Experimental and finite element analysis of jointed structure for evaluation of damping

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Abstract- The damping mechanism of various jointed structures can be explained by considering the energy loss due to friction and the dynamic slip produced at the interfaces. The frictional damping is evaluated from the relative slip between the jointed interfaces and is considered to be the most useful method for inspect the structural damping. The damping characteristics in jointed structures are influenced by the intensity of pressure distribution, micro-slip kinematic coefficient of friction and logarithmic decrement at the interfaces. All the above basic parameters are largely influenced by the thickness ratio of the beam and thereby affect the damping capacity of the structures. In addition to this, beam length of the structures and diameter of connecting rivet and bolt also play key roles on the damping capacity of the jointed structures is assessable. For rivet bolt and welded joints the analysis proposes two different methods to calculate damping: experimental and finite element method. The effects of all these parameters are studied distinctly in the present investigation. It is established that the damping capacity can be increased appreciably using larger beam length and their diameters as well as lower thickness ratio of the beams. This design concept of using these structures can be effectively utilized in trusses and frames, aircraft and aerospace structures, bridges, machine members, robots and many other applications where higher damping is required. Comprehensive experiments have been conducted on a number of mild steel specimens under different initial conditions of excitation for establishing the accuracy of the theory develop. Finally damping on various joint structures has been compared.

I. INTRODUCTION

The study of damping and its importance in structures has become increasingly significant for controlling the undesirable effects of vibration. Following are the requirements of modern technology, there has been significant increase in demand to design, develop and fabricate machine tools, space structures, high speed automobiles, etc. to meet the global demand. The manufacturer of such structures also requires high damping capacity and stiffness with light weight for its effective use. Such requirements demanded and popularized the use of welded, bolted and riveted layered beams as structural members with high damping capacity. In the alternative, cast structures can be used, but unfortunately, these are more expensive to manufacture and as a result, the development of welded, bolted and riveted multi-layered beam structures is becoming increasingly common in such industries. Joints have a great potential for reducing the vibration levels of a structure and have attracted the interest of many researchers. Many comprehensive review papers on joints and fasteners have appeared in recent years. Although a lot of work has been carried out on the damping capacity of bolted structures, but a little amount of work has been reported till date on the mechanism of damping in layered and jointed riveted structures. Furthermore, the effect of the influencing parameters on the damping rate of such structures is investigated and discussed in this study. Damping ratio, a measure of damping capacity of jointed structures is determined by energy principle considering interface pressure at the interfaces of contacting layers. Huge amount of work has been reported by Masuko et al. [2], Nishiwaki et al. [3], on damping capacity of such structures assuming uniform pressure distribution at interfaces of jointed structures. B.K Nanda and Behera [8] have established that energy dissipation in jointed structure take place due to micro-slip at the interfaces of contacting layers. B.K Nanda [1] found that the damping increases with an increase in number of layers in jointed structure due to an increase in interface friction layers which causes an increase in energy loss.

1.1Various Types of Jointed Structures

1.1.1. Riveted:

A rivet is a perpetual mechanical fastener. Before being mounted a rivet involves in a smooth cylindrical shaft with a head on one end. The end opposite the head is called the buck tail. On connection the rivet is placed in a pierced or pre-drilled hole, and the tail is upset, or bucked (i.e. deformed), so that it expands to about 1.5 times the original shaft diameter, holding the rivet in place. To extricate between the two ends of the rivet, the unique head is called the factory head and the distorted end is called the shop head or buck-tail. Because there is effectually a head on each end of an installed rivet, it can support tension loads (loads parallel to the axis of the shaft); however, it is much more capable of supporting shear loads (loads perpendicular to the axis of the shaft). Bolts and screws are better matched for tension applications. Fastenings used in traditional wooden boat building, like copper nails and clinch bolts, work on the same standard as the rivet but were in use long before the term rivet came about and, where they are recollected, are usually classified among the nails and bolts respectively.

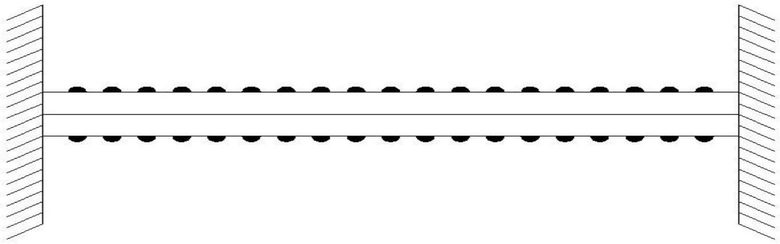


Fig: 1.2 Fixed-Fixed Condition of Riveted Joints

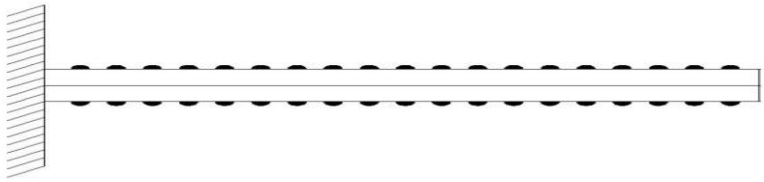


Fig: 1.3 Fixed-Free Condition of Riveted Joints

1.1.2. Bolted:

Bolted joints are one of the most collective elements in construction and machine design. They entail of fasteners that capture and join other parts, and are protected with the mating of screw threads. There are two chief types of bolted joint designs. In one method the bolt is stiffened to a calculated clamp load, usually by smearing a measured torque load. The joint will be intended such that the clamp load is never overwhelmed by the forces acting on the joint (and therefore the joined parts see no relative motion). The other type of bolted joint does not have a intended clamp load but depend on on the shear strength of the bolt shaft. This may comprise clevis linkages, joints that can change, and joints that depend on on a locking mechanism (like lock washers, thread adhesives, and lock nuts).The clamp load, also called preload, of a clasp is created when a torque is smeared, and is commonly a percentage of the fastener's resilient strength; a fastener is contrived to various values that define, among new things, its asset and clamp load. Torque charts are accessible to identify the required torque for a fastener created on its property class or grade.

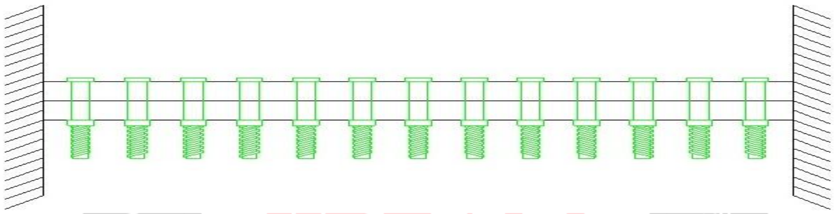


Fig: 1.4 Fixed-Fixed Condition of Bolted Joints

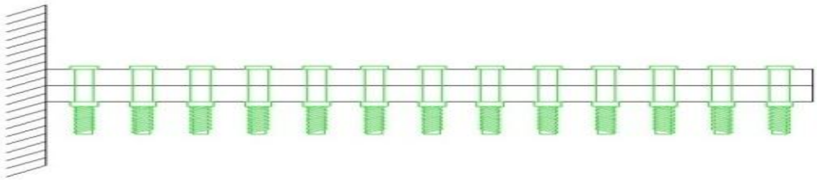


Fig: 1.5 Fixed-Free Condition of Bolted Joints

1.1.3 Adhesive:

If the load is not very large adhesive joints become very useful in joining metallic or non–metallic dissimilar materials. No special device is needed. But the disadvantage of this joint is that the joint gets weakened by moisture or heat and some adhesive needs meticulous surface preparation. In an adhesive joint, adhesive are applied between two plates known as adherend. The strength of the bond between the adhesive and adherend arise become of various reasons given below.

- The adhesive materials may penetrate into the adherend material and locks the two bodies.
- Long polymeric chain from the adhesive diffuse into the adherend body to form a strong bond.
- Electrostatic force may cause bonding of two surfaces.

Fig: 1.6 Fixed-Fixed Condition of Adhesive Joints

Fig: 1.7 Fixed-Fixed Condition of Adhesive Joints

1.1.4 Clamped:

We are using c clamps for joining two plates such as shown in fig. Figure shows cross section of c clamp. A friction screw joint that is used to secure various parts such as levers adjusting rings and pulleys which have detachable elements or split hubs to shafts or spindles by means of screws. The connection is provided by the frictional forces acting between the surfaces of the plates(see Figure). Unlike key or serrated joints, a clamp joint can attach a part to a shaft at any angle and at any place along its length; it also facilitates assembly.

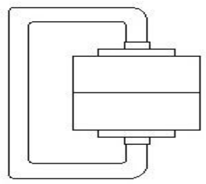


Fig: 1.8 Clamped Joint

1.2 PROBLEM DEFINITION

Now-a-days vibration is very important factor for study in many fields because vibration causes many undesirable effects on machine. To reduce the effect of vibration and to predict the suitably damped structure is the main purpose of this project work.

II. OBJECTIVES OF THE WORK

Many researchers have emphasized their studies on techniques to improve the damping capacity of laminated structures to control the adverse effects of vibrations. Although the knowledge on the friction joint is limited, efforts have been put in the present investigation to study the damping aspect of the friction joints in built-up structures.

1) Experimental analysis of jointed structures is carried out to find damping ratio of jointed structures with increasing number of strucures under different conditions of excitation.

2) FEA analysis of jointed structures is developed to calculate damping ratio in ANSYS 11.0 software for mild steel cantilever beams.

3) Both the FEA and experimental results are compared for authentication.

III. EXPERIMENTAL TECHNIQUES

In order to find experimentally the damping ratio of jointed beams and to compare it with the simulation ones, an experimental set-up with a number of specimens has been fabricated.

3.1 Preparation of Specimens

Jointed beam structures are made with the mild steel and Aluminium bars. In preparing the structure beam specimens the face layers are made free from grease, dirt etc by cleaning their surface with acetone and carbon tetrachloride. The Joints are made by bolts , rivets clamps and adhesive (Araldite) used for bonding purpose of structured beam. For bolting and riveting purpose we drilled with specific dimensions and made five drill holes at a distance of 15 mm from each hole. For clamping ,clamps are made in a work shop as per required dimensions. For adhesive joint , after application of thin layer and equal amount of adhesive on surfaces of all layers, the specimens were allowed to settle down for 24 hrs for perfect bonding under the load and proper care was taken to avoid the slippage between the layers by providing the positioning guides at all the edges of the specimen. The details of physical and geometrical properties of specimen are given as: the total thickness of joints 6 mm, the length and width of beam are taken as 600 mm and 50 mm respectively. The material properties of jointed beams considered here are given in Table

Table: 3.1 Specification of Beam

Plate dimension	
Materials For beam	1) Aluminum 2) Mild Steel
Length of Beam	600 mm.
Thickness (t)	6 mm.

Width	50 mm

Table : 3.2 Properties of Materials

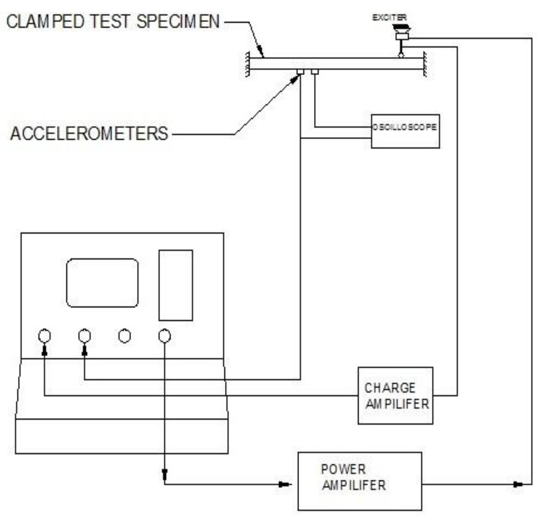
Type of material	**Young's Modulus E (GPa)**	**Shear Modulus G (GPa)**	**Density ρ (Kg/m^3)**	**Poisson's Ratio** ν
Aluminium	69	27.3	2766	0.33
Steel	210	80	7850	0.3

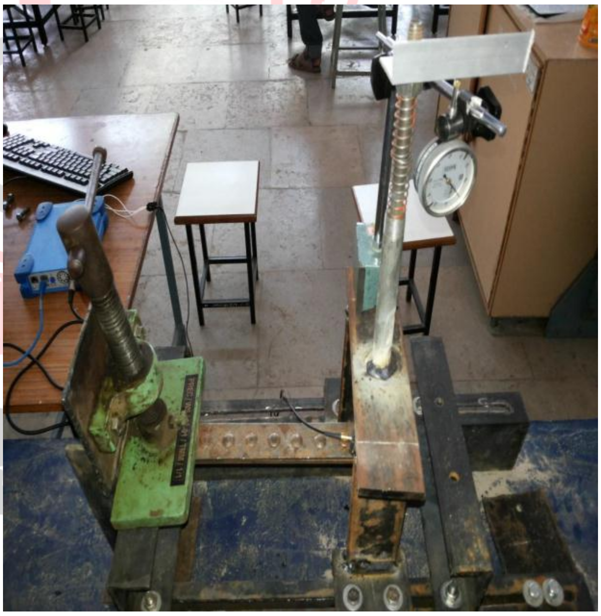
Table : 3.3 Jointed Structure

Stage	**No. of plates**	**Material**	**Joints**			
I	**2**	**MS+MS**	**Bolted**	**Riveted**	**Adhesive**	**Clamped**
II	**2**	**MS+Al**	**Bolted**	**Riveted**	**Adhesive**	**Clamped**
III	**2**	**Al+Al**	**Bolted**	**Riveted**	**Adhesive**	**Clamped**

These are harmonic response of the beams for fixed-free and fixed-fixed boundary the specimens considered in the modal analysis and experimental analysis with jointed structures and combinations of materials such as mild steel and aluminum

IV EXPERIMENTAL SETUP (DETAILS)





Experimental-Setup consists of following parts:-
1. OROS 4 Channel FFT Analyzer
2. Accelerometer
3. Spring Loaded Exciter
4. Different joint structures beam
5. Dial Indicator

The Experimental Set-up consists of frame work fabricated from steel C, I section by welding. The frame is grounded to concrete base with foundation bolts. The one end of riveted beam is fixed using mechanical vice. The spring loaded exciter is provided for giving excitation at the free end of riveted beam, this excitation is noted on dial gauge.

Damping Measurement

There are many methods for measuring the damping of vibration system. Logarithmic decrement method and bandwidth method ,

3.2.1 Logarithmic Decrement Method

Logarithmic decrement method is used to measure damping in time domain. In this method, the free vibration displacement amplitude history of a system to an impulse is measured and recorded. A typical free decay curve is shown as below. Logarithmic value of the ratio of two adjacent peak values of displacement in free decay vibration.

$$\delta = \frac{1}{n} ln \frac{x_1}{x_2}$$

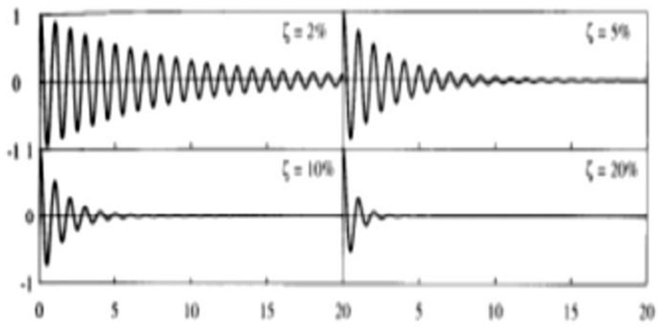


Fig: 3.2 Logarithmic Decrement Method

3.2.2 Bandwidth method

To estimate damping ratio from frequency domain, we may use half power bandwidth method. In this method, FRF amplitude of the system is obtained first. Corresponding to each natural frequency, there is a peak in FRF amplitude. The more the damping, the more the frequency range between this two point. Half -power Bandwidth is defined as the ratio of the frequency range between the two half power points to the natural frequency at this mode.

$$\frac{\omega_2 - \omega_1}{\omega_n} = 2\zeta = \frac{1}{Q}$$

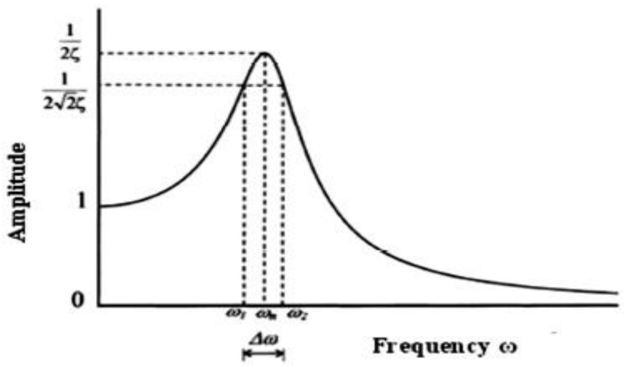


Fig: 3.3 Bandwidth Method

V. EXPERIMENTAL ANALYSIS

5.1 Introduction

The PULSE software analysis was used to measure the frequency ranges to which the foundations of 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 in such a way that they are able to resist the vibration caused in them.

5 . 2 Modal testing

Modal testing is a common method of characterizing the vibrations of a structure by imparting a known force and measuring the response of the structure. By measuring both the input to the structure and the response, the frequency response of the structure can be calculated. Calculating the frequency response over multiple locations, either simultaneously or individually, will yield data that can be used to estimate the dynamic response of the structure.

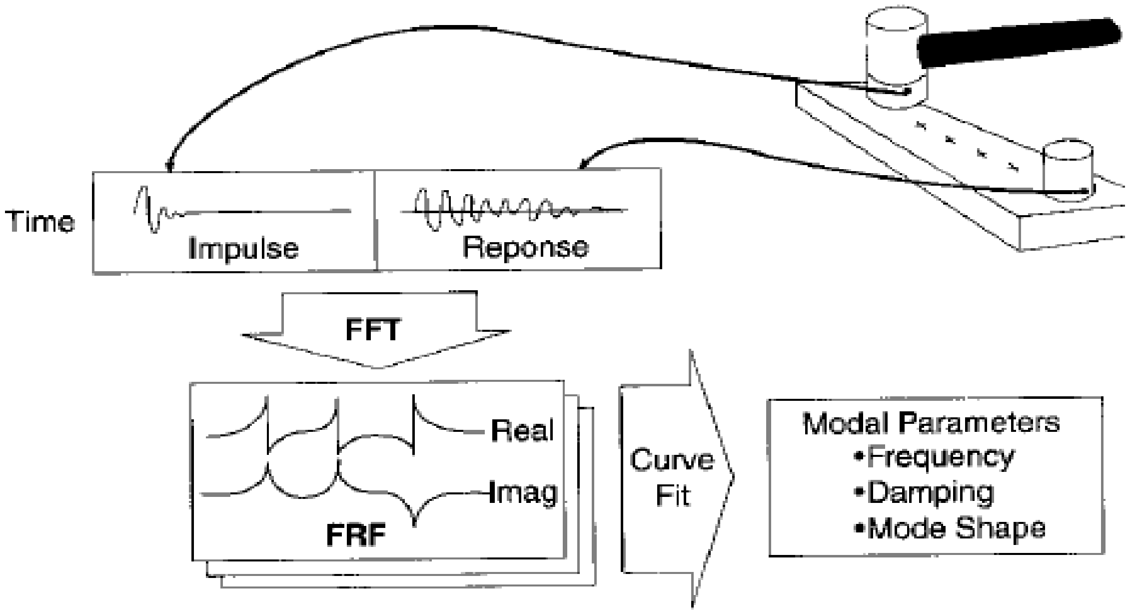


Fig: 5.2 Schematic Diagram of model testing

A wide variety of structures and machines can be subjected to impact hammer modal testing. Realistic signals from a typical impact test are shown in Figure.

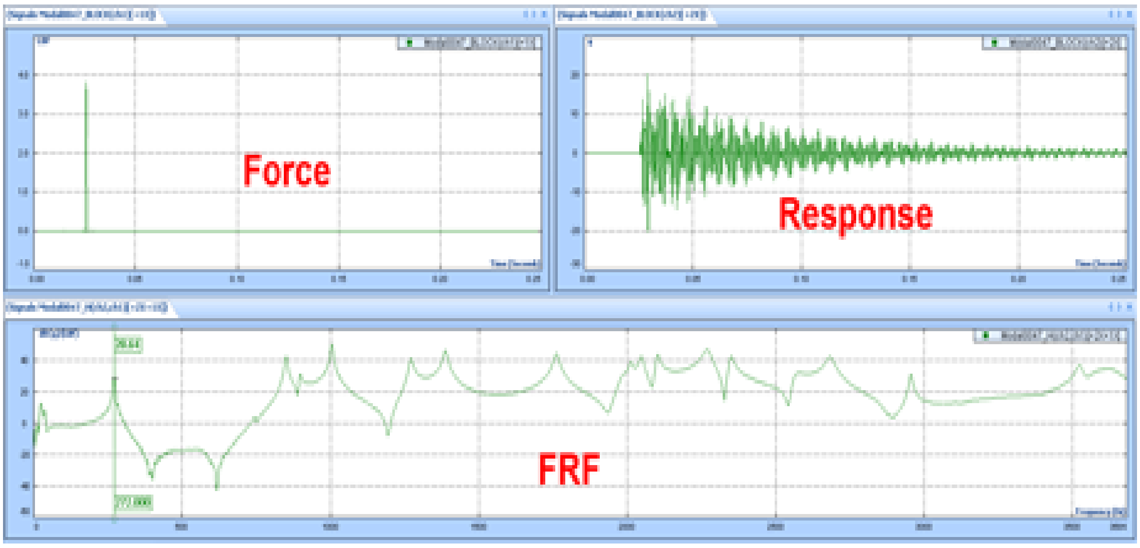


Fig: 5.4 Frequency Response Curve

Typical impact hammer modal testing data, top left shows excitation impulse force time signal. Top right shows acceleration time signal and bottom shows frequency response function (FRF) spectrum

V.I FINITE ELEMENT ANALYSIS

4.6 ANSYS Modeling and Result for Bolted Beam (6 mm Thickness)

Bolted Beam

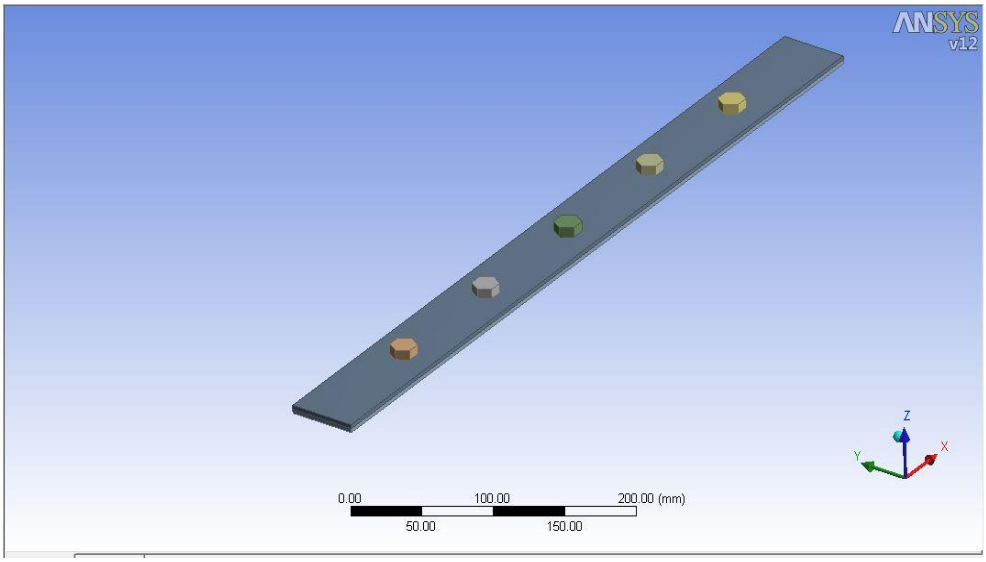


Fig: 4.2Model

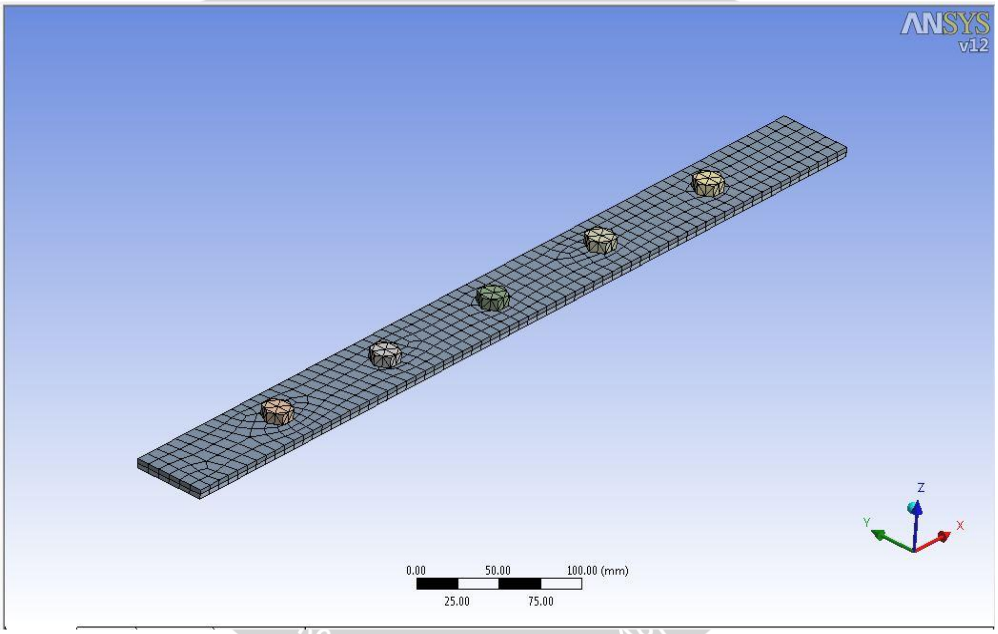


Fig: 4.3Mesh Model

4.7 ANSYS Modeling and Result for Riveted Beam (6 mm Thickness)

Riveted Beam

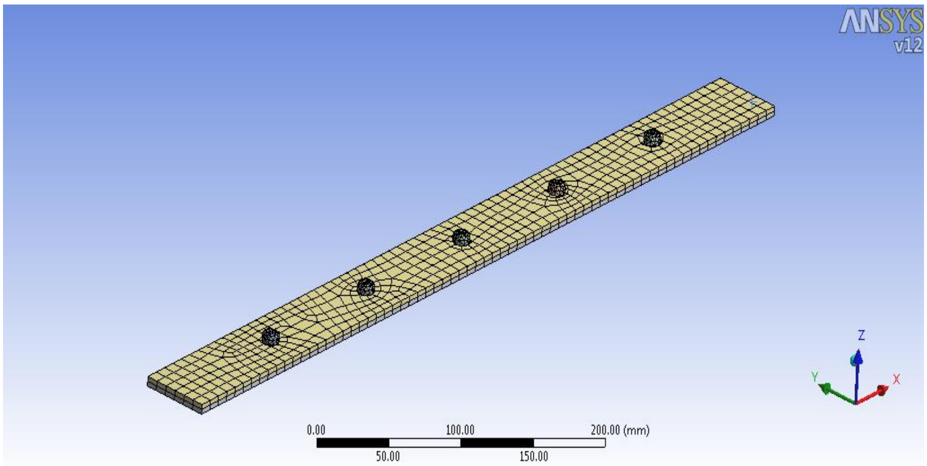


Fig: 4.4Mesh Model

4.8 ANSYS Modeling and Result for Adhesive Beam (6 mm Thickness)

Clamped Beam

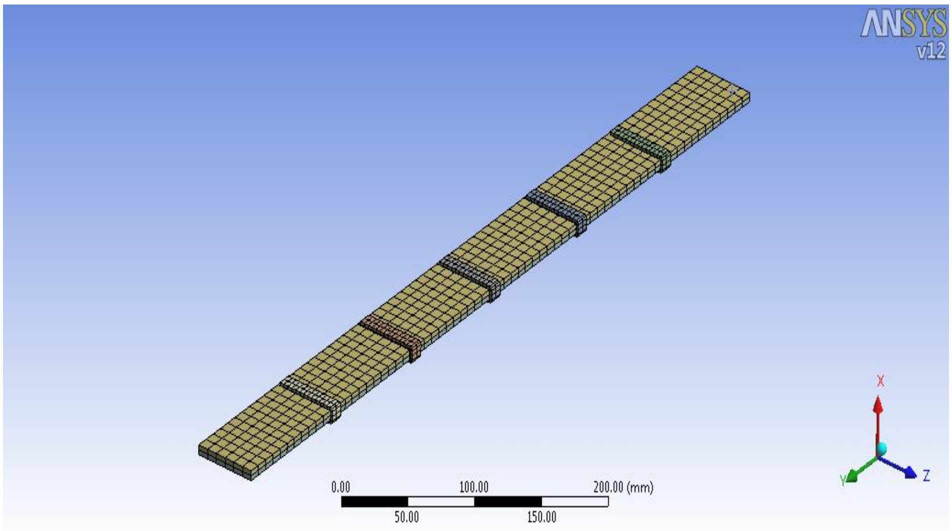


Fig: 4.5 Mesh Model

4.9 ANSYS Modeling and Result for Adhesive Beam (6 mm Thickness)

Adhesive Joint

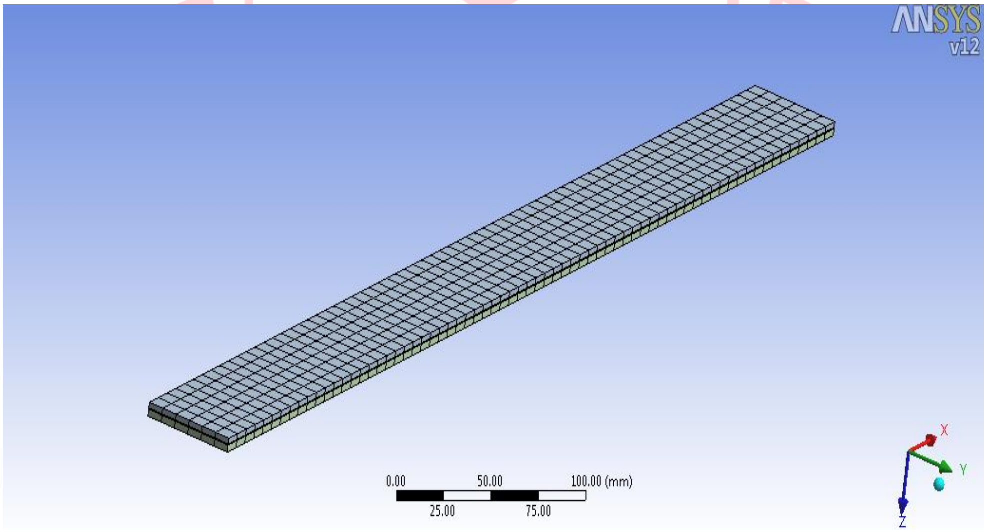


Fig:4.6 Mesh Model

VII. CONCLUSION

The various jointed structure has been successfully modeled using finite element method. The developed model have been validated with the earlier theory, experimental verification has also been done for the different types of Jointed structure. The structures modeled here with varying joints such as bolted , riveted , clamped and adhesive having combinations of MS-MS , Al-Al and MS-Al modeled here are carried out for modal analysis using finite element method to study the damping effect on the beams for the fixed-free and fixed-fixed boundary conditions.

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