Vibration Analysis of Structures

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Abstract: **The present focuses on dynamic nature of various structures present in an environment where they are bound to undergo vibrations. In such vibrating conditions when they are subjected to a resonance they experience high amplitudes, leading to the failure of the structure. Hence, the study of operating frequencies of**

1) Machine Foundations
i) Los Angels Abrasion Machine
ii) Jaw Crushing Machine
2) Fiber Reinforced Glass Composites – varying the number of layers
i) 16 layers
ii) 12 layers
3) Steel Flats

In this study we have used a non computational technique for analysis of dynamic nature of structures. *Brüel&Kjær PULSE™*, Multi-analyzer System Type 3560 was used in the analysis. The operating frequency ranges in case of Los Angels Abrasion Machine is found to be 48 Hz – first frequency and 73 Hz – second frequency. In case of Jaw Crushing Machine is 42.2 Hz – first frequency and 71.8 Hz – second frequency. Whereas, in case of steel flat the operating frequency is found to be 41.50 Hz. The fiber reinforced glass composites were decreased in area in a regular pattern and the pattern of frequency variation was observed. In case of 16 layers the first frequency decreased from 284 Hz – 236 Hz and the second frequency also depicted similar pattern. In case of 12 layers the first frequency decreased from 190 Hz – 160 Hz and the second frequency varied from 588 Hz – 390 Hz. The observed trend is justified as the value of K decreases as we decrease the area of the sample. We have also studied the determination of Buckling load from frequency study in case of a steel flat. When steel flat is subjected to increasing axial load the operating frequency is observed to decrease. When this operating frequency tends to zero the axial load nears the buckling load of that structure. 30cm steel flat is tested in a UTM under increasing axial load. The initial frequency under no load condition is 260 Hz. Under a load of 0.4 ton the first frequency decreases to 168 Hz. Extrapolating the decreasing trend we get the buckling load as 1.1739 ton. A similar trend was observed in case of second frequencies. The vibration analysis of the foundations of various machines will help us in designing them such that their serviceability is increased. Similarly, fiber reinforced composites are being used in various structural members. These demands require a deeper understanding of fiber composite behavior. Composites offer great promise as light weight and strong structural materials. The study of dynamic behavior of a structure holds at most importance in evaluating its engineering performance and serviceability.

The Finite Element Method

A promising approach for developing a solution for structural vibration problems is provided by an advanced numerical discretization scheme, such as, finite element method (FEM).The finite element method (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called finite elements or elements for short. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions, at a set of nodal points. The response of the mathematical model is then considered to be approximated by that of the discrete model obtained by connecting or assembling the collection of all elements. A straight beam element with uniform cross section is shown in Figure.1. The Euler-Bernoulli beam theory is used for constituting the finite element matrices. The longitudinal axis of the element lies along the x axis. The element has a constant moment of inertia I, modulus of elasticity E, density r and length l . Two degrees of freedom per node, translation along y-axis (y1, y2) and rotation about z-axis (y1 |,y2 |) are considered.

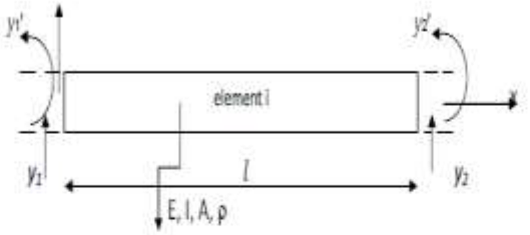


Figure.1 straight beam element

I Introduction

Civil engineering structures are always designed to carry their own dead weight, superimposed loads and environmental loads such as wind or waves. These loads are usually treated as maximum loads not varying with time and hence as static loads. In some cases, the applied load involves not only static components but also contains a component varying with time which is a dynamic load. In the past, the effects of dynamic loading have often been evaluated by use of an equivalent static load, or by an impact factor, or by a modification of the factor of safety. Many developments have been carried out in order to try to quantify the effects produced by dynamic loading. Examples of structures where it is particularly important to consider dynamic loading effects are the construction of tall buildings, long bridges under wind-loading conditions and buildings in earthquake zones, etc. Typical situations where it is necessary to consider more precisely the response produced by dynamic loading are vibrations due to equipment or machinery, impact load produced by traffic, snatch loading of cranes, impulsive load produced by blasts, earthquakes or explosions. So it is very important to study the dynamic nature of structures. Dynamic characteristics of a damaged and undamaged body are, as a rule, different. This difference is caused by a change in stiffness and can be used for the detection of damage and for the determination of its parameters (crack magnitude and location). Many mechanical structures in real service conditions are subjected to combined or separate effects of the dynamic load, temperature and corrosive medium, with a consequent growth of fatigue cracks, corrosive cracking and other types of damage. The immediate visual detection of damage is difficult or impossible in many cases and the use of local non-destructive methods of damage detection requires time and "financial expense and frequently is inefficient. In this connection, the use of vibration methods of damage diagnostics is promising. These methods are based on the relationships between the vibration characteristics (natural frequencies and mode shapes) or peculiarities of a non-linear vibration system behavior (for example, non-linear distortions of the displacement wave in different cross-sections of a beam, the amplitudes of sub-resonance and super resonance vibrations, the anti-resonance frequencies, etc.) and damage parameters. It is important to note that the essential non-linearity of vibrations of a body with a fatigue crack is due to the change of stiffness at the instant of crack opening and closing and is the main difficulty in the solution of such class problems. The analytical Investigation of vibrations of damaged structures is a complicated Problem. This problem may be simplified if a structure can be represented in the form of a beam with corresponding boundary and loading conditions. This class of structures can include bridges, offshore platforms, pipelines, masts of electricity transmission, TV towers, aircraft wings, blades and rotors of turbine engines, propellers of helicopters and many others. Depending on the assumptions adopted, the type of analysis used, the kind of the loading or excitation and the overall beam characteristics, a variety of different approaches have been reported in the literature and a great number of both theoretical and experimental findings are related to beam dynamics. The present study of vibration analysis of cantilever beam uses the tool Bruel&Kjær PULSE™, Multi-analyzer System Type 3560 for generating the vibration spectrum and to get results for various structural elements.

III Vibrations

Vibrations:: Vibration are time dependent displacements of a particle or a system of particles w.r.t an equilibrium position. If these displacements are repetitive and their repetitions are executed at equal interval of time w.r.t equilibrium position the resulting motion is said to be periodic. One of the most important parameters associated with engineering vibration is the natural frequency.. Each structure has its own natural frequency for a series of different modes which control its dynamic behavior. Whenever the natural frequency of a mode of vibration of a structure coincides with the frequency of the external dynamic loading, this leads to excessive deflections and potential catastrophic failures. This is the phenomenon of resonance. An example of a structural failure under dynamic loading was the well known Tacoma Narrows Bridge during wind induced vibration. In practical application the vibration analysis assumes great importance. For example, vehicle-induced vibration of bridges and other structures that can be simulated as beams and the effect of various parameters, such as suspension design, vehicle weight and velocity, damping, matching between bridge and vehicle natural frequencies, deck roughness etc., on the dynamic behavior of such structures have been extensively investigated by a great number of researchers . The whole matter will undoubtedly remain a major topic for future scientific research, due to the fact that continuing developments in design technology and application of new materials with improved quality enable the construction of lighter and more slender structures, vulnerable to dynamic and especially moving loads. Every structure which is having some mass and elasticity is said to vibrate. When the amplitude of these vibrations exceeds the permissible limit, failure of the structure occurs. To avoid such a condition one must be aware of the operating frequencies of the materials under various conditions like simply supported, fixed or when in cantilever conditions.

Classification of vibration

Vibration can be classified in several ways. Some of the important classification is as follows:

_ **Free and forced vibration:** If a system, after an internal disturbance, is left to vibrate on its own, the ensuing vibration is known as free vibration. No external force acts on the system. The oscillation of the simple pendulum is an example of free vibration. If a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as forced vibration. The oscillation that arises in machineries such as diesel engines is an example of forced vibration. If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as resonance occurs, and the system undergoes dangerously large oscillations. Failures of such structures as buildings, bridges, turbines and airplane have been associated with the occurrence of resonance.

Undamped and damped vibration: If no energy is lost or dissipated in friction or other resistance during oscillation, the vibration is known as undamped vibration. If any energy lost in this way, however, it is called damped vibration. In much physical system, the amount of damping is so small that it can be disregarded for most engineering purposes. However, consideration of damping becomes extremely important in analyzing vibratory system near resonance.

Linear and nonlinear vibration: If all the basic components of vibratory system—the spring, the mass and the damper—behave linearly, the resulting vibration is known as linear vibration. If however, any of the basic components behave non linearly, the vibration is called non linear vibration.

Deltatron Accelerometer:

Deltatron accelerometer combines high sensitivity, low and small physical dimensions making them ideally suited for model analysis. The slits in the oscilrometer housing make it simple to mount with bee box that one easily fitted to the plate.

Model hammer

The model hammer exits the structure with a constant force over a frequency range of interest. Three interchange tips are provided which determine the width of the input pulse and thus the band width the hammer structure is acceleration compensated to avoid glitches in the spectrum due to hammer structure resonance

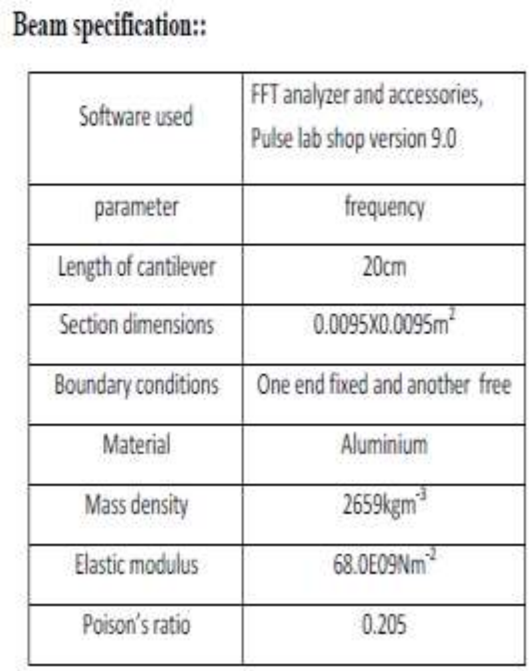
Portable pulse T- type (3560C)

Bruel and kjaer pulse analyzer system type – 3560. The software analysis was used to measure the frequency ranges to which the foundation various machines are subjected to when the machine is running with no load and full load. This will help us in designing the foundations of various machines on such a way that they are able to resist the vibration caused in them.

Display unit

This is mainly in the form of PC(Laptop) when the excitation occurs to the structure the signals transferred to the portable PULSE and after conversion comes in graphical form through the software . Mainly the data includes graphs of force Vs time, frequency Vs time resonance frequency data etc.

Results and discussion



Beam specification::

Software used	FFT analyzer and accessories, Pulse lab shop version 9.0
parameter	frequency
Length of cantilever	20cm
Section dimensions	$0.0095X0.0095m^2$
Boundary conditions	One end fixed and another free
Material	Aluminium
Mass density	$2659kgm^{-3}$
Elastic modulus	$68.0E09Nm^{-2}$
Poison's ratio	0.205

IV CONCLUSION

The vibration analysis of a structure holds a lot of significance in its designing and performance over a period of time. In aluminum fixed-free condition it was seen that the results were in good co-ordinance with theoretical values. The lowest frequency was in 1st mode. The frequency was increasing with each subsequent mode of vibration. The percentage of error was also decreasing as frequency is increasing. The predicted values of natural frequencies and mode shapes for the specimens with a fatigue crack are close to those obtained experimentally. The verification of the analytical approach with a considerable amount of experimental data and with the results of other author's calculations showed that the analytical approach enables one to obtain well-founded relationships between different dynamic characteristics and crack parameters and to solve the inverse problem of damage diagnostics with sufficient accuracy for practical purposes.

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