Sample report on accelerometer experiment lab

Environment, Nature

ABSTRACT

In the vibrating beam experiment, an aluminum cantilever beam was made to vibrate. An accelerometer transducer was used to convert the mechanical vibrations into a signal that was fed into an oscilloscope via a power supply. The oscilloscope mapped the signal into a sine curve and displayed it on the screen.

The oscillations' decay curve was studied and the beam's damping ratio was determined. The decay curve's logarithmic decrement was used to determine the beam's damping ratio and its natural frequency.

The beam's damping ratio was observed to be underdamped at a damping ratio of 0. 0066.

LIST OF SYMBOLS

EModulus of Elasticity

IMoment of inertia

mMass

ζDamping Ratio

fFrequency

kSpring Constant

TTime

- INTRODUCTION

The vibrating cantilever beam experiment is under the study of vibrating systems that exhibit transient displacement. An accelerometer is used to measure the rate of change in displacement and how it varies with time.

- Objective

The objective of the experiment was to study the natural frequency and stiffness of a vibrating beam. This was done by observing and analyzing the decay curve of the oscillations of an underdamped system as it moves towards its equilibrium position

- Specific objective

- LITERATURE REVIEW

Damping ratio is used in engineering describes a dimensionless parameter which defines the decay in oscillations in a system that is not at rest. A system that is not in a position of static equilibrium exhibits oscillations. Oscillations decay as the system tries to regain equilibrium but shoots past the point of equilibrium. Energy losses in form of friction reduce the amplitude of the oscillations. The damping ratio is a measure of reduction in amplitude between successive peaks or crests of a sine wave plotted from the vibrations (1, p. 45). Oscillations are studied in a range of engineering disciplines such as mechanical, structural, electrical and control Engineering.

In a hypothetical situation where there are no losses, the system would oscillate infinitely. Such a situation is referred to as undamped system. If a vibrating system is subjected to very high losses such as vibrating in a heavy and viscous fluid, the body would slowly assume its equilibrium position without overshooting. This condition is referred to as an overdamped system. A system overshoots its resting position and then return again whereby it overshoots again. With each overshoot, energy is lost and the amplitude of oscillation declines steadily towards the horizontal zero line.

This situation is referred to as an underdamped system (2, p. 65).

A system that is neither underdamped nor overdamped is said to be critically damped. A critically damped system does not overshoot its resting position. The main difference between an overdamped system and a critically damped system is that a critically damped system assumes its resting position within the least time possible.

The damping ratio for an underdamped system is less than one while the ratio for an overdamped system is greater than one. The ratio for a critically damped system is 1 (2, p. 100).

When a beam vibrates with no damping force acting on it, it vibrates at a theoretical natural frequency.

- ANALYTICAL APPROACH

A cantilever beam is an example of a single degree of freedom (SDOF) system. Damping is caused by losses in energy in the beam material.

Equations used to describe oscillations are stated as:

K = 3EI/L3

Where k s the spring constant of the cantilever beam, E is the modulus of elasticity, L is the length of the beam, and I is the moment of inertia (4, p66).

The moment of inertia is given by, I = bh3/12

The theoretical natural frequency of abeam is given by

ftheo= 1/2π √(k/m)

Total mass of the system, m, is obtained by adding up all constituent weights.

Meq = mtip + maccel + 0. 23*mbeam

mtip is the mass at the tip of the beam.

The spring constant affects the nature of vibrations produced by a disturbance. A very high constant will produce displacement of minimal amplitude and very high frequency while a low constant will produce high displacement oscillations with very low frequency (2, p. 150).

The damping ratio (ζ) is determined by logarithmic decrement of the decay curve and is given as:

ζ= 1nlnVoVn1/2π

- EXPERIMENTAL PROGRAM

- Equipment used:

- Accelerometer

An accelerometer is used to measure acceleration. A mass is suspended within a casing and the force it exerts to the casing is measured by the use of a strain gauge. A strain gauge is a resistive element whose resistance changes linearly as it is stressed. Change in resistance is proportional to acceleration. Acceleration is equal to the output voltage from the sensor (3, p. 120).

Figure 1: An accelerometer

- Brass mass

- Oscilloscope

Figure 2: An oscilloscope

- Beam

- Stainless ruler
- Power unit
- Procedure

Figure 3: Experiment setup, connection between accelerometer, power unit, and oscilloscope

Figure 4: Experiment set up, image of an accelerometer loaded to a clamped cantilever beam

- Determine the beam’s thickness, width, length, and mass.
- Determine accelerometer model, mass, and sensitivity.
- Power the accelerometer from the mains by using the 10-32 mini connecter cable. Attach the cable to the accelerometer by twisting the knurled fitting only while keeping the rest of the cable still to avoid damage to the cable.
- Connect the output signal from the power supply to the oscilloscope by use of appropriate connection adapters.
- Configure the oscilloscope to triggered input and single mode capture as follows:
- Press save/recall
- Exit the menu
- Press measures button
- Set the offset voltage by selecting the menu button then the offset function. Adjust the offset voltage until its equal to an average of the maximum and the minimum.
- Exit menu.
- Adjust horizontal scale to 400 ms

- Deflect the beam by ¼” and then release it

- Data collection

The waveform displayed by the oscilloscope will be as shown

Figure 5: An Oscilloscope waveform trace of the accelerometer signal

Record successive maximum deflections for 5 cycles, V1 to V5

Record the period T for the sine wave

- RESULTS

- Actual data collected

Beam parameters

Voltage peak values

Assumptions

- The beam is made from aluminum and E= 71 GPa

- Accelerometer sensitivity (1g = 9. 81 m/s2).

- Calculations

- Damping ratio ζ

The damping ratio for the beam’s acceleration is calculated by the use of the logarithmic decrement of the waveform divided by 2π . The calculation is as shown below.

Logarithmic Decrement=(1/n)ln(Vo/Vn)

ζ= 15ln2. 121. 7212π= 6. 6561

ζ= 0. 0066

- periodic time T,

T= 60. 00ms

- maximum acceleration, Amax

The maximum acceleration is given by the following equation,

Amax = VoSen. (9. 81)

Amax= (2. 12*103)/300 *9. 81= 69. 324ms2

- Damped natural frequency of the beam

fexp= 17. 03Hz

- Theoretical natural frequency

ftheo= 1/2π √(k/m)

Where k is given by, k= 3EI/L3

And I is given by I= bh3/12

m is the total mass of the system given by the total of accelerometer mass, beam mass, and the brass mass.

Therefore:

I= 0. 02566*0. 00634312= 5. 449*10-10m4

k= 3*71*109*5. 449*10-100. 2753= 5575N/m

ftheo= 12π557539*10-13+0. 2341+(0. 1388)0. 23= 23. 0399Hz

Percentage difference between the damped natural frequency and the theoretical natural frequency

23. 0399-17. 0323. 0399*100= 26. 09%

- CONCLUSION

The results of the experiment show that beam was underdamped and overshoot the equilibrium point several times. Aluminum has a low spring constant as compared to other metals. A low beam spring constant was evidenced by high amplitude displacement. The theoretical natural frequency is higher than the actual measured damped frequency. This is because at natural frequency, there is no dampening force and the beam moves freely and infinitely without the decay of the oscillations. A natural frequency equal to the damped frequency would lead to resonance and the setup would disintegrate. The maximum displacement reduces with time according to the exponential decay curve.

- References

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- APPENDIX

Accelerometer Specifications