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ROLE OF VIBRATION ANALYSIS TO FIND NATURAL AND RESONANT FREQUENCY OF EXCAVATOR BUCKET AND ITS OPTIMIZATION

Mr. Jay V. Awdhut[1], Mr. Anis Ahmad M. Shaikh[2], Mr. Saurabh M. Thakare[3], Mr. Ajinkya V. Nardange[4]

[1]*Student, Department of Mechanical Engineering, JDIET, Yavatmal,Maharashtra,India,* **ajayawdhut@gmail.com**

[2]*Student, Department of Mechanical Engineering, JDIET Yavatmal,Maharashtra,India,,* **anisahmadsm@gmail.com**

[3]*Student, Department of Mechanical Engineering JDIET Yavatmal,Maharashtra,India,,***saurabh.thakare1995@gmail.com**

[4]*Student, Department of Mechanical Engineering, JDIET ,Yavatmal,Maharashtra,India ,* **najv44@gmail.com**

Abstract

Excavator bucket is designed for heavy duty work. Hence the sudden jerks, stresses, deformations are usually accurse during working. Due to sudden jerks and impact with rocks or tough materials, vibrations induce. This vibration is measured in the form of natural frequency of a bucket. Continuous impact of such vibration range may affect the bucket life. And hence the cracks can be developed which leads to failure of bucket. There is a particular range of frequency up to which bucket can withstand. But beyond that range bucket may fails. Hence the study of resonant frequency also an important aspect for excavator buckets.

In this paper the excavator bucket virtual model is prepared with the help of CAE tool and brought to CAE software's. Maximum range of frequency set is obtained for excavator bucket and further conclusions are drawn.

Index Terms: *CAE Software, CAD model, ANSYS, Loading Conditions*

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1. INTRODUCTION TO NATURAL, HARMONIC AND RESONANT FREQUENCY

- **NATURAL FREQUENCY CONCEPT:**

Natural frequency, also known as **Eigen frequency**, is the frequency at which a system tends to oscillate in the absence of any driving or damping force. The motion pattern of a system oscillating at its natural frequency is called the normal mode. If the oscillating system is driven by an external force at the frequency at which the amplitude of its motion is greatest (close to a natural frequency of the system), this frequency is called resonant frequency.

- **HARMONIC FREQUENCY:**

For a simple harmonic oscillator the period r is given by:

$$r = 2\pi\sqrt{\frac{\mu}{k}}$$

Where k is the force constant. A molecule can absorb a photon that vibrates at the same frequency as one of its normal vibration modes. That is, if a molecule, initially in its ground vibration state, could be excited so that it vibrated at a given frequency, then that molecule could absorb a photon that vibrates at the same frequency. Although vibration frequencies are usually expressed as kilohertz or megahertz, in chemistry vibration frequencies are normally expressed in terms of the number of vibrations that would occur in the time that light travels one centimeter, i.e., ν = 1/cr Using this equation for simple harmonic motion, the vibration frequency can be written as:

$$\nu = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}.$$

In order for ν to be in cm-1, c, the speed of light must be in cm.sec-1, k, the force constant in erg/cm2, and μ the reduced mass in grams.

- **RESONANCE FREQUENCY:**

In mechanical systems, resonance is a phenomenon that occurs frequency at which a force is periodically applied is equal or nearly equal to one of the natural frequencies of the system on which it acts. This causes the system to oscillate with larger amplitude than when the force is applied at other frequencies.

Frequencies at which the response amplitude is a relative maximum are known as resonant frequencies or resonance frequencies of the system. Near resonant frequencies, small periodic forces have the ability to produce large amplitude oscillations, due to the storage of vibration energy.

1.1 Effect of Resonance Frequency on Object

In the resonance frequency, object deviates with its maximum amplitude. Hence it directly tends to maximum stresses. This stresses may damage the object. Hence the resonance frequency is always harmful for the object.
As far as excavator bucket is concern, it may damage the bucket and its teethes. Hence the study of resonant frequency is important.

1.2 Effect of Continuous Impact

Continuous impact of resonant frequency on any object, damages object. Greater the natural frequency safer the object. But continuous impact develops greater deviation for long period of time. This deviation develops the stresses and hence the object fails before designed life

1.3 Methods to Improve Natural Frequency

There are several methods of improvement of Natural Frequency of an object. Few of them are listed below.

- **Addition of stiffener:** By adding the stiffener at a specific location can improve the natural frequency of the excavator bucket. But it may create problem for the working of bucket. Hence stiffener may not be good idea to improve the natural frequency.
- **Dynamic Absorbers:** This method is also much effective to improve the natural frequency. But the problem is again same. i.e. installation of dynamic absorber may create problems for proper movement of excavator bucket.
- **Self Stiffness:** Improvement of stiffness of excavator bucket is an another option which is more reliable option which does not create any problem with the bucket movement and working.

2. LITRATURE SURVEY

There are several research papers are available regarding this topic. Some of them are focusing on the stability of bucket and others are focusing on dynamic balancing, vibrations, loading conditions.

2.1 Outcome from Literature Study

- ➢ Research on Natural frequency and resonant frequency of excavator bucket is needed more concentration.
- ➢ There is a large scope to improve the natural and harmonic frequency of bucket.
- ➢ Loading conditions should include the frequency generation during working of excavator bucket.

2.2 Aims and Objectives of study

- ➢ Vibration analysis performance on Excavator bucket.
- ➢ Review of vibration modes obtained from vibration analysis.
- ➢ Study of Natural and Harmonic frequency of bucket.
- ➢ Excavator bucket reconstruction support.

3. VIBRATION ANALYSIS USING CAE TOOL

3.1 CAD model preparation:

To prepare CAD model we have used small excavator bucket which is shown in Figure 3.1. This bucket is small in size and general bucket which is used in most of the operations.

Figure 3.1: Excavator Bucket.

Figure 3.2 shows the CAD model of excavator bucket which is developed by using CAD tool. Several commands are used to develop it like extrude, pocket, fillet, chamfer etc.

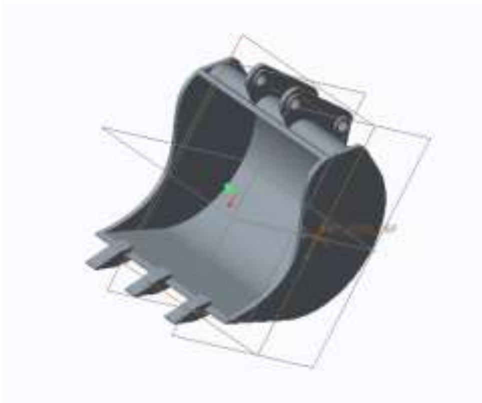

Figure 3.2: Excavator Bucket CAD model.

3.2 Conversion of CAD file

IGES (Initial Graphics Exchange Specification) is the neutral file format used for conversion and importing of CAD file into CAE tool.
Various formats are as follows : GLM , GRB , GTC , IAM , ICD , IFC , etc.

3.3 ANSYS as a CAE Tool

ANSYS software is used to design products and semiconductors, as well as to create simulations that test a product's durability, temperature distribution, fluid movements, and electromagnetic properties.

3.4 Required Material Properties

Following are the properties required for the vibration analysis.

Property	Value
Young's Modulus (E)	2.2e5 MPA
Poisson's Ratio	0.3
Density	7850 m^3

Table 3.1: Properties of Stainless Steel for Vibration Analysis.

4. 4. Result and Discussion

Results obtained by performing vibration analysis are listed below

- Frequency at mode 1 is 36.312 Hz and this is the natural frequency of bucket and deformation of bucket is 4.86mm.
- The frequency at mode 2, 3, 4, and 5 are 11.34Hz 97.93Hz, 127.09Hz and 215.37Hz respectively.
- Frequency at mode 6 is 216.04Hz and deformation is 8.130mm and it is the resonance frequency of the bucket if the frequency is increase above the resonance frequency the bucket will damage.

Sr. No.	Mode Shape	Frequency (Hz)	Deformation (mm)
1.	Mode 1	36.312	4.86
2.	Mode 2	51.353	11.34
3.	Mode 3	97.937	5.57
4.	Mode 4	127.09	5.53
5.	Mode 5	215.37	14.47
6.	Mode 6	216.04	8.103

Table 4.1: Frequency values at different modes.

4.1 Frequency and deformation

Total deformation obtained at different frequency mode is shown in following diagrams.

- At mode 1 the frequency of vibration is 36.312 Hz and deformation is 4.86mm and it is the natural frequency of the bucket as shown in fig.4.1
- At mode 2 the frequency of vibration is 57.353 Hz and deformation is 11.34mm and it is the natural frequency of the bucket as shown in fig.4.2
- At mode 3 the frequency of vibration is 97.937 Hz and deformation is 5.57mm and it is the natural frequency of the bucket as shown in fig.4.3
- At mode 4 the frequency of vibration is 127.09 Hz and deformation is 5.53mm and it is the natural frequency of the bucket as shown in fig.4.4
- At mode 5 the frequency of vibration is 215.37 Hz and deformation is 14.47mm and it is the natural frequency of the bucket as shown in fig.4.5
- At mode 6 the frequency of vibration is 216.04 Hz and deformation is 8.103mm and it is the natural frequency of the bucket as shown in fig.4.6 and it is the resonance frequency of bucket.

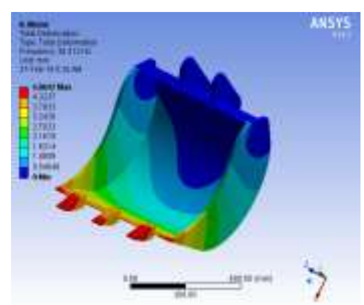

Figure 4.1: Deformation at mode shape 1

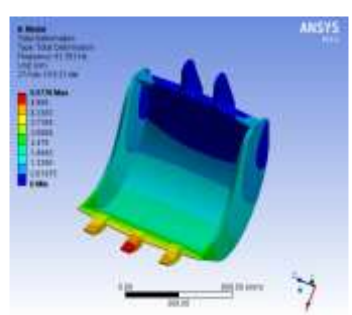

Figure 4.2: Deformation at mode shape 2

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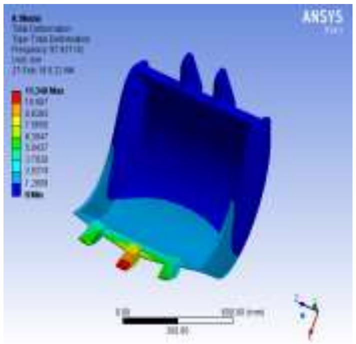

Figure 4.3: Deformation at mode shape 3

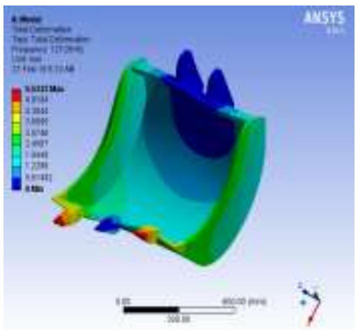

Figure 4.4: Deformation at mode shape 4

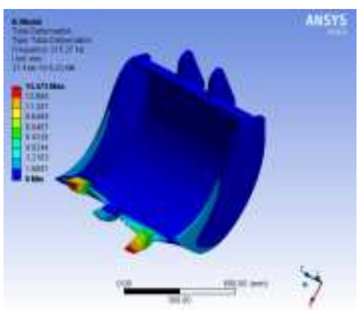

Figure 4.5: Deformation at mode shape 5

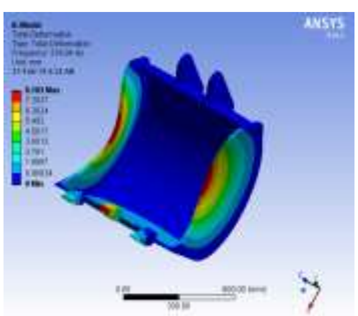

Figure 4.5: Deformation at mode shape 5

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4. RESULT AND DISCUSSION

Results obtained by performing vibration analysis are listed below

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- At mode 5 the frequency of vibration is 215.37 Hz and deformation is 14.47mm and it is the natural frequency of the bucket as shown in fig.4.5

- At mode 6 the frequency of vibration is 216.04 Hz and deformation is 8.103mm and it is the natural frequency of the bucket as shown in fig.4.6 and it is the resonance frequency of bucket.

5. CONCLUSION FROM STUDY

The maximum natural frequency of excavator bucket found to be 216 Hz at mode 6 and the maximum deformation is 14.47mm at mode 5. Also the dynamic stability can be improved by adding stiffness. Hence this analysis is useful for life and performance improvement of bucket.

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