A Review on Experimental Investigation on Damping of Layered and Riveted Structure Beam

Durgesh Kumar Chaurasia\textsuperscript{1} Prof. A. K. Jain\textsuperscript{2}

\textsuperscript{1}\textsuperscript{\textit{M.E. Student}}\textsuperscript{2}\textit{Associate Professor}

\textsuperscript{1,2}Department of Mechanical Engineering

\textsuperscript{1,2}Jabalpur Engineering College, Jabalpur (MP), India

Abstract— In the present work, the mechanism of damping in layered and jointed structures with connecting rivet have been extensively studied. A lot of experiments have been conducted on a number of specimens with connecting rivet of various diameters, length and thickness to study its effect on the damping capacity of the layered and jointed structures and to establish the authenticity of the theory developed. Intensity of interface pressure, diameter of the connected rivet, length and thickness of beam, number of layers, kinematic coefficient of friction at the interfaces and frequency and amplitude of excitation are found to play a major role on the damping capacity of such structures. This design concept of using layered structures with riveted joints 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.

Key words: Slip Damping, Riveted Joint, Multiple Interfaces, Amplitude, Frequency, In-Plane Bending Stress, Dynamic Loading

I. INTRODUCTION

Problems involving vibration occur in many areas of mechanical, civil and aerospace engineering. So as a structural member there is a critical need for development of reliable and practical mathematical models to predict the dynamic behavior of such built-up structures to control the vibration of structures at a desirable level. Engineering structures are generally fabricated using a variety of connections such as bolted, riveted, welded and bonded joints etc. Usually, such structures possess both low structural weight and damping. Unwanted vibrations with high amplitude can be the cause of the fatigue failures in machine elements and the reduction of their working life.

This situation calls for use of additional measures to improve the damping characteristics by dissipating more energy. The dynamics of mechanical joints is a topic of special interest due to their strong influence in the performance of the structure. Joints are inherently present in the assembled structures which constitute significantly to the slip damping in most of the fabricated structures. Further, the inclusion of these joints plays a significant role in the overall system behavior, particularly the damping level of the structures. Joints have a great potential for reducing the vibration levels of a structure thereby attracting the interest of many researchers. The mechanical engineers are concerned of energy such as heat. Dissipation of energy takes with many unwanted vibrations in mechanical devices and replace at any time that the system vibrates.

In the present investigation, damping capacity of layered and jointed structures is to be evaluated from analytical expressions developed in the investigation and compared experimentally for aluminum cantilever beams under different - different conditions of excitation in order to establish the accuracy of the theory developed.

A. Damping

Term damping refers to the energy dissipation properties of a material. When a structure is subjected to an excitation by an external force then it vibrates in certain amplitude of vibration, it reduces as the external force is removed. This is due to some resistance offered to the structural member who may be internal or external. This resistance is termed as damping.

B. Classification of Damping-

Damping can be broadly divided into two classes depending on their sources.

1) Material Damping:

Damping due to dissipative mechanism working inside the material of the member is termed as material damping.

2) System Damping:

System damping involves configuration of distinguishable part arises from slip and boundary shear effects of mating surfaces. Energy dissipation during cyclic stress at an interface may occur as a result of dry sliding (coulomb friction), lubricated sliding (viscous forces) or cyclic strain in a separating adhesive (damping in visco-elastic layers between mating surfaces).

System damping to our need is classified as:

- Support damping.
- Damping due to sandwich construction.
- Damping due to joints.

C. Riveted Joint:

A joint holding two or more elements together by the use of rivets is called riveted joint. A rivet is a short cylindrical bar with a head integral with it. The set head is made before hand on the body of the rivet by upsetting. The second, called the closing head, is formed during riveting. A riveted joint is made by inserting rivets into holes in the elements to be connected.

1) Damping Capacity of Riveted Joint

Damping capacity of a riveted joint depends mainly on the following factors:

- Co-efficient of friction between joint surfaces.
- Micro-slip between joint surfaces.
- Reaction force of a base applied during vibration
- Joint material, machining method of joint surfaces, interfacial layers, thickness of the beam, amplitude of vibration has large effect on damping and frequency.
2) **Various types of rivet head**

![Rivet heads](image1.png)

Fig. 1: Various types of rivet head

3) **Pressure Distribution at the riveted jointed interface**

When two or more plates are pressed together by riveted joint, a circle of contact will be formed around the rivet with a separation taking place at a certain distance from the rivet hole as shown in Figure. It is shown that the pressure distribution inside this zone is parabolic in nature being maximum at the rivet hole and zero at the circumference of the influencing zone. Due to this uneven pressure distribution, a local relative motion termed as micro-slip occurs at the interfaces of the connecting members.

![Pressure distribution](image2.png)

Fig. 2(a): Plates clamped by a rivet (b) Free body diagram of a riveted joint with Influence zone

II. **MECHANISMS OF MICRO-SLIP**

Micro-slip is the mechanism by which mechanical joints dissipate energy and therefore, a better understanding of its phenomenon is required for the study of damping effects in the jointed structures. When the external load is applied on the beam, then contacting layer tend to move relative to each other. This provides the micro slip and serves as a catalyst for energy dissipation. The amount of damping depends on surface roughness of contacting parts, contact pressure and the amplitude of vibration. The energy dissipated per cycle depends upon the co-efficient of friction, the pressure at the contacting parts and amplitudes. Larger the energy dissipation, larger is the effective damping in the system.

![Micro-slip mechanism](image3.png)

Fig. 3: Mechanism of micro slip at jointed interface

A. **Beam**

A beam is a horizontal structural member that is capable of withstanding bending load. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending movement.

A beam with a laterally and rotationally fixed support at one end with no support at the other end is called a cantilever beam.

III. **THEORY OF VIBRATION OF BEAM**

A. **Timoshenko theory of Beam**

This beam theory was developed by Ukrainian-born scientist Stephen Timoshenko. The model takes into account shear deformation and rotational inertia effects, making it suitable for describing the behaviour of short beams, sandwich composite beams or beams subject to high-frequency excitation when the wavelength approaches the thickness of the beam. Practically taking into account the added mechanisms of deformation effectively lowers the stiffness of the beam, while the result is a larger deflection under a static load and lower predicted frequencies for a given set of boundary conditions. The latter effect is more noticeable for higher frequencies as the wavelength becomes shorter, and thus the distance between opposing shear forces decreases.

B. **Euler Bernoulli Beam Theory**

This Beam Theory also known as an engineer’s beam theory or classical beam theory that is a simplification of the linear theory of elasticity which provides a means of calculating the load carrying and deflection characteristics of beams. It covers the case for small deflections of a beam which is subjected to lateral loads only. It is thus a special case of Timoshenko beam theory which accounts for shear deformation and is applicable for thick beams.

IV. **LITERATURE REVIEW**

The literature review related to research of damping on layered and jointed cantilever beam are given as follows-

W. Chen, X. Deng et. al [1] - Damping in built-up structures is often caused by energy dissipation due to micro-slip along frictional interfaces (e.g., at bolted joints), which provides a beneficial damping mechanism to control the vibration. In this paper, a careful study of the micro-slip phenomenon has been carried out using the finite element method. Two classical joint configurations, the press-fit joint and the Lap-shear joint, have been used as the model problems. The focus of this paper is to evaluate the effect of dry friction on the damping response of frictional joint interfaces, to understand the evolution of the slip and stick regions along a joint interface during loading, and to quantify the amount of energy dissipation during cyclic loading and its dependence on structural and loading parameters. In this journal Finite element method is used to compare the experimental measurement and limitation of early analytical treatments in the literature.

B.K. Nanda et. al [2] - The aim of this paper is to study the effect of bolt diameter and washer on damping in layered and jointed structures. A lot of experiments have been conducted on a number of specimens with connecting bolts of various diameters to study its effect on the damping
capacity of the layered and jointed structures and to establish the authenticity of the theory developed. Intensity of interface pressure, diameter of the connecting bolts, washers, number of layers, kinematic coefficient of friction at the interfaces and frequency and amplitude of excitation are found to play a major role on the damping capacity of such structures. It is established that the damping capacity of structures jointed with connecting bolts can be improved substantially by increasing the number of layers connected with bolts of smaller diameters along with use of washers.

Bijoy Kumar Nanda et. al [3] – In this paper damping mechanism in layered and welded structures has been identified. Welded joints are often used to fabricate assembled structures in machine tools, automotive and many such industries requiring high damping. Vibration attenuation in these structures can enhance the dynamic stability significantly. It has been observed that friction damping at interfaces in built up structures provides a beneficial role in reducing the adverse effects of vibrations thereby enhancing their life. A little amount of work has been reported till date on the damping capacity of welded structures.

The present work outlines the basic formulation for the slip damping mechanism in layered and welded structures. The numerical stability of the method and its applicability to actual working conditions have been investigated in case of a tack welded cantilever beam structure. The developed damping model of the structure is found to be in fairly good agreement with measured data. In the present work damping model has been developed for multilayered structures that have been overlooked by earlier researchers. It is observed that there are a number of vital parameters such as; pressure distribution characteristics, relative slip and kinematic coefficient of friction at the interfaces, initial amplitude of excitation, length and thickness of the beam specimen and number of layers govern the damping capacity of the welded structures.

Fig. 4(a): Two layered tack welded cantilever beam (b) two halves of beam depicting load and co-ordinates

Bhagat Singh et. al [4]- In this journal a mathematical analysis has been presented to investigate the mechanism of slip damping in layered and tack welded aluminum structures with multiple interfaces. It is quite evident that the relative slip increases with the distance from the fixed end. Moreover, the relative slip in multilayered cantilever beam is higher as compared to that of two layered beam at the same distance from the fixed end. In the multilayered beam there are multiple interfaces whereas in the case of two layered beam there is only single interface, thereby increasing the relative slip in case of the former. It is observed that a considerable increase in damping capacity can be achieved by increasing the number of layers. A uniform and coherent treatment of the subject is presented, by integrating theoretical and experimental techniques. This investigation helps the designers to estimate the damping capacity of the structures in order to maximize it as per the requirements in actual applications.

Huifang Xiao et. al [5]-In this journal author has investigated the energy dissipation of a lap joint using the one-dimensional micro slip friction model by incorporating the effect of interface tangential contact stiffness. A nonuniform pressure distribution of exponent law at the interface is considered and the resulted distinct stick-slip transitions along the contact interface are presented. Expressions of the critical slip loads giving rise to stick-slip transitions along the contact interface are determined. The loading force displacement curves for different pressure distribution laws and different interface tangential stiffness are obtained and compared with each other. The hysteresis curves of the oscillating tangential contact forces versus tangential displacements and the dissipated energy at the contact are determined. The obtained results suggest that the joint interface tangential stiffness and interfacial pressure distribution are reasons for the varying exponent values obtained in experimental work.

O. Damisa et. al [6] -In this paper, dynamic analysis of slip damping in clamped layered beams is investigated with non-uniform pressure distribution at the interface. However, while most analyses of the mechanism assume an environment of uniform pressure at the interface. With the earlier research, it has confirmed that this is rarely the case. There have been recent attempts to relax the restriction of uniform interface pressure to allow for more realistic pressure profiles that are encountered in practice. This paper is an attempt to extend such analyses to account for cases of realistic dynamic loading that drive such structural vibration in the first instance and find that it is shown that under dynamic loads, frequency variation more than non-uniformity in the interface pressure can have significant effect on both the energy dissipation and the logarithmic damping decrement associated with the mechanism of slip damping in such layered structures.

Bhagat Singh, Bijoy Kumar Nanda et. al [7] - In this paper author develops a mathematical model to estimate the damping capacity of welded structures with multiple interfaces. The problem idealized as a multi-layered and tack welded mild steel beam model, vibrating at dynamic conditions. The beam is cantilevered from one end. Experiments are performed on mild steel specimens with a number of layers under different initial conditions of excitation to validate the theory developed. It was observed that a considerable increase in damping capacity can be achieved by increasing the number of layers. A uniform and coherent treatment of the subject was presented, by integrating theoretical and experimental techniques.
Jean-Luc Dion et al [8]: The problem of damping estimation was solved by above researcher. They improve the measurement techniques for damping induced by micro-sliding. The purpose of this academic bench was to measure the damping induced by partial slip and friction in a planar joint. A new method for so-called stopped-sine excitation was developed. It allows more precise monitoring of the evolution of the vibration frequency and damping of non-linear modes. This method was associated with piezoelectric exciters for greater efficiency when stopping excitation. A large number of experiments were presented and discussed. Conclude that their excitation method is more efficient to measure vibration than previous one.

V. CONCLUSION

After studying the review of the earlier researcher it is concluded that mechanical joints and fasteners are primary sources of improving damping in structural design caused by friction and micro-slip between the interfaces. A lot of analytical, computational and experimental works have been carried out by several researchers in the recent past on the damping of bolted and welded structures, but no substantial work has been reported till date on the damping capacity of riveted structures. So I want to work for study both theoretically and experimentally, the damping in riveted joint construction and to compare their relative magnitudes. Consequently, it is highly desirable that the machine members, building structures and industries can definitely make use of jointed construction for the improvement of damping without sacrificing strength where vibration is encountered.

REFERENCES