HEALTH MONITORING OF LATHE TOOL

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Abstract - Tool condition monitoring systems are essential in micro milling applications. A tool's slenderness requires high-precision monitoring systems for online measurements. In most cases, tool health is indirectly estimated by processing and analysing the cutting process parameters Cutting tool wear is a critical phenomenon which influences the quality of the machined part. Vibration signals from metal cutting processes have been investigated for various purposes, including in-process tool wear monitoring. Reducing the machining energy consumption (MEC) of machine tools for turning operations is significant to promote sustainable manufacturing. In this study, the relationship between vibration and tool wear is investigated during high-speed dry turning by using statistical parameters. It is aimed to show how tool wear and the work piece surface roughness changes with tool vibration signals. For this purpose, a series of experiments were conducted in a lathe machine. Modal analysis of both normal and wear cutting tool will be perform for finding Natural frequency of cutting tools in ANSYS 19 software. Experimental testing of cutting tool will be perform using FFT analyser. After that the comparative analysis will be carried out between the experimental and analysis results and after that the result & conclusion will be drawn

Key Words: Manufacturing, vibration, Taguchi method, surface roughness, lathe tool, vibration effect

1.INTRODUCTION

In turning operations, vibration is a frequent problem, which affects the result of machining, in particular, the tool wear. Vibration can be defined as an object being repeatedly displaced at a very high frequency. In turning process, three types of mechanical vibrations are present. They are free, forced and self-excited vibrations. They occur due to lack of dynamic stiffness/rigidity of the machine tool system comprising tool, tool holder, work piece and machine tool. Machining vibrations, also called as chatter, correspond to the relative movement between the work piece and the cutting tool. These vibrations affect typical machining processes, such as turning, milling and drilling. Relative vibration amplitude between the work piece and cutting tool influences the tool life. Cutting tool and tool holder shank are subjected to dynamic excitation due to the deformation of the work material during the cutting operation. The dynamic relative motion between the cutting tool and work piece will affect the quality of the machining, in particular, the surface finish. Furthermore, the tool life is correlated with the amount of vibration. In turning, the presence of tool vibration is a major factor which leads to poor surface finish, cutting tool damage, increase in tool wear and unacceptable noise. With the production and productivity increasing in modern society, the manufacturing energy consumption is increased with intensifying the energy crisis and global warming [1]. According to International Energy Agency [2], manufacturing is responsible for nearly 1/3 of the global energy consumption and 36% of carbon dioxide emissions [3]. Increasing energy price and requirements to improve energy efficiency are the severe challenges faced by modern manufacturing enterprises. Increase in manufacturing production is characterized by technological development, which is driven by increased competitiveness.

Today the standard procedure to avoid vibration during machining is by careful planning of the cutting parameters. The methods are usually based on experience and trial and error to obtain suitable cutting data for each cutting operation involved in machining a product. Machining vibration exists throughout the cutting process. While influenced by many sources, such as machine structure, tool type, work material, etc., the composition of the machining vibration is complicated. However, at least two types of vibrations, forced vibration and self excited vibration, were identified as machining vibrations. Forced vibration is a result of certain periodical forces that exist within the machine. The source of these forces can be bad gear drives, unbalanced machine-tool components, misalignment, or motors and pumps, etc. Self-excited vibration, which is also known as chatter, is caused by the interaction of the chip removal process and the structure of the machine tool, which results in disturbances in the cutting zone. Chatter always indicates defects on the machined surface; vibration especially self-excited vibration is associated with the machined surface roughness. The surface roughness can be affected by built up edge formation. The analysis of tool vibration on surface roughness is also investigated by some authors the purpose of these paper is to investigate the effects of tool vibration on the resulting surface roughness in the dry turning operation of carbon steel. The aim of this research is to investigate the effects of cutting tool vibration on the resulting surface roughness in the dry turning operation of medium carbon steel. To achieve such objective, the research should have completed a fractional experimental design that allows considering a different level interactions between the cutting parameters (cutting speed, feed rate, depth of cut and tool length) on the two measured dependant variables (surface roughness and cutting tool vibration).

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2. Body of Paper

2.1 OBJECTIVES

1. Understand the effect of cutting tool wears on Surface roughness of work piece
2. Modelling of exist cutting tool in CATIA V5 software.
3. Modal and Harmonic analysis of cutting tool by using ANSYS 19 software.
4. To manufacturing of turning work piece samples on both normal and wear tool of lathe machine.
5. To measure vibration of cutting tools during the turning process are recorded using accelerometer of FFT analyzer.
6. To measure Surface roughness of work piece samples.
7. Experimental testing and correlating results.

2.2 TAGUCHI METHOD

A Taguchi design is a designed experiment that lets you choose a product or process that functions more consistently in the operating environment. Taguchi designs recognize that not all factors that cause variability can be controlled. These uncontrollable factors are called noise factors. Taguchi designs try to identify controllable factors (control factors) that minimize the effect of the noise factors i.e. designing a product or process in such a way so as to make its performance less sensitive to variation due to uncontrolled or noise variables which are not economical to control

1. It provides a considerable reduction of time and resource needed to determine important factors affecting operations with simultaneous improvement of quality and cost of manufacturing.
2. The concept of Taguchi's robust design is based on 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.
3. Designing a product or process in such a way so as to make its performance less sensitive to variation produce high-quality products with low development and manufacturing costs.

Orthogonal Array - Taguchi designs use orthogonal arrays, which estimate the effects of factors on the response mean and variation. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be assessed independently of all the other factors, so the effect of one factor does not affect the estimation of a different factor. This can reduce the time and cost associated with the experiment when fractionated designs are used.

S/N Ratio - The signal-to-noise ratio measures how the response varies relative to the nominal or target value under different noise conditions. In a Taguchi designed experiment, you manipulate noise factors to force variability to occur and from the results, identify optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors. Higher values of the signal-to-noise ratio (S/N) identify control factor settings that minimize the effects of the noise factors

2.2.1 MINITAB SOFTWARE

Minitab is a software product that helps you to analyze the data. This is designed essentially for the Six Sigma professionals. It provides a simple, effective way to input the statistical data, manipulate that data, identify trends and patterns, and then extrapolate answers to the current issues. This is most widely used software for the business of all sizes - small, medium and large. Minitab provides a quick, effective solution for the level of analysis required in most of the Six Sigma projects.

The following Procedure were carried –

• The specimens are turned on lathe machine.
• The Speed, Feed & Depth of Cut Required for Turning operation were first decided.
• We decided 3 speed, feed & depth of cut values.
• After that the Orthogonal Array was formed with the help of MINITAB Software.
• According to that Orthogonal Array, nine Turning Operations were carried out on CNC machine.
• The Surface Hardness testing was carried out for all the specimens.
• Then all the values of Surface roughness were put down in MINITAB software &Analyzed as the TAGUCHI design.

• After getting the graph, the optimum Solution was drawn

Conducting a Taguchi designed experiment can have the following steps:

1. Choose Stat > DOE > Taguchi > Create Taguchi Design to generate a Taguchi design (orthogonal array)

2. After we create the design, we can display or modify the design:

• Choose Stat > DOE > Display Design to change the units (coded or uncoded) in which Minitab expresses the factors in the worksheet.

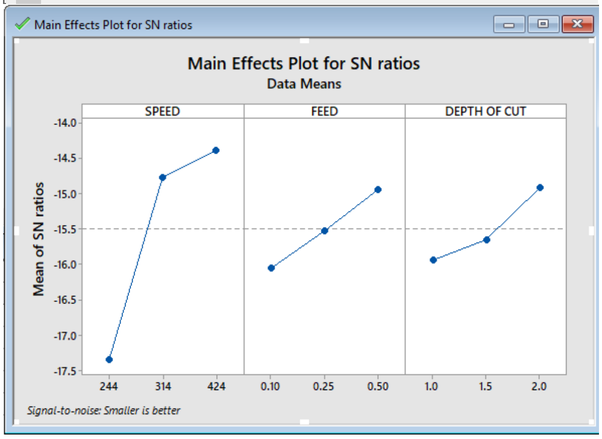
• Choose Stat > DOE > Modify Design to rename the factors, change the factor levels, add a signal factor to a static design, ignore an existing signal factor (treat the design as static), and add new levels to an existing signal factor

3. Conduct the experiment and collect the response data. The experiment is done by running the complete set of factor settings at each combination of control factor settings (at each run).

4. Choose Stat > DOE > Taguchi > Analyse Taguchi Design to analyse the experimental data.

Worksheet 2 ***

↓	C1	C2	C3	C4
	SPEED	FEED	DEPTH OF CUT	SURFACE ROUGHNESS
1	244	0.10	1.0	8.75
2	244	0.25	1.5	7.45
3	244	0.50	2.0	6.14
4	314	0.10	1.5	5.64
5	314	0.25	2.0	5.44
6	314	0.50	1.0	5.35
7	424	0.10	2.0	5.17
8	424	0.25	1.0	5.25
9	424	0.50	1.5	5.29



2.3 FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) is a problem-solving approach for the practical (engineering) problems. The problems are first converted to matrix and partial differential equation forms. Eventually the partial differential and integral equations are being solved to reach the solution of the problem. The volume of the equations to be solved is usually so large that arriving solution without using computer is practically impossible. And, that's why the need of different FEA packages is felt. There are many FEA packages available for different applications. Some popular FEA packages are Pro Mechanica, ANSYS, NASTRAN, and Gambit etc.

FEA solution of engineering problems, such as finding deflections and stresses in a structure, requires three steps:

1. Pre-processing
2. Solution
3. Post processing

In present research for analysis ANSYS (**An**alysis **Sys**tem) software is used. Basically, its present FEM method to solve any problem. Following are steps in detail

1. Geometry
2. Discretization (Meshing)
3. Boundary condition
4. Solve (Solution)
5. Interpretation of results

Step 1: Details of material namely copper, steel, grey cast iron, composite material, fluid domain material is defined in engineering data. i.e. ANSYS default material is structural steel.

Step 2: Import of geometry created in any CAD software namely CATIA, PRO E, SOLIDWORK, INVENTOR etc. in geometry section. If any correction is to be made it can be created in geometry section in Design modeler or space claim.

Step 3: In model section after import of component

• Material is assigned to component as per existing material

• Connection is checked in contact region i.e. bonded, frictionless, frictional, no separation etc. for multi body components.

• Meshing or discretization is performed i.e. to break components in small pieces (elements) as per size i.e. preferably tetra mesh and hexahedral mesh for 3D geometry and for 2 D quad or trial are generally preferred.

Step 4: Boundary condition are applied as per analysis namely in fixed support, pressure, force, displacement, velocity as per condition.

Step 5: Now problem is well defined and solve option is selected to obtain the solution in the form of equivalent stress, strain, energy, reaction force etc.

2.3.1 Martial Properties :

Properties of Outline Row 3: HSS STEEL

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	8150	kg m^-3
4	Isotropic Elasticity		
5	Derive from	Young's Modulus and Po...	
6	Young's Modulus	2E+11	Pa
7	Poisson's Ratio	0.28	
8	Bulk Modulus	1.5152E+11	Pa
9	Shear Modulus	7.8125E+10	Pa

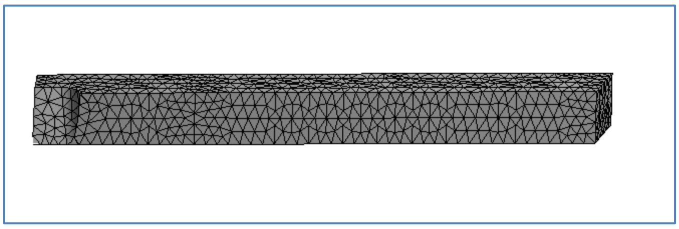
2.3.2 MODAL ANALYSIS OF LATHE CUTTING TOOL

Modal analysis is a process of extracting modal parameters (natural frequencies, damping loss factors and modal constants) from measured vibration data. Since the measured data can be in the form of either frequency response functions or of impulse responses, there are frequency domain modal analysis and time domain modal analysis. The fundamental of modal analysis using measured frequency response function data is about curving fitting the data using a predefined mathematical model of the measured structure. This model assumes the number of DOFs of the structure, its damping type and possibly the number of vibration modes within the measured frequency range. These assumptions should dictate the mathematical expression of each FRF curve from measurement. As a result, the subsequent work will be a curve fitting process trying to derive all modal parameters in a mathematical formula of an FRF using measurement data. The accuracy of modal analysis is not a simple question of how a measured FRF curve is best fitted in a pure mathematical sense. Obviously, the more accurate the measured FRF data are, the better chance we have to get more accurate curve fitting. In mathematics, the accuracy or successfulness of a curve-fitting Endeavour can usually be appraised by defining an error function and aiming to minimize it. This approach is only valid if the correct mathematical formula is used in the curve fitting. If, however, an incorrect mathematical model is used, the curve-fitting outcome is doomed to be a bad one if not a failure, even if the error function is actually minimized numerically. Every object has an internal frequency (or resonant frequency) at which the object can naturally vibrate. It is also the frequency where the object will allow a transfer of energy from one form to another with minimal loss. As the frequency increases towards the "resonant frequency," the amplitude of response asymptotically increases to infinity. In other words, the results of the modal analysis are these frequencies at which the amplitude increases to infinity.

Every system can be described in terms of a stiffness matrix that connects the displacements and forces. These frequencies are known as natural frequencies of the system and are provided by the eigenvectors of the stiffness matrix. These frequencies are also known as the resonant frequencies.

2.3.3 MESH

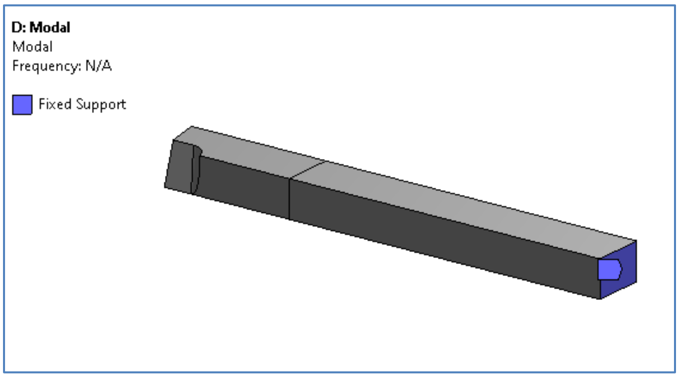
ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multi physics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.



Statistics	
Nodes	15812
Elements	10176

BOUNDARY CONDITIONS

Fixed support is applied at both sides of tool as per existing mounting condition



MODE SHAPES RESULTS

MODE SHAPE 1

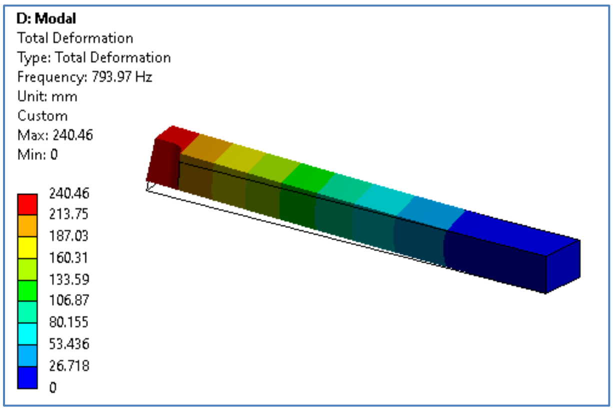


Fig. Natural frequency of lathe cutting tool at mode shape 793.97 Hz

MODE SHAPE 2

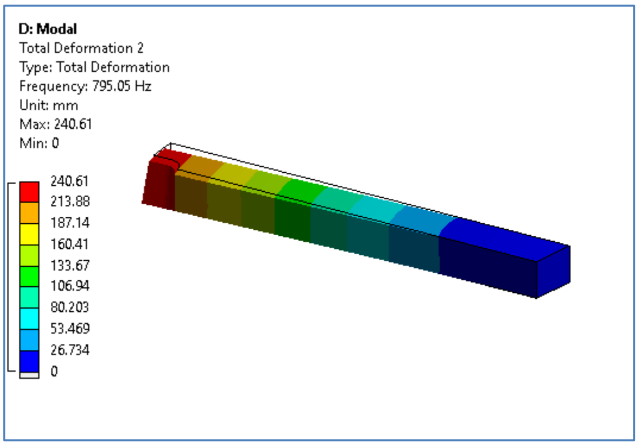


Fig. Natural frequency of lathe cutting tool at mode shape 2 was 795.05 Hz

MODE SHAPE 3

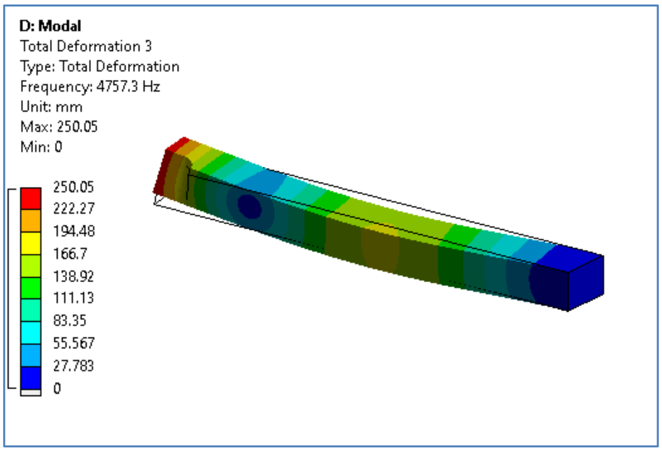


Fig. Natural frequency of lathe cutting tool at mode shape 3 was 4757.3 Hz

MODE SHAPE 4

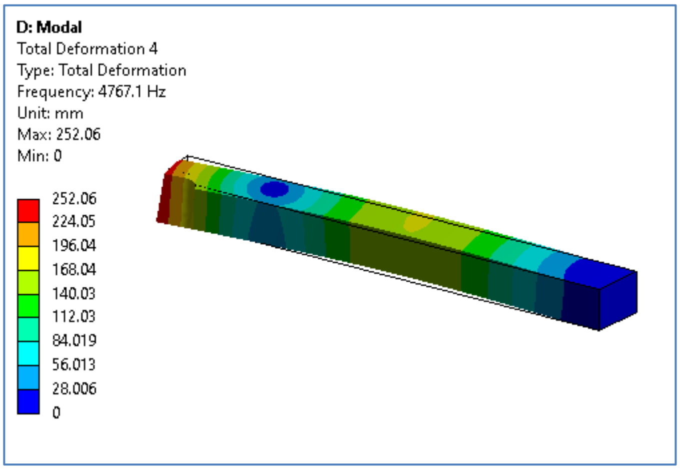


Fig. Natural frequency of lathe cutting tool at mode shape 4 was 4767.1 Hz

MODE SHAPE 5

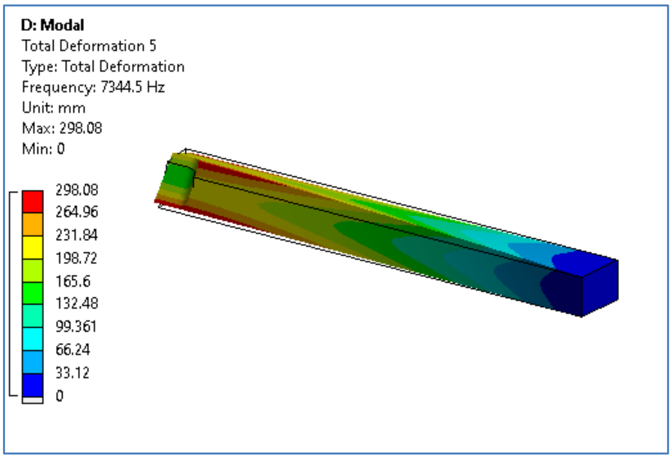
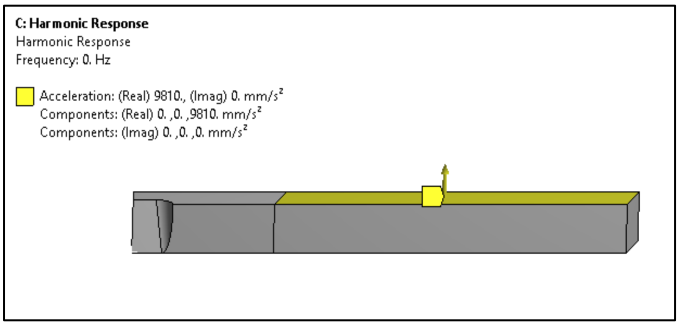


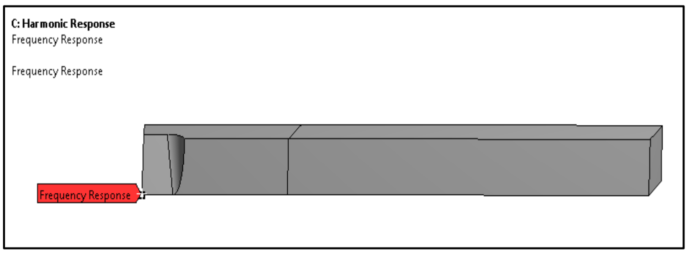
Fig. Natural frequency of lathe cutting tool at mode shape 5 was 7344.5 Hz

2.3.4 HARMONIC ANALYSIS OF CUTTING TOOL

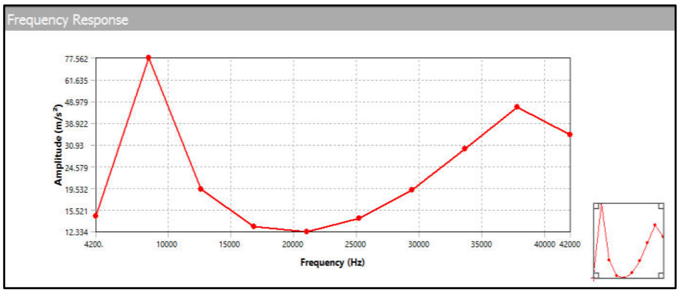
Harmonic response



Frequency response is calculated at tip to determine peak acceleration



Graph



Frequency Vs Amplitude

Maximum acceleration is observed around 77 m/s^2

2.4 EXPERIMENTAL TESTING

Fast Fourier Transform

The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzers.

Fourier analysis of a periodic function refers to the extraction of the series of sines and cosines which when superimposed will reproduce the function. This analysis can be expressed as a Fourier series. The fast Fourier transform is a mathematical method for transforming a function of time into a function of frequency. Sometimes it is described as transforming from the time domain to the frequency domain. It is very useful for analysis of time-dependent phenomena.

Impact Hammer Test

Impact excitation is one of the most common methods used for experimental modal testing. Hammer impacts produce a broad banded excitation signal ideal for modal testing with a minimal amount of equipment and set up. Furthermore, it is versatile, mobile and produces reliable results. Although it has limitations with respect to precise positioning and force level control, overall its advantages greatly outweigh its disadvantages making it extremely attractive and effective for many modal testing situations.

A phenomena commonly encountered during impact testing is the so called "double hit". The "double hit" applies two impulses to the structure, one initially and one time delayed. Both the temporal and spectral characteristics of the "double hit" input and output are significantly different than a "single hit". The input force spectrum for the "double hit" no longer has the wide band constant type characteristics of a single hit. The purpose of this paper is to examine the use of impact vibration testing in relation to the constraints imposed by typical FFT' signal processing techniques. The characteristics of the impact testing procedure are examined with analytical time and spectral functions developed for an idealized test: a single degree of-freedom system excited by a half sine impact force. Once an understanding of the fundamental characteristics is developed it is applied to examine the specific situations encountered in structural impact testing. The relationship of the system's parameters with respect to data capture requirements is evaluated. The effects of exponential windowing are developed to examine the effects on the estimated spectra and modal parameters. Finally, the "double hit" phenomena is examined by combining the results from the single degree-of-freedom system excited by two impulses, one of which is time delayed. The results from these related studies are combined to provide insight into data acquisition guidelines for structural impact testing.

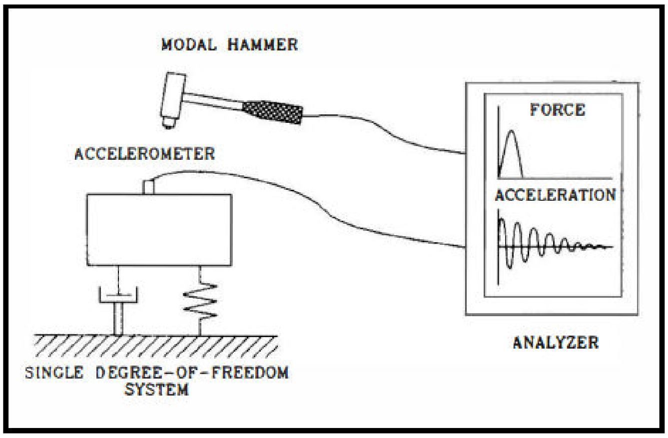


Fig 15: FFT construction

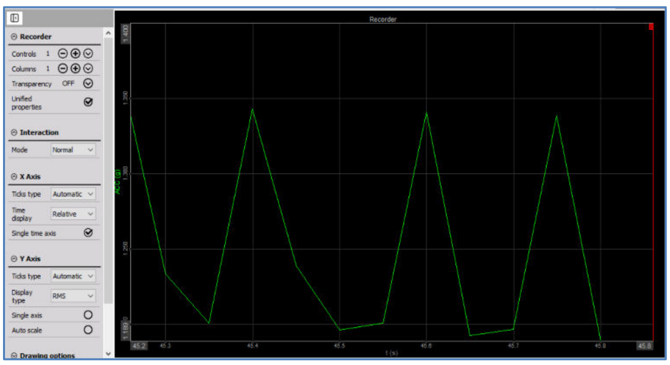


Fig. FFT result for dry testing

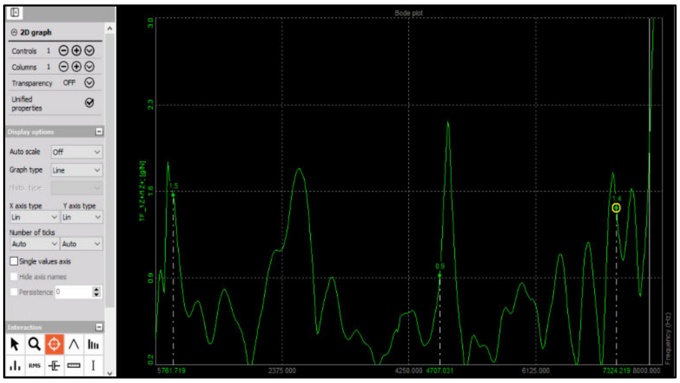


Fig. FFT plot of natural frequency

MODE SHAPE	FEA	EXPERIMENTAL
1	793.97	761.71
2	795.05	761.71
3	4757.3	4707.03
4	4767.1	4707.03
5	7344.5	7324.0

Chart. Comparison between FEA and experimental result

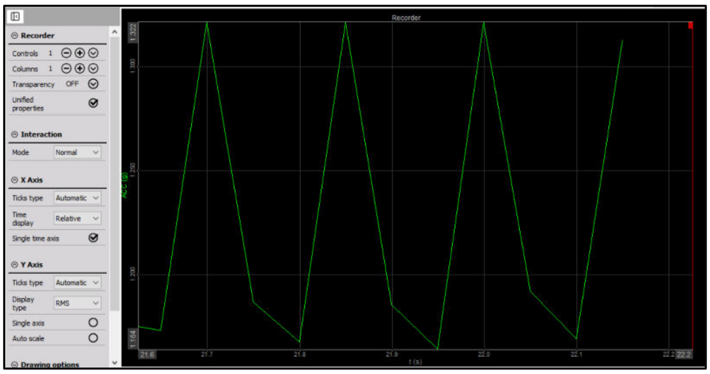
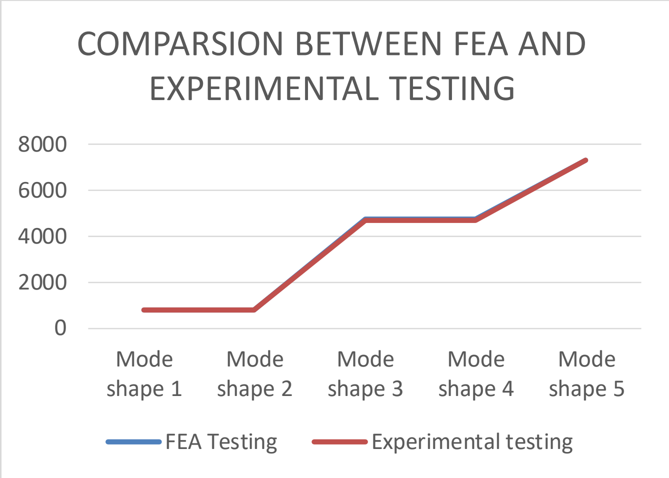


Fig. Experimental result of turning FFT

3. CONCLUSIONS

The optimize the Surface roughness of the turning process.

- The optimization result for MS is:
- Speed = 424 RPM, Feed = 0.10 Depth of Cut = 2.0
- From FEA modal analysis it concludes that natural frequency of lathe cutting tool at mode shape is maximum that is 7344 Hz.
- harmonic analysis of lathe cutting tool conclude that Maximum acceleration is observed around 77 m/s^2



Graph. FEA and Experimental natural frequency graph

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REFERENCES

1. Hu Luokea, Tang Renzhong "Optimisation of cutting parameters for improving energy efficiency in machining process" Robotics and Computer Integrated Manufacturing 59 (2019) 406–416
2. " Rogério Pontes Araújo , Tiago L Rolim "Analysis of the surface roughness and cutting tool wear using a vapor compression assisted cooling system to cool the cutting fluid in turning operation Journal of Manufacturing Processes 44 (2019) 38–46
3. Shuang Yia, Jinjin Lia, "Investigation of machining Ti-6Al-4V with graphene oxide nanofluids: Tool wear, cutting forces and cutting vibration" Journal of Manufacturing Processes 49 (2020) 35–49
4. Hakan Arslan and Ali Osman Er Tool Condition Monitoring in Turning Using Statistical Parameters of Vibration Signal International Journal of Acoustics and Vibration, Vol. 21, No. 4, 2016 (pp. 371_378) https://doi.org/10.20855/ijav.2016.21.4432
5. JUAN C. JÁUREGUI " Frequency and Time-Frequency Analysis of Cutting Force and Vibration Signals for Tool Condition Monitoring " 2169-3536 2018 IEEE. March 9, 2018. Digital Object Identifier 10.1109/ACCESS.2018.2797003
6. Farhana Dilwar, Rifat Ahasan Siddique, "Analyzing the Effect of Overhang Length on Vibration Amplitude and Surface Roughness in Turning AISI 304" International Journal of Scientific & Engineering Research, Volume 9, Issue 6, June -2018 IISSN 2229-5518
7. Balla Srinivasa Prasad ⇑, M. Prakash Babu "Correlation between vibration amplitude and tool wear in turning: Numerical and experimental analysis" Engineering Science and Technology, an International Journal xxx (2016)
8. Sadaf Zahoor1 & Nadeem Ahmad Mufti Int J Adv Manuf Technol "Effect of machine tool's spindle forced vibrations on surface roughness, dimensional accuracy, and tool wear in vertical milling of AISI P20" (2017) 89:3671–3679 DOI 10.1007/s00170-016-9346-1