DAMPING OF FIXED-FIXED WELDED JOINTS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE IN

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

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UNDER THE SUPERVISION OF

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CERTIFICATE

This is to certify that the thesis entitled, "**DAMPING OF FIXED- FIXED WELDED JOINTS**" submitted by ***Chitta Ranjan Mehre*** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University), is an authentic work carried out by him under my supervision.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Date:

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CONTENTS

ABSTRACT

Welded joints are often used to fabricate assembled structures in machine tools, automotive and many such industries requiring high damping. The damping mechanism of welded 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 investigating the structural damping. The theoretical analysis proposes two different methods to calculate damping: *classical method and finite element method*. The damping characteristics in jointed structures are influenced by the intensity of pressure distribution, micro-slip and kinematic coefficient of friction at the interfaces and the effects of all these parameters on the mechanism of damping have been extensively studied. All the above vital parameters are largely influenced by the thickness ratio of the beam and thereby affect the damping capacity of the structures. In addition to this, number of layers, beam length and distance between two take welding also play key roles on the damping capacity of the jointed structures quantitatively. It is established that the damping capacity can be enhanced appreciably using larger beam length and distance between two welded points as well as lower thickness ratio of the beams. Further improvement in damping is possible with the use of more number of layers compared to its equivalent solid one. This design concept of using layered structures with welded 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. Extensive experiments have been conducted on a number of mild steel specimens under different initial conditions of excitation for establishing the authenticity of the theory developed.

CHAPTER -1

INTRODUCTION

1. INTRODUCTION

The vibration occur in many areas of mechanical, aerospace engineering and civil Engineering structures are generally fabricated using a variety of connections such as bolted, welded, riveted and bonded joints etc. The dynamics of mechanical joints is a topic of special interest due to their strong influence in the performance of the structure. Further, the inclusion of these joints plays a significant role in the overall system behavior, particularly the damping level of the structures. However, the determination of damping either by analysis or experiment is never straightforward owing to the complexity of the dynamic interaction of components. The estimation of damping in beam-like structures with passive damping approach is the essential problem addressed by the present research. Friction damping is when relative motion between two surface in the presence of friction. In case of a jointed structure, the relative motion between contacting layers is a function of normal load which arises from the tightening of the joints holding the components. When the joint is very loose, the normal load is insignificant and the contact surface experiences pure slip. Since no work is required to be done against friction, no energy is dissipated. On the other hand, when the joint is very tight, high normal loads cause the whole contact interface to stick. This results in no energy dissipation again since no relative motion is allowed at the interfaces. For normal loads lying between these two extremities, energy is dissipated and the maximum value of energy dissipation occurs within this range. The contact pressure between the surfaces is generated by the clamping action of the joints and plays a vital role in the joint properties. Due to uneven pressure distribution, a local relative motion termed as micro-slip occurs at the interfaces of the connecting members. Hence, damping studies are mainly experimental in nature and all problems of damping are to be ultimately resolved through experimental analysis. With the development of jointed beams, the fabricated structures can be used as a replacement for solid structures with enhanced damping.

1.1 DAMPING

Damping is the energy dissipation properties of a material or system under cyclic stress. 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 résistance offered to the structural member, which may be internal or external. This resistance is termed as damping. The origin and mechanism of damping are complex and sometimes difficult to comprehend. The energy of the vibrating system is dissipated by various mechanisms and often more than one mechanism may be present simultaneously.

1.2 CLASSIFICATION OF DAMPING

1. Internal damping
2. Structural damping

1.2.1 INTERNAL DAMPING

Internal damping, also called solid or material damping, is related to the energy dissipation within the volume of material. This mechanism is usually associated with internal reconstructions of the micro and macro structure ranging from crystal lattice to molecular scale effects, thermo-elasticity, grain boundary viscosity, point-defect relaxation, etc. [1, 2]. Besides, there are two types of internal damping: hysteretic damping and viscos-elastic damping.

1.2.2 STRUCTURAL DAMPING

Since the damping in the structural material is not significant, most of the damping in real fabricated structures arises in the joints and interfaces [1]. It is the result of energy dissipation caused by rubbing friction resulting from relative motion between components and by intermittent contact at the joints in a mechanical system. However, the energy dissipation mechanism in a joint is a complex phenomenon being largely influenced by the interface pressure and degree of slip at the interfaces. It is this slip phenomenon occurring in the presence of friction at the joint interface that causes the energy dissipation and nonlinearity in the joints.

1.3 MEASUREMENT OF DAMPING

There are several ways of expressing the damping in a structure. They are time response and frequency-response methods where the response of the system is expressed in terms of time and frequency, respectively. Depending on the mathematical model of the physical problem, the above two methods are used to measure the damping capacity of the structures. Logarithmic decrement (δ) is determined using time domain method and the quality factor (Q) by frequency domain method. However, the other nomenclatures such as; damping ratio (ζ), specific damping capacity (ψ) and loss factor (η) are estimated from either of the above two methods for measuring the damping.

1.3.1 LOGARITHMIC DECREMENT (δ)

The logarithmic decrement method is the most widely used time-response method to measure damping from the free-decay of the time history curve. When the structure is set into free vibration, the fundamental mode dominates the response since all the higher modes are damped out quickly. The logarithmic decrement represents the rate at which the amplitude of a free damped vibration decreases. It is defined as the natural logarithm of the ratio of any two successive amplitudes. Thus, the logarithmic decrement δ is obtained as;

$$\delta = \text{Ln}.\ \frac{a_1}{a_2} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$

Where a_1 and a_2 are the successive amplitudes and ζ is the damping ratio. For small damping, the above relation is approximated as; $\delta \simeq 2\pi\zeta$ .Generally for low damping, it is preferable to measure the amplitudes of oscillations of many cycles so that an accurately measurable difference exists. In such a case,

$$\delta = \frac{1}{n} \ln\left(\frac{a_0}{a_n}\right)$$

Where a_0 , a_n and n are the amplitudes of first and last cycles and number of cycles, respectively.

1.3.2 DAMPING RATIO (ζ)

The damping ratio is another way of measuring damping which shows the decay of oscillations in a system after a disturbance. Many systems show oscillatory behavior when they are disturbed from their position of static equilibrium. Frictional losses damp the system and cause the oscillations to gradually decay to zero amplitude. The damping ratio provides a mathematical means of expressing the level of damping in a system. It is defined as the ratio of the damping constant to the critical damping constant.

The rate at which the motion decays in free vibration is controlled by the damping ratio ζ, which is a dimensionless measure of damping expressed as a percentage of critical damping. Figure 2.3 displays the free vibration response of several systems with varying levels of damping ratios. It is observed that the amplitude of vibration decays more rapidly as the value of the damping ratio increases.

2. OBJECTIOVE

In general fabricated many type of fasteners like riveted bolted and welded it is know that improvement in damping provision of welded joints in not appreciable compare to bolted and riveted joints. Therefore, the use of welded joints is usually avoided in structural applications where higher damping is the main criterion .the dynamics of bolted structures have been studied by many investigators as evidenced from the wealth of published literatures. However, a little amount of research has been reported till date on the welded joints. Welding joints are widely used in aircraft, building constructions, trusses, frames, bridges and various other applications requiring high joint strength and damping. The use of welding in such applications is cheaper compared to other fasteners thereby giving low assembly cost. Further, welding is not susceptible to unintended loosening which might otherwise cause joint failures and hazardous environments. Moreover, the basic mechanism of energy loss due to interface friction and slip is same in case of all the fasteners. Therefore, an attempt has been made in the present investigation to study the mechanism of interface slip damping considering the above concept for layered and jointed welded structures.

CHAPTER-2

LITERATURE SURVEY

3. LITERATURE SURVEY

Riveting is widely used for construction of many structures. Although a considerable amount of work has been reported on the study of damping in riveted structures with non-uniform pressure distribution at the interfaces, no generalized theory has been established for layered and riveted beams with uniform pressure distribution at the interfaces. Most engineering structures are built up by connecting structural components through mechanical connections.

Over the past few decades, most of the work has been confined in the area of micro- and macro-slip phenomena [4]. These concepts are utilized to study the dynamic behavior of jointed structures having friction contact [8-10]. This model is generally adopted when the normal load at the interface is small. On the other hand, many researchers [13, 14] have utilized the micro-slip concept considering the friction surface as an elastic body. In this case, the interface undergoes partial slip at high normal load. Masuko et al. [9] and Nishiwaki et al. [17, 18] have found out the energy loss in jointed cantilever beams considering micro-slip and normal force at the interfaces. Olofsson and Hagman [8] have shown that the micro-slip at the contacting surfaces occur when an optimum frictional load is applied. They have also presented a model for micro-slip between the flat smooth and rough surfaces covered with ellipsoidal elastic bodies.

Den Hartog [21] has analytically solved the steady state response of a simple friction-damped system with combined Coulomb and viscous friction. Reviews on the effects of joint friction on structural damping in built-up structures have been presented by many researchers [22, 5, 23]. Their findings have shown that the friction in structural joints is regarded as a major source of energy dissipation in assembled structures.

Recently, Nanda and Behera [13] have developed a theoretical session for the pressure distribution at the interfaces of a bolted joint by curve fitting the earlier data reported by Ziada and Abd [14]. They have obtained an eighth order polynomial even function in terms of normalized radial distance from the centre of the bolt such that the function assumes its maximum value at the centre of the bolt and decreases radially away from the bolt. They have used Dunn's curve fitting software to calculate the exact spacing between bolts that would result in a uniform interfacial pressure distribution along the entire length of the beam. Using exact 15 spacing of 2.00211 times the diameter of the connecting bolts, Nanda and Behera have been successful in simulating uniform interface pressure over the length of the beam. Thereafter, they have investigated the effect of interface pressure on the behavior of interfacial slip damping.

There are various measuring methods available in practice to know the contact pressure between layers. The technique of using ultrasonic waves is most capable among them as it measures the real contact pressure without changing the characteristics of the contact surface. This measurement has produced fair results using a normal probe [14,]. However, the angle probe used by Minakuchi et al. [14] is more convenient to measure. They have found out the contact pressure between two layered beams of different thicknesses by establishing a relationship between the mean contact pressure and sound pressure of reflected waves. This method is widely 12 accepted as the experimental results fairly agree with the theoretical ones. The present investigation uses the numerical data of Minakuchi et al. [15] to obtain the theoretical equation for non-uniform pressure at the interfaces of a jointed beam by curve fitting with MATLAB software.

CHAPTER-3

EXPERIMENTATION

3. EXPERIMENTATION

The damping capacity of fixed-fixed welded joint, depend on different parameter like number of take, number of layer and length of beam.

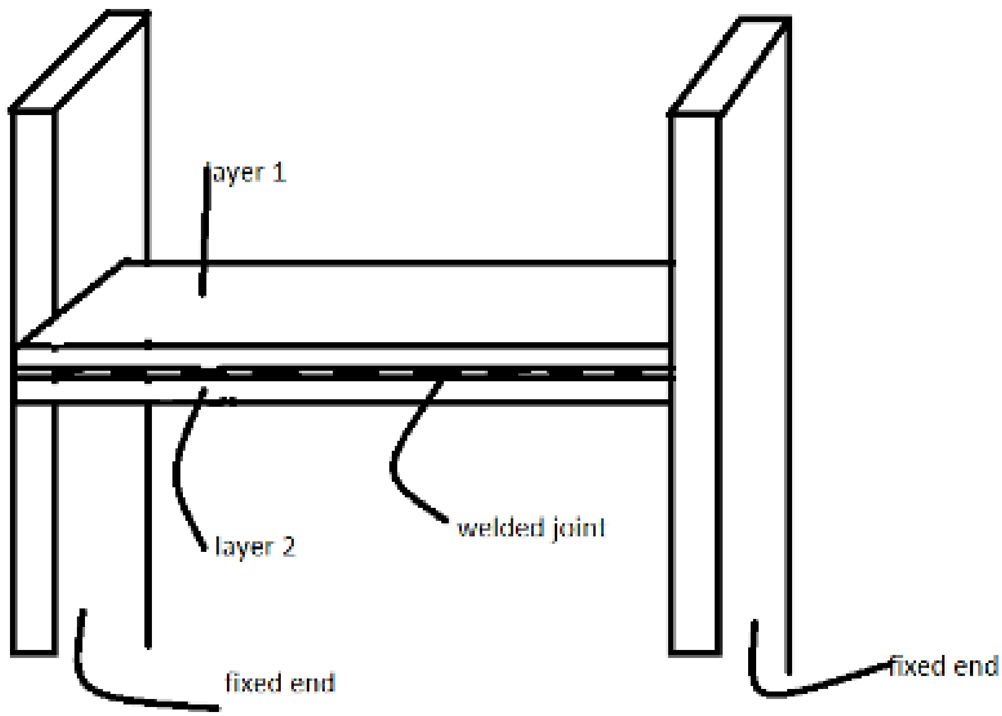

Fig-1

Fig-2 (Top view of mild steel specimen)

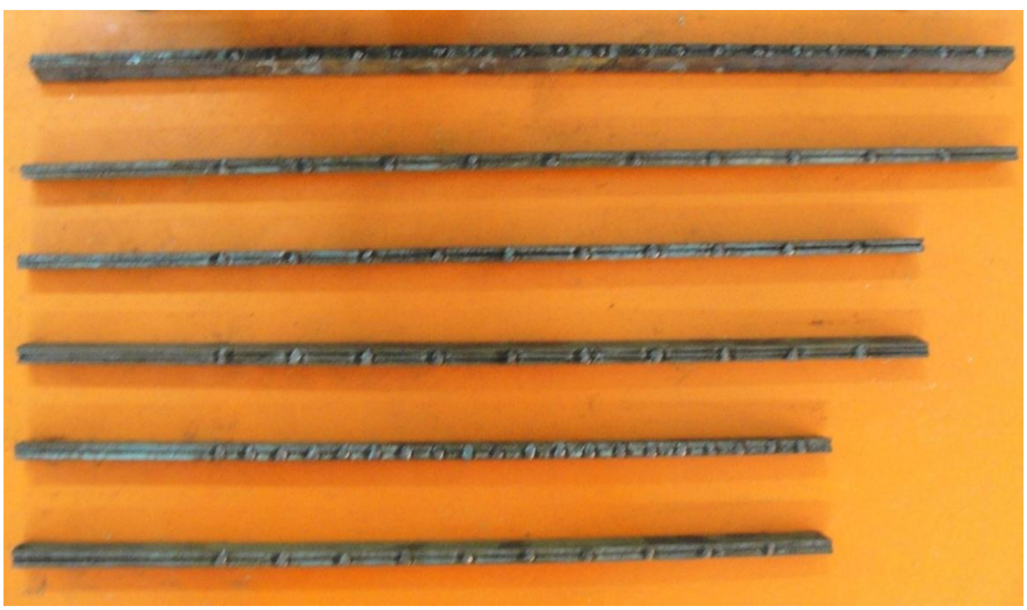

Fig-2 (Side view of mild steel specimen)

Fig-4 (Experimental set up fixed fixed beam)

3.1 TEST SPECIMEN

The test specimens of different sizes are prepared from the stock of commercial mild steel. The two layered specimens are prepared by tack welding at the sides of the specimens. The distance between the tacks has been varied in steps. Further, specimens of various thicknesses and length are also prepared for conduct the experiments.

Sufficient care has been taken while welding in order to ensure the following salient features by the tack welded joints;

Holds the assembled components in place and establishes their mutual location

Ensures their alignment

Controls movement and distortion during welding

Sets and maintains the joint gap

Ensures the assembly's mechanical strength against the external loading

Table -1(Detail of mild steel specimen used in the experiment for the thickness ratio 1.0)

Thickness x width (mm x mm)	**Number of layer**	**Number of tack welds**	**Length (mm)**
(3+3)x 42.25	2	10	420.14
(4+4)x 42.25	2	20	430.05
(6+6)x 42.25	2	30	460.20
(3+3)x 42.25	2	10	330.36
(4+4)x 42.25	2	20	364.34
(6+6)x 42.25	2	30	398.23

3.2 INSTRUMENTATION

In order to measure the logarithmic damping decrement, natural frequency of vibration of different specimen the following instruments were used as shown in circuit diagram fig:-

(1) Power supply unit

(2) Vibration pick-up

(3) Load cell

(4) Oscilloscope

(5) Dial gauge

3.3 LOAD CELL SPECIFICATION

(1) Capacity: - 5 tones

(2) Safe Over load: - 150 % of rated capacity

(3) Maximum Overload:- 200 % of rated capacity

(4) Fatigue rating: - 105 full cycles

(5) Non-linearity:- ± 1% of rated capacity or better

(6) Hysteresis: - ± 0.5 % of rated capacity or better

(7) Repeatability: - ± 0.5 % of rated capacity or better

(8) Creep error: - ± 1% of rated capacity or better

(9) Excitation: - 5 volts D.C. 46

(10) Terminal Resistance:-350Ω (nominal)

(11) Electrical connection: - Two meters of six core shielded cable/connected

(12) Temperature: - ± 10ċ to 50 ċ

3.4 ENVIRONMENT

(1) Safe operating temperature: - + 10^0 C to + 50^0 C

(2) Temperature range for which specimen hold good: - + 20^0 C to + 30^0 C

3.5 OSCIOLLOSCIP

Display: - 8x10 cm. rectangular mono-accelerator c.r.o. at 2KV e.h.t.

Vertical Deflection: - Four identical input channels ch1, ch2, ch3, ch4.

Band-width: - (-3 db) D.C. to 20 MHz (2 Hz to 20 MHz on A.C.)

Sensitivity: - 2 mV/cm to 10 V/cm in 1-2-5 sequence.

Accuracy: - ± 3 %

Variable Sensitivity :-> 2.5 % 1 range allows continuous adjustment of sensitivity from 2mV/cm to V/cm.

Input impedance: - 1M/28 PF 47

Input coupling: - D.C. and A.C.

Input protection: - 400 V D.C.

An oscilloscope measures two things:

- Amplitude in time domain

- Amplitude in frequency domain

3.6 SETTING UP AN OSCILLOSCOPE

Oscilloscopes are complex instruments with many controls and they require some care to set up and use successfully. It is quite easy to 'lose' the trace off the screen if controls are set wrongly! There is some variation in the arrangement and labeling of the many controls so the following instructions may need to be adapted for your instrument

3.7 EXPERIMENTAL TECHNIQUES

The actual logarithmic damping decrement of fixed-fixed welded joints is different from numerical results evaluate by theory .the experimental set up of fixed-fixed with detail instrument show in figure-1. All specimens were tested for their natural frequency, amplitudes and logarithmic damping decrement. A load cell was placed on the ground and above it a packing was given on which the specimen is kept. A certain load as per experiment is applied at the fixed end of each of the specimens. The midpoint of fixed-fixed beams specimens was excited with a spring. The excitation amplitude given to the specimen is indicated in the dial gauge. Vibration signal was picked up with the help of vibration pick-up and it was fed to oscilloscope. From there it is fed to oscilloscope where amplitude and frequency of the test signal were measured.

CHAPTER 4

RESULT AND DISCUSSION

4. RESULT

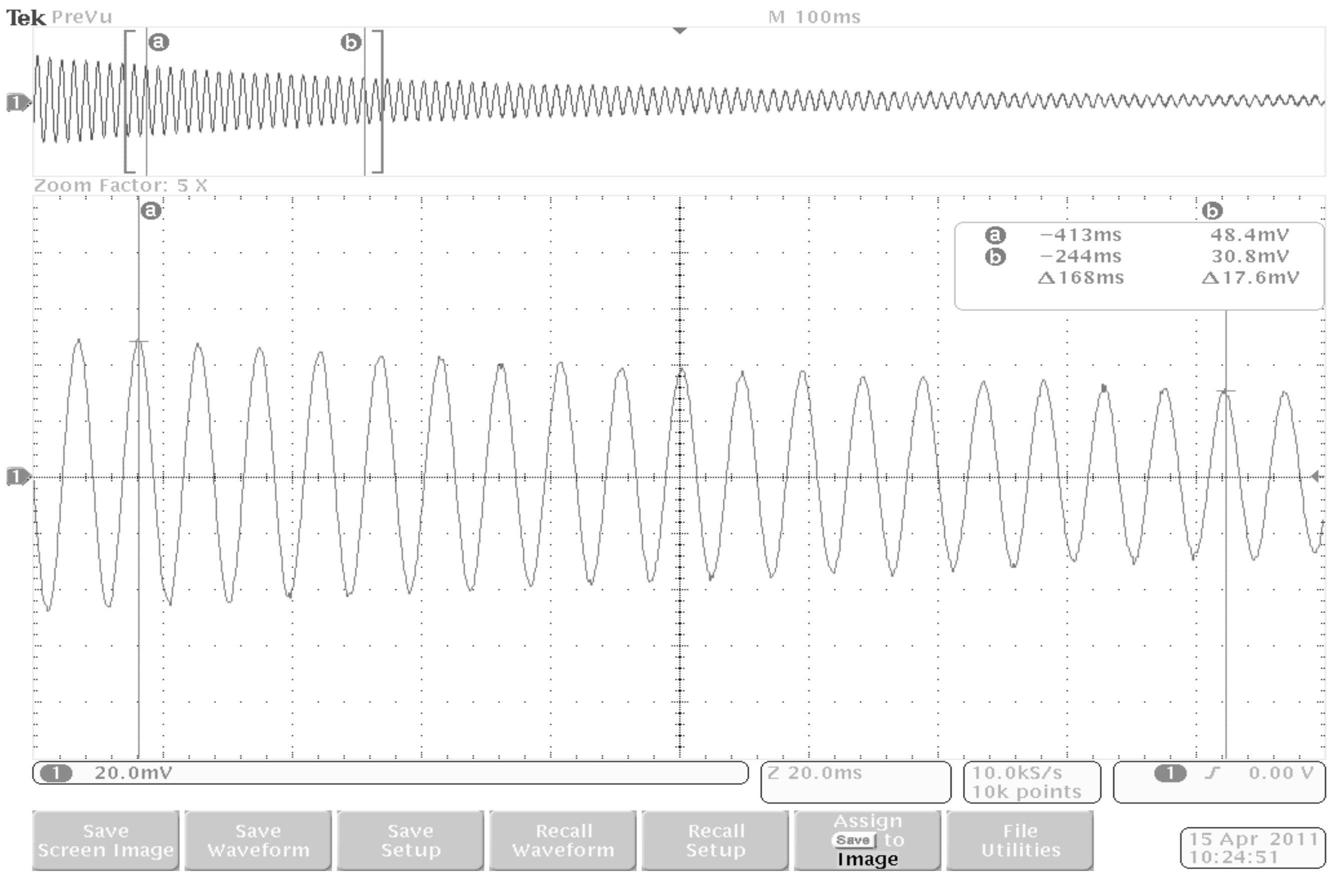

Fig-4(photograph of result of experiment by oscilloscope for fixed-fixed beam)

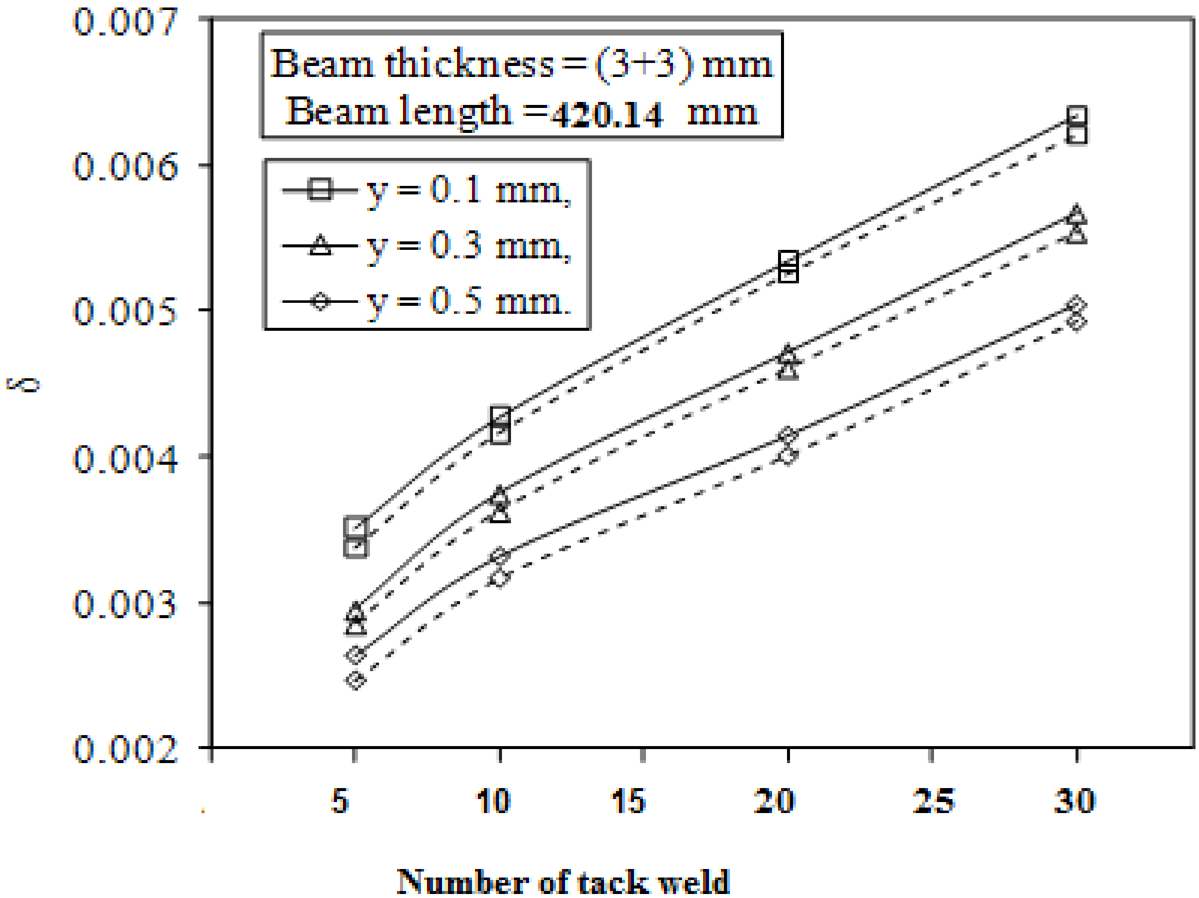

Fig-5(Variation of logarithmic decrement with the number of tack welds)

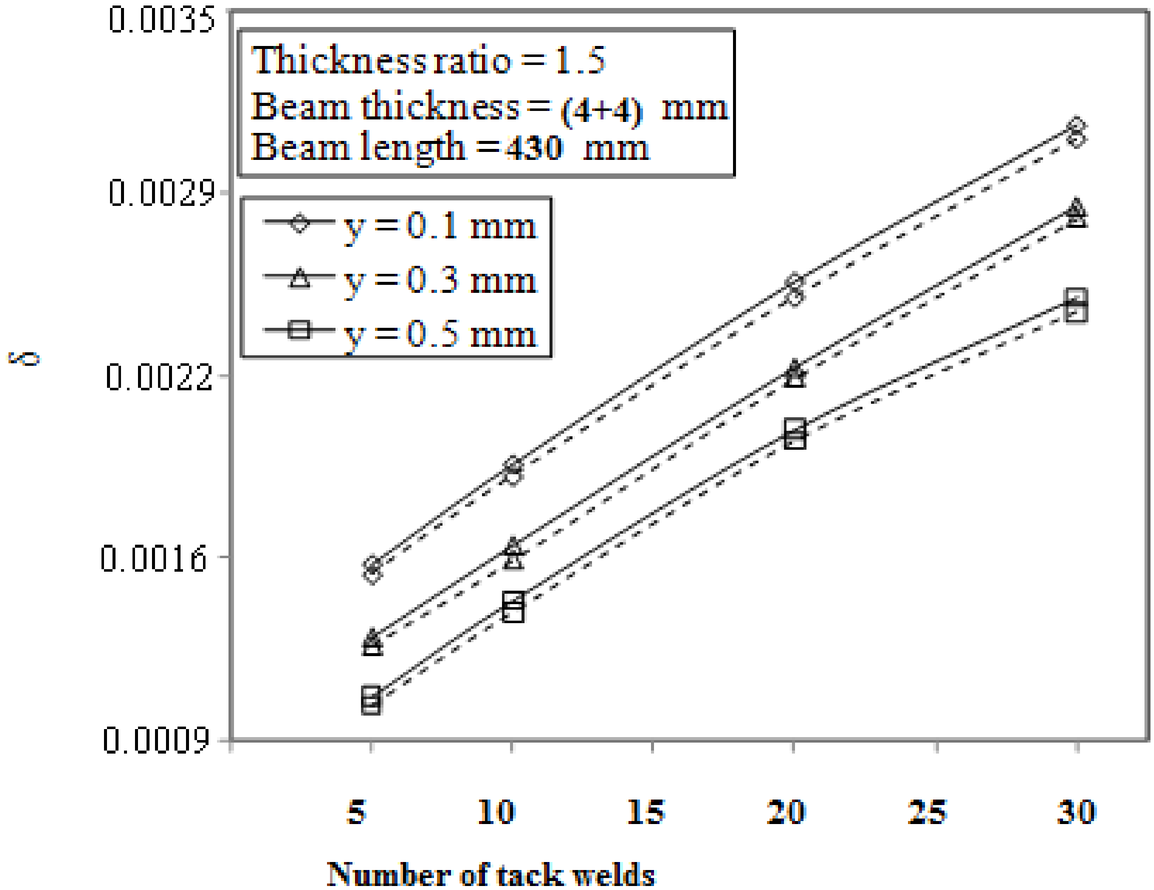

fig-6(Variation of logarithmic decrement with the number of tack welds)

4.1 DISCUSSION

From the experiment following points have been discussed in the given below

1 .damping ratio of layered increased then the decrease the initial amplitude of exciter .with an increase initial amplitude of excitation the input strain energy into the system is increased.

2 damping ratio of joint structure increases with increase of distance between two tack welds and so maintain uniform distance.

3 damping ratio layered and jointed structure increase with an increase in length if the length increase then thereby resulting in an increased area for energy dissipation of the structure.

CHAPTER-5

CONCLUSION

5. CONCLUSION

Mechanical joints and fasteners are primary sources of improving damping in structural design caused by friction and micro-slip between the interfaces. The damping of jointed welded structures has been studied theoretically considering the energy loss due to friction and the dynamic slip at the contacting layers. Further, the theoretical results obtained by using mathematical models have been verified by conducting extensive experiments for the validation of results. From the foregoing discussions, it is found that the damping of layered and welded structures can be improved by the following influencing parameters:

(a) Amplitude of excitation,

(b) Frequency of excitation,

(c) Length of specimens

(d) End condition of the beam specimen.

Finally, it is established that a useful increase in the inherent damping in a jointed structure can be achieved at lower initial excitation, greater number of layers and larger length of specimens. The welded structures being largely used in aircraft, pressure vessels, frames, trusses and machine members can be effectively designed to enhance the damping characteristics so as to minimize the disastrous effects of vibration and thereby increasing their life.

FEATURE WORK

1. Analysis study of damping of flat structures beam.
2. Analysis can extent for forced vibration
3. Damping study of layer of different material

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