

Vibration Isolation of Grinding Machine Structure Subjected to Forced Vibrations

Rajashri T. Patil¹, R. B. Barjibhe², A. V. Patil³

¹Research Scholar, ²PG Coordinator, ³Head, Department of Mechanical Engineering, SSGB, COET, Bhusawal, Jalgaon (MS), India

Abstract-- The aim of this Project is to the application of ANSYS software to determine the natural vibration modes and find the free frequency of the Industrial Pedestal grinder Mounted on fabricated welded structure. The effect of vibrations transmitted to the structure is weakening the welded joints and also effecting on accuracy of the component due to vibration. Pedestal grinder running constant speed by finding natural frequency of the Pedestal grinder component in order to prevent resonance generated or vibration generated by grinder body which cause the failure Welded structure below it, the trial has made to improve the life of that structure by providing intermediate isolation material like Rubber, plywood and thick cotton sheet, and find out that the most suitable intermediate material us for the vibration isolation.

Keywords: ANSYS, isolation material, natural frequency, resonance, structure, vibration, etc.

I. INTRODUCTION

A] Vibration

Any motion which repeats itself after a certain interval of time is called vibration. The swing of pendulum is a typical example of vibration. The theory of vibration deals with study of oscillatory motions of bodies and the forces associated with them. A vibration can caused due to external unbalanced force also. A vibratory system, in general, includes elastic member for storing potential energy, a mass or inertia member for storing kinetic energy and damper by which gradual loss of energy takes place. A simple pendulum as shown in Figure 1 is an example of vibration system. Pendulum has a string for elastic nature, mass of bob acts as a means for kinetic energy. Like pendulum, spring-mass system, vehicle suspension system, simply supported and cantilever beam, lateral vibrating string, vibration due to unbalance reciprocating or rotating force, etc. are the examples of vibrating system.

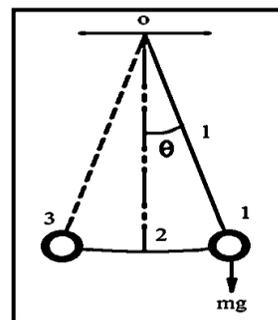


Figure 1 Free Vibrations of Simple Pendulum

B] Problem Definition

Vibrations are important in some applications like vibration conveyer, for separation of grains from agricultural waste, etc. The time domain of vibrations shows that the vibrations are helpful for future inventions. But excessive vibrations leads to resonance of mechanical system which in turn to failure of mechanical system under vibration.

Taking simple application of machining like grinding. In grinding, the small part of cutting tools are finished to obtain desired cutting edge. Today's grinders are built up on a fabricated welded structure for sake of convenience. Such grinders have speed range from 2000 RPM to 10000 RPM. Due to this high speed, the dynamic motion of the grinder is directly transmitted to the structure and structure vibrates with certain frequency. If this frequency of excitation of structure coincides with natural frequency of grinding structure the structure vibrates with maximum amplitude results in resonance phenomenon. This resonance may cause damage to the grinding structure.

Certain techniques are used to avoid such failures due to resonance either by placing rubber pads or other material in between grinder and structure. This technique is known as vibration isolation. The vibration isolation has two types which are passive vibration isolation and active vibration isolation.

In passive type isolation the rubber pads and cotton type materials are used to avoid transmission of excessive vibrations to structure. These elements provides certain type of damping to vibrations. "Passive vibration isolation" refers to vibration isolation or mitigation of vibrations by passive techniques such as rubber pads or mechanical springs, as opposed to "active vibration isolation" or "electronic force cancellation" employing electric power, sensors, actuators, and control systems.

The present study includes the study of vibration isolation with combined isolating material and piezoelectric material. The analytical model has created with theoretical data and evaluated by standard vibration analysis method. To validate the result, software modelling has performed in CATIA V5R19 and analyze in ANSYS 15.0 to obtain results. The FFT analysis also performed to validate the result and measuring the actual frequency of vibration of grinding structure.

II. PROPOSED METHOD

Pedestal grinder or bench grinder (Figure 2) is a type of bench top grinding machine used to drive abrasive wheels. A pedestal grinder is a larger version of a bench grinder that is mounted on a pedestal, which is bolted to the structure on floor. These types of grinders are commonly used to hand grind cutting tools and perform other rough grinding.

Depending on the grade of the grinding wheel it may be used for sharpening cutting tools such as lathe tools or drill bits. Alternatively it may be used to roughly shape metal prior to welding or fitting. A wire brush wheel or buffing wheels can be interchanged with the grinding wheels in order to clean or polish work-pieces.

Grinding wheels designed for steel should not be used for grinding softer metals, like aluminum. The soft metal gets lodged in the pores of the wheel and expands with the heat of grinding. This can dislodge pieces of the grinding wheel.

A mathematical model is base for studying the various properties of vibration. So, mathematical model has created by using various stiffness and damping properties. Solving the mathematical model for grinder to calculate the natural frequency and force transmitted.

Geometric modeling shows the better results for analyzing the objects. Therefore, a solid model has created in CATIA V5R19 by using certain geometric modeling commands. The solid model is then imported in ANSYS Workbench to observe the vibrations of structure. Then modal ansys has carried out to find the natural frequency of the model.

The boundary conditions are given as fixed at base and free at the connection between grinder and structure.

The typical model of grinder with structure is shown in figure 2. For our experiment we use the grinder as per following details.

- Power: 0.55 Watt or 0.75 hp,
- Speed: 3000 RPM,
- Made: Mahalakshmi pvt. Ltd.,
- Shaft Dia.: 20 mm,
- Wt.: 35 Kg,
- Mount: Mounted of Fabricated Welded Structure.

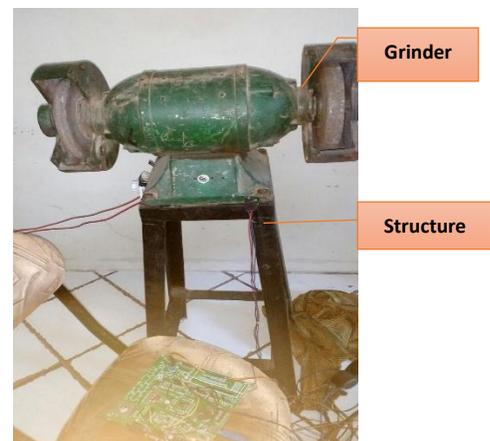


Figure 2 Grinder Assembled on Structure

III. THEORETICAL BACKGROUND

A. Equation Of Motion For Forced Vibration

Here the equation of motion for forced damped vibration has discussed with single degree of freedom system. Consider the system shown in figure 3.

Let,

The mass of grinder = M Kg,

The cyclic load on structure = $F \sin(\omega t) = M g \sin(\omega t)$,

Stiffness of structure = K_{st} ,

Damping Coefficient of structure = C_{st}

Consider the mass is slightly deflected by X , and then equation of motion for the system can be written as,

$$M\ddot{X} + KX + C\dot{X} = F \sin(\omega t) \dots\dots\dots \text{(Equation 1)}$$

The steady state response of the system can be determined by solving equation (1) in many different ways. Here a simpler graphical method is used which will give physical understanding to this dynamic problem. From solution of differential equations it is known that the steady state solution (particular integral) will be in the form,

$$x = X \sin(\omega t - \phi) \dots\dots\dots \text{(Equation 2)}$$

As each term of equation (1) represents a forcing term viz., first term represent the inertia force, second term the spring force, third term the damping force and term in the right hand side is the applied force, one may draw a close polygon as shown in figure 4. Considering the equilibrium of the system under the action of these forces.

- Spring Force = $KX \sin(\omega t - \phi)$
 - Damping Force = $C\omega X \cos(\omega t - \phi)$
 - Inertia Force = $-M\omega^2 X \sin(\omega t - \phi)$
- The imperial relations are,

$$\omega_n = \sqrt{K/M} \dots\dots\dots \text{(Equation 3)}$$

$$\text{Critical Damping coefficient} = C_c = 2M\omega_n \dots\dots\dots \text{(Equation 4)}$$

$$\text{damping factor} = \epsilon = \frac{c}{C_c} \dots\dots\dots \text{(Equation 5)}$$

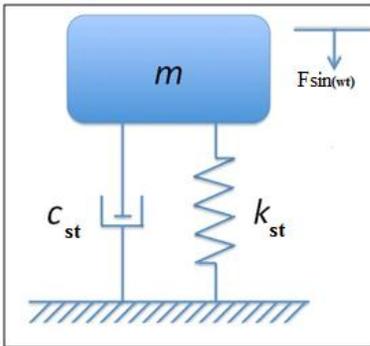


Figure 3 Forced Damped Vibration of Structure

$$\text{Frequency ratio, } r = \frac{\omega}{\omega_n} \dots\dots \text{(Equation 6)}$$

$$\frac{C\omega}{K} = 2\epsilon r \dots\dots\dots \text{(Equation 7)}$$

So, from figure 3.2, the amplitude of vibration can be calculated as,

$$X = \frac{F}{\sqrt{(K - M\omega^2)^2 + (C\omega)^2}} \dots\dots \text{(Equation 8)}$$

Or, we can write,

$$\frac{X}{X_{st}} = \frac{1}{\sqrt{(1-r^2)^2 + (2\epsilon r)^2}} \dots\dots\dots \text{(Equation 9)}$$

And phase difference is given by,

$$\phi = \tan^{-1} \left(\frac{2\epsilon r}{1-r^2} \right) \dots\dots\dots \text{(Equation 10)}$$

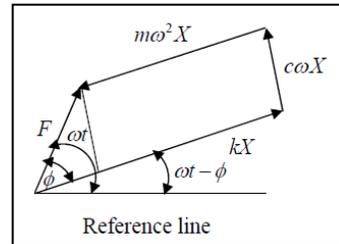


Figure 4 Force polygon

A Natural Frequency is the key point for obtaining and comparing the results from FEA. So here, natural frequency and its three mode shapes are considered for the analysis of the system. The natural frequency is calculated by conventional technique.

The properties are taken from table 1. The three modes of vibration is calculated and shown in table 2.

**Table 1
Properties of materials**

Sr. No.	Material	Young Modulus [GPa]	Stiffness 10 ⁶ [N/M]	Damping Factor
1	Structural Steel	200	250	0.00
2	Rubber Pad	0.05	102	0.15
3	Plywood Pad	11	15400	0.07
4	Cotton Pad	3	720	0.05

IV. FINITE ELEMENT ANALYSIS

In the finite element method, the actual continuum or body of matter like solid, liquid or gas is represented as an assemblage of sub-divisions called finite elements. These elements are considered to be interconnected at specified joints which are called 'nodal points' or nodes. The nodes usually lie on the elements boundaries where adjacent elements are considered to be connected. Since the actual variation of the field variable (displacements, stress, temperature, pressure, velocity) inside the continuum is not known, we assume that, the variation of the field variable inside a finite element can be approximated by a simple function. These approximating functions (are called interpolating models) are defined in terms of field variables at the nodes. When field equations for the whole continuum are written, the new unknowns will be the nodal values of the field variable.

By solving the field equations, which are generally in the form of matrix equation, the nodal values of the field variables will be known. Once these are known, the approximating functions define the field variables throughout the assemblage of elements.

A. Modal Analysis Of Structure

Finite element analysis has been carried out by ANSYS 15 software. ANSYS is a general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems.

Here the structure is discretized into approximately 3145 elements having 8633 nodes by default meshing of tetrahedral and mesh size is 2 mm. The solution is obtained by using ANSYS Work Bench modeler. The 20 modes of natural frequencies are found out and from the resulted data, the comparison has made among the all types of insulating materials. The results are tabulated in Table 2.

Following steps show the guidelines for carrying out Modal Analysis.

Define Materials

1. Set preferences. (Structural steel, rubber, plywood, and cotton)
2. Define constant material properties. (Density, Young's modulus, Poisson's ratio, damping ratio)

Model the Geometry

3. Follow bottom up modelling and create/import the geometry.

Generate Mesh

4. Define element type. (Default mesh of element size 2 mm)
5. Mesh the area.

Apply Boundary Conditions

6. Apply constraints to the model. (Fixed support, Rotational velocity and Damping properties)

Obtain Solution

7. Specify analysis types as Modal ANSYS and options. (Modal ANSYS up to 20 modes)
8. Solve

The ANSYS 15 finite element program was used for modal analysis of structure. For this purpose, the total 4 models are created depending on isolating materials in CAD software (CATIA) and imported in ANSYS (.iges file). Each model have fixed at bottom and rotational velocity at top surface.

The figure 5 represents the sample modal analysis for calculation of all types of structure. The table 2 shows the tabulated data of finite element formulation for all types of models.

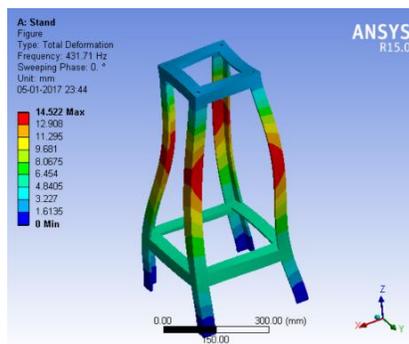


Figure 5 Sample Mode of Natural Frequency by ANSYS

**Table 2
Comparison of Results from Theoretical and ANSYS Solution**

Material	Numerical			ANSYS		
	FNF [Hz]	SNF [Hz]	TNF [Hz]	FNF [Hz]	SNF [Hz]	TNF [Hz]
Stand	404	595	825	431	608	768
Rubber Pad	218	320	444	168	343	411
Plywood	400	590	818	412	585	790
Cotton Pad	348	513	710	343	485	705

V. CONCLUSION

Following are the conclusions drawn from this study.

1. Vibration is one of the important phenomena to design the structure.
2. Presence of vibrations leads to the damage of structure.
3. It is always required to damp these vibrations at certain level so that the structure is safe from resonance.
4. It is conclude that from table 2, rubber pad is most suitable material for sustaining the vibrations due to grinding machine operation.

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5. The damped frequency is lower which shows that lesser force will be transmitted to the structure.
6. It is also concluded that, Finite Element Analysis is one of the effective software tools to perform Modal Analysis.

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