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INVESTIGATION OF THE DIFFERENT MODE SHAPE AND FREQUENCIES OF A LATHE MACHINE BY FINITE ELEMENT MODAL ANALYSIS

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Abstract: *The paper presents a systematic procedure and details of the analytical modal analysis technique for dynamic evaluation processes of a lathe machine. The main results deal with assessment of the mode shape of the different components of the lathe machine. The model of the different dominating components of the lathe machine is made by design software AutoCAD and analyzed by finite element simulation using Finite Element software to extract the different theoretical mode shape of the components. The analysis resulted in determination of the direction of the maximal compliance of a particular machine component.*

Key words: *Experimental modal analysis, vibration, Lathe machine, mode shape*

1. INTRODUCTION

The dynamic behavior of a structure in a given frequency range can be modeled as a set of individual modes of vibration. The parameters that describe each mode are: natural frequency or resonance frequency (modal) damping mode shape these are called the modal parameters. By using the modal parameters to model the structure, vibration problems caused by these resonances (modes) can be examined and understood [1-2].Vibration occurring on machine tools has been being a serious problem for engineers for more than one century. Undesired relative vibrations between the tool and the work-piece jeopardize the quality of the machine surfaces during cutting. Modal analysis is a process whereby a structure may be defined in terms of its natural characteristics which are the frequency, damping and mode shapes –its dynamic properties. Since all bodies have both mass and elasticity, they are capable of vibration. Therefore, most engineering structures and machines experience some form of oscillatory motion. To better understand any structural vibration problem, the resonances of a structure need to be identified and quantified. A common way of doing this is to define the structure's modal parameters. Static and dynamic deformations of machine tool, tool holder and cutting tool play an important role in tolerance integrity and stability in a machining process affecting part quality and productivity.

Many researchers [3-4] tried to analysis the static and dynamic analysis of the structure involved in machining system by resting using stiffness measurements and modal analysis. Anayet U Patwari et al have observed that chatter arising during end milling and turning is a result of resonance, caused by mutual interaction of the vibrations due to serrated elements of the chip and the natural vibrations of the system components, e.g. the spindle and the tool holder [5-7]. The chatter phenomena were indicated by the some of the researchers as a resonance effect where system components played a vital role. So it is important to extract the accurate mode shape of the dominating components of machine structure to identify the chatter formation causes [8]. The paper is focused at dynamic properties of a vertical Lathe machine, namely at the resonance frequencies and vibration shapes of a Lathe machine components.

2. SIMPLIFIED MODAL ANALYSIS OF LATHE MACHINE

Aiming to investigate the vibration phenomena occurring occasionally at the different components of Lathe machine an analytical modal analysis was performed. The study focused on extracting the mode shape of the dominating components of the Lathe machine. In a first step, the dynamic behavior of the machine components was simulated using an FE model. In order to obtain an equivalent model which agrees with the practicable machining state, a FEA model is set up first to get the theoretical natural frequency and mode shape. The combined amendment procedure and the solid model of the different parts of the Lathe machine are presented in Fig. 1.

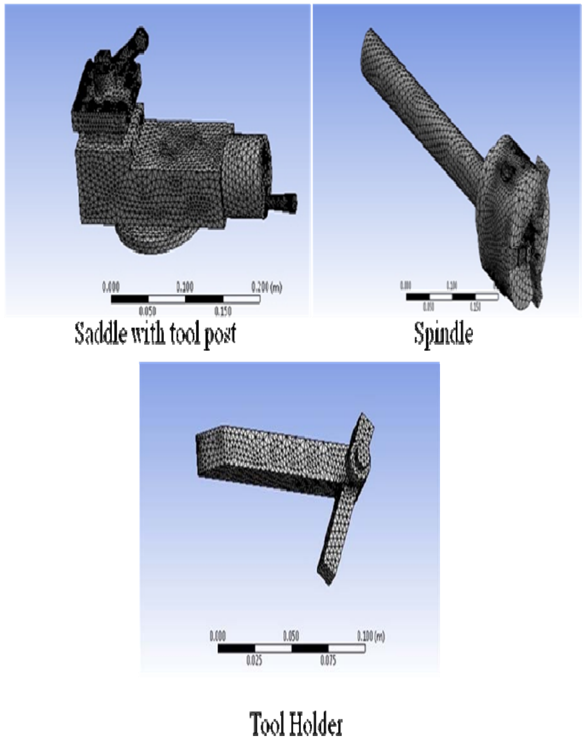


Fig.1: Solid model of different parts of lathe machine

In order to make a finite element model, a three dimensional geometrical model of machine's structure was generated by AutoCAD software. This model provides natural values and response frequency extraction. The observation of vibration modes of machine tool components are three-dimensional shapes which provides better capability to analysis of vibration model. The model is applied on Lathe machine. After modeling selection, the necessary input data as material properties such as modulus of elasticity, Poisson ratio and density is applied. The elements used in the FEM model for mesh generation is quadratic tetrahedral element. The element distribution is uniform to exceed boundary and it is so that in the parts with relatively small dimensions like spindle, tool holder etc. The element dimensions are finer and controlled. Afterwards, boundary conditions on supporting are applied on the earth connection of machine tool and finally modal analysis has been done to obtain natural frequencies.

3. FE MODAL ANALYSIS

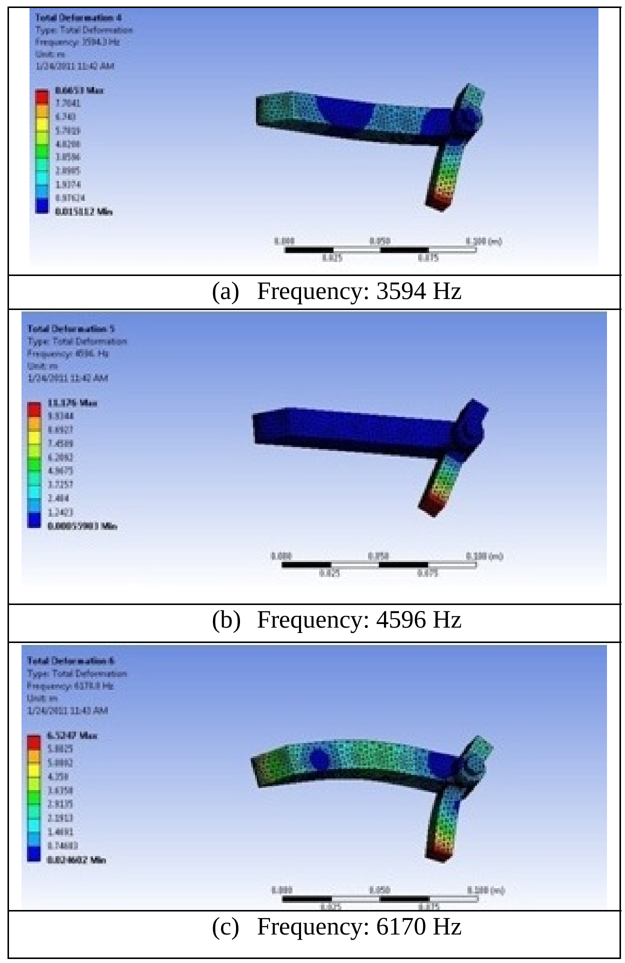
Modal analysis has been done on the three different components of Lathe machine using finite element model to determine the natural frequency of machine tool structure elements and to discrete them from each other. These models are as follows:

- Model No. 1: Complete model of Saddle with tool post.
- Model No. 2: Complete model of spindle.
- Model No. 3: Complete model of tool holder.

The element used in this analysis is quadratic tetrahedral element. As the boundary conditions the nodes' displacements *x*, *y* and *z* of the surface of lathe components, is constrained according to the actual contact state. Centrifugal force is considered in analyses, three steps are taken namely load, load centrifugal force to get the pre-stress, and then have modal analysis. In ANSYS, the loading of centrifugal force is obtained by defining the angular velocity of model.

4. RESULTS AND DISCUSSION

The Finite element modal analysis and their corresponding mode frequencies with the mode shape are shown in Fig. 2-4 below. Figure 2 shows the calculated distortion of the element mesh for the tool holder used in lathe machine. The results of analysis of the calculated mode shape are mentioned with their different dominating mode frequencies.



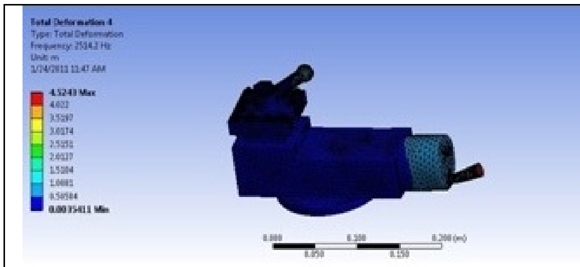
(a) Frequency: 3594 Hz

(b) Frequency: 4596 Hz

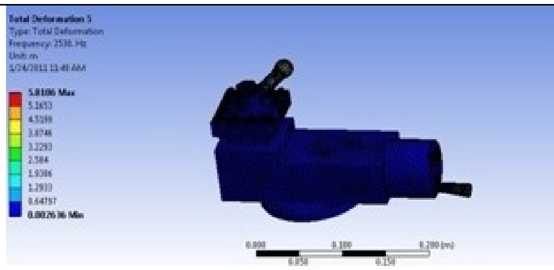
(c) Frequency: 6170 Hz

Fig.2: (a-c) Selected Eigen modes of the tool holder by FE Analysis

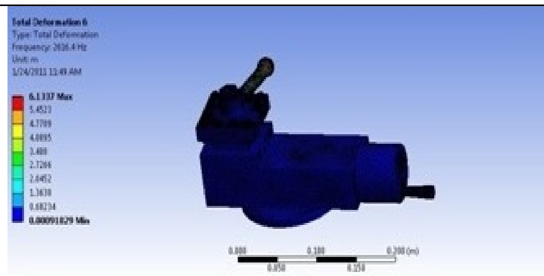
From the calculated results it has been observed that three mode frequencies are very much dominated for tool holder. The different dominating mode frequencies for the tool holder are 3594, 4596 and 6170 Hz.



(a) Frequency: 2514 Hz



(b) Frequency: 2530 Hz

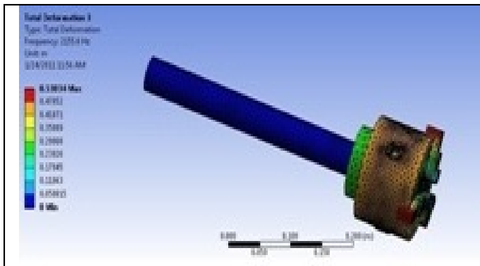


(c) Frequency: 2616 Hz

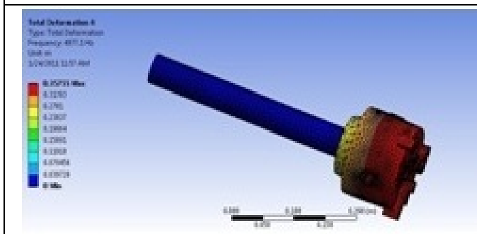
Fig.3: (a-c) Selected Eigen modes of the saddle with tool post by FE Analysis

Finite element analysis of the saddle with the tool post is performed using ANSYS. The calculated distortions of the each element are shown in Fig.3 (a-c) at different mode shapes. The elements used in the FEM model for this mesh generation are also quadratic tetrahedral element. It has been observed from the calculated results that there is few prominent mode shape of the saddle with the tool post but all the mode lies in between 2500 Hz to 2600 Hz.

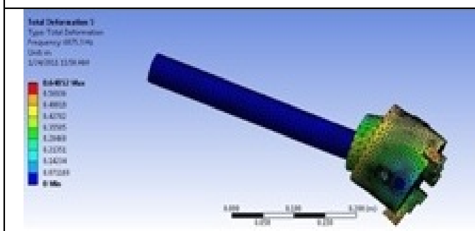
The calculated distortions of the each element for spindle of a lathe machine are shown in Figure 4. It has been observed form the calculated results that there are four prominent mode shape of the spindle. In most of the mode shape the distortion is significant. The different mode shape varies from 2155 Hz to 6900 Hz. FEA is carried out to get the theoretical natural frequency and mode shape of the turning machine components. The natural frequencies obtained from FEA are shown in the Table 1.



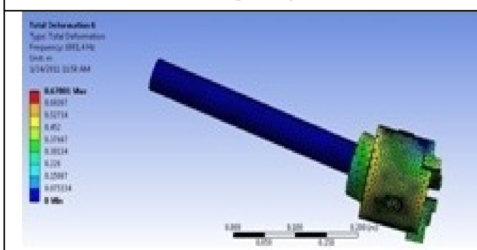
(a) Frequency: 2155 Hz



(b) Frequency: 4977 Hz



(c) Frequency: 6875 Hz



(d) Frequency: 6881 Hz

Fig.4: (a-d) Selected Eigen modes of the spindle by FE Analysis

Table1: Prominent Frequencies analysis of Lathe components

	Different Major Mode Shape [Hz]			
Parts	**1st**	**2nd**	**3rd**	**4th**
Tool holder	3594	4596	6170	-
Saddle with Tool post	2514	2530	2616	-
Spindle	2155	4977	6875	6881

The second and third vibration mode of tool holder is almost similar to the second and third vibration mode of spindle respectively. The vibration frequency region of spindle model is much higher than the vibration frequencies of tool holder and tool post.

5. CONCLUSIONS

In this paper a finite element model is used to analysis the mode frequencies and shapes of different machining components. This model is produced in AutoCAD software based on the real dimensions of Lathe machine and analysis was done by ANSYS software. According to the modal analysis, the natural frequencies and vibration modes shape of the model in spindle, tool holder and tool post were determined and then evaluated. From the results, it has been observed that the suitable frequency ranges for turning will be up-to 7000 Hz. This research work will help to find out the natural frequencies of the machining components.

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