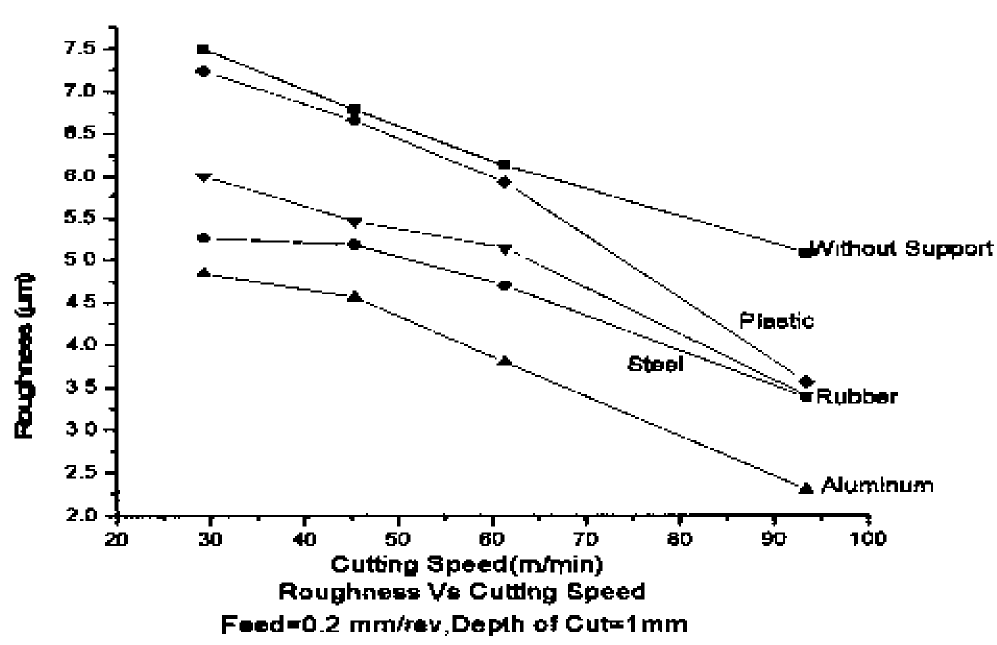

Figure: 6.15 Roughness Vs Cutting Speed (Feed = 0.2mm/rev, Depth of cut = 1mm)

6.2 RESULT AND DISCUSSION

Analysis of vibration of machine tool in turning is a very significant way to improve the machine health as well as surface quality.

Overall performance of machine tool changes with the changing of supporting materials. A very promising result can obtained from the machine tool by introducing a proper support with tool holder. Hence, every machining industry should follow an effective way to use supporting materials while machining work piece in a lathe.

The thesis presents the results of analysis and development a setup for improving surface quality on work piece in turning by analyzing both vibration and roughness measurement varying cutting parameters. In this thesis various supporting materials has been used to develop a setup of improving machining performance at different condition.

6.2.1 Vibration Result

In this chapter and Figure: 6.4 to 6.9 shows Amplitude of vibration velocity increases with the increasing of spindle speed. A very promising result obtained using supporting materials. Amplitude of vibration velocity has been reduced dramatically at each condition using support.

Amplitude of vibration velocity has been taken for both with and without any support under tool holder; each cutting condition was same as previous. Amplitude of vibration found lowest at each condition for aluminum support than other supports. Sequence of increasing amplitude for each support at each condition like, Aluminum < Steel < Rubber < Plastic < Without support.

6.2.2 Roughness Result (R_a)

In this chapter and Figure: 6.10 to 6.15 shows value of Roughness, R_a (μm) decreases with the increasing of cutting speed. A very promising result obtained using supporting materials. Roughness value has been reduced dramatically at each condition using support.

Surface roughness, R_a (μm) has been taken for both with and without any support under tool holder; each condition was same as previous. Surface roughness, R_a (μm) found better than previous at each condition for aluminum support than other supports. Sequence of increasing amplitude for each support at each condition like, Aluminum<Steel< Rubber<Plastic<Without support.

So from above analyses inspection of the result showed significant changes in the amplitude of vibration and surface roughness by changing supporting material of tool holder. The result showed that changing the supporting material at same condition surface roughness on work piece and amplitude of vibration decreased more for aluminum support than others. As amplitude of vibration velocity and surface roughness varies with the supporting materials it is wise to select proper supporting materials to improve performance in turning.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

In most of the machining industries in Bangladesh, operators don't give importance on effect of vibration which reduces productivity and dimensional accuracy. Because of their ignorance about the vibration effect on work-piece machining industries are losing to have good surface finish of product with dimensional precision.

The thesis is carried out for the purpose of analysis and development of a simple system for improving surface quality as well as reducing vibration of machine tool based on the used of supporting materials under tool holder in turning. To develop a proper system of improving surface various machining condition and supporting materials has been studied.

According to the experimental result, aluminum support system explored in the present work is capable of controlling the vibration occurring during the turning operation. It is obvious that surface quality can improve and amplitude of vibration velocity can be reduced by supporting aluminum slice under tool holder in turning.

It is clear that, the amplitude of vibration velocity in turning can be reduced and surface roughness can be improved by using aluminum support. As cost regarding, aluminum support can be used instead of complex model, developed recently for reducing machine tool vibration in turning.

7.2 RECCOMMENDATIONS FOR FUTURE WORK

From the above results it is clear that tool vibrations that occur in a lathe during turning can be controlled using proper supporting materials. It is clear that, reducing the machine tool vibration using proper supporting materials is important to the economica, dimensional precision and future tool design development in reconfigurable manufacturing. The main advantage of using support can be easily setup under the tool holder at the time of fixing tool holder. No need extra time for fixing this. So, time can be saved in this system. But the study is limited to the measuring amplitude of vibration only. Today, minimization of tool vibration has become is the greatest challenge as it can lead to optimized product throughput ensuring tool integrity, surface roughness and dimensional accuracy. Future work may include the followings:

1. It is necessary to examine the time domain and frequency domain data using modern sensor.

2. Vibration data can be analyzed by mathematical/simulation model.

3. A future study can be carried out to find the proper support analyzing all the factors. Gray cast iron, composite materials etc. can be used for this.

4. A future study can be carried out using cutting fluid.

5. Work material and cutting conditions can be changed for future study.

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