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Vibration analysis of welded joints in aluminium structure and its consequences on damping of structure

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ABSTRACT

In this paper, study of structural vibration characteristics by implying welded joints is presented. The theoretical analysis of damping mechanism can be carried out by two ways. One of which is the traditional method with classical analysis approach and another can be finite element analysis method. The damping characteristics are very much influenced by intensity of pressure, micro slips and kinematic coefficient of friction at joints. But in addition to all these fundamental parameters, there are also some geometric parameters like number of joints, type of joint, type of welding, type of support of structure, type of material, inter distance between joints, layers of materials, which affect damping of structure. So parameters such as number of layers for same net thickness, material, number of weld joints, type of support to structure are studied wisely. The design concepts of constructing welded structures can be utilized in beams, trusses, automobiles, marine structures, aircrafts and aerospace structures, civil constructions, robotics and measuring, lab instrumentations. Most of these applications include wide use of aluminium, mild steel and their respective alloys. Hence, large numbers of experiments are selected under cantilever beam and fixed ends case using Fast Fourier Transform (FFT) analyzer in controlled vibration excitation conditions. And as in modern age various software are available for vibration analysis purpose, so for validation of experimental analysis, help of computerized aided engineering (CAE) is also taken.

Keywords— **Beam model, damping ratio, displacement excitation, frequency, welded joints.**

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I. INTRODUCTION

Damping of structures is subject of great interest and for applications for various fields as it relates to strength of structure, shock survivability and acoustic noise control. The concept of damping can be thought of as the culmination of various energy dissipation that removes mechanical energy from vibrating system.[1] The damping characteristics in layered and welded structures are influenced by the intensity of pressure distribution, relative dynamic slip and kinematic coefficient of friction at the interfaces and their correct assessment is very important to understand the mechanism of damping in such structures. All above parameters being largely influenced by the thickness ratio of the beam has been critically studied in subsequent chapters. [2]. 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. [12] The dynamics of mechanical joints is a topic of special interest due to their strong influence in the performance of the structure. [13] Further, the inclusion of these joints plays a significant role in the overall system behaviour, 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. [14] 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. [11] 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. [12] 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. [10] Tengyun Cao, Sutherland, Zheng studied damping measurement through experimental modal analysis by curve fitting method in frequency domain cut discriminate damping ratios for lightly damping ratios differences. They have carried out bolted joints under study for experimental analysis; 1996. [1]

R Singh examined dynamic analysis in 2 different cases. Case (I) was about role and performance of passive & adaptive hydraulic mounts. Case (II) was about importance of weld joints and adhesive joints in vehicle bodies and chassis structures via “T- shaped” and “L- shaped” beam assemblies. Dynamic analysis he carried numerical and analytical methods for exposure of challenges usually faced by engineers, designers. Also concluded dynamic analysis of vehicle components and systems is now integral part of engineering design process in adaptive industry; June 2000. [2] BK Nanda carried out analysis on modal to study mechanism of damping in layered and jointed structures with connecting bolts & washers. For that, conducted several no. of experiments to study effects on dynamic capacity of layered as well as jointed structures; August 2005. [3] Sergey Bograd, Andr´e Schmidt, Lothar Gaul went for the prediction damping in assembled structures with the help of a finite element solution. The influence of joint parameters, such as normal contact force and frequency dependence is examined. Once the joint parameters are found, they are input into a finite element model. An assembled structure is modelled with thin layer elements on the joints’ interfaces; 2005. [4] Jacek Cieslik & Janina Pieczara carried out quantitative analysis estimation of vibration energy transmitted through welded connection of ribbed plates. The structural intensity was used as parameter for analysis. Obtained results of calculation gave quantitative information on amount of energy transmitted, reflected, stored and the damped in welded joints of plates. Analysed cases were intentional to show utility of intensity method in diagnostics of joints in mechanical constructions. Calculations were verified experimentally by measurements of stress with application lock-in-thermography; October 2008. [5] Bhagat Singh & BK Nanda performed experimental & theoretical analysis investigation of slip damping in layered and jointed welded cantilever beams using finite element analysis approach. Came to conclusion that damping capacity of structure in welded joints influenced by parameters like- intensity of pressure distribution, slip at interface, welding techniques, spacing between tack welding, no. of joints, amplitude and frequency of vibration, dimensions of beam. Damping capacity can be improved largely by fabricating same with tack welds instead of continuous weld; March 2010. [6] A. Chattopadhyay, Glinka, Zein, Qiank studied nature of welded joints. By carrying stress analysis and fatigue analysis of welded structures. Nature of weld varies with pressure distribution on weld part, weld type, joint type. Numerical method is used for analysis of strength; June 2011. [7]. Shinji, Yoshiaki, Harusiha & Kenichi proposed of identifying dynamic characteristics of joints. They considered bolted joint method structure for finite element analysis and experimental analysis on FFT analyser. Spring stiffness and damping coefficient parameters are helpful to find dynamic characteristics of joint; April 2012. [8] Takao Hirai, Fumiyasu, Kazushi, Ichiro proposed procedure for calculating dissipated energy at interface using finite element static analysis. 3 plates structure by bolted joint, where long plate is sandwiched in between two short plates. The results obtained showed that when node shapes obtained from linear finite element model approximate actual deformation [9].

1.1 Objective:

This dissertation consists of two different parts: a theoretical analysis of the problem and an experimental work. The theoretical analysis proposes three different methods to evaluate damping: classical, finite element and response surface method. The validity of the theoretical methods has been validated by conducting the experiments. Time and frequency domain approaches have been adopted to experimentally evaluate the damping capacity. Both the finite element analysis results obtained through use of CAE software and experimental results are compared for authentication. Finally, useful conclusions have been drawn from the finite element analysis software and experimental results. So in brief description, we may find our objectives,

1. To develop a damping model that is capable of describing the effects of welded joints on a vibrating structure for both specimen material mild steel (M.S.) and also for aluminium (Al).
2. A careful theoretical and experimental study to quantify the effects of the joints on the structural damping.
3. The damping characteristics in layered and welded structures in both cantilever beam as well as fixed-fixed support beam keeping thickness ratio constant i.e. 1.00.

4. The damping characteristics in layered and welded structures are influenced by the intensity of pressure distribution, no. of layers, no. of tack weld, dimension of beam and their correct assessment in both support cases.

Thickness X Width	No. of Layers	Type of Joint	No. of Tack Welds	Beam Length
(3+3) X 40	2	Welded	4	440
(2+2+2) X 40	3	Welded	4	440
(1.5+1.5+1.5+1.5) X 40	4	Welded	4	440
(1+1+1+1+1+1) X 40	6	Welded	4	440
6 X 40	1	Solid	-	440

5. Comparative analysis of damping characteristics of welded joints with respect to bolted and riveted joints.

1.2 General Assumptions:

In the present analysis, certain assumptions are made while exploring the joint dynamics. These include:

(1) Each layer of the beam undergoes the same transverse deflection.

(2) The initial excitation at the free end of the beam is of small amplitude.

(3) There is no gross or macro-slip at the joint.

(4) The local mass of the joint area is not considered as significant in altering the behaviour of the beam.

(5) The effect of residual stress due to tack welding is neglected.

(6) There is no displacement and rotation of the beam at the clamped end.

(7) The material behaves linearly.

(9) The deflections are small compared to the beam thickness.

(10) The material and support damping are neglected.

The dynamic analysis is performed under free vibration mode. So it is needed to develop dynamic equations of free transverse vibrations.

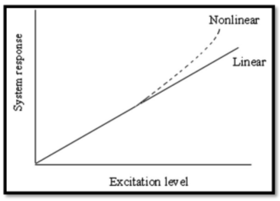


Fig 1: Structure response Vs Excitation

II. EXPERIMENTATION

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

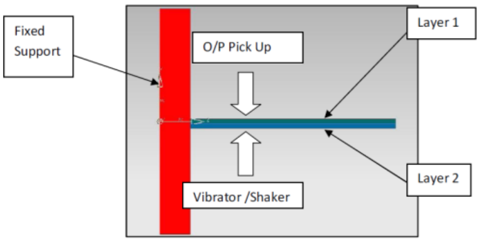


Fig 2: Cantilever welded joint beam case

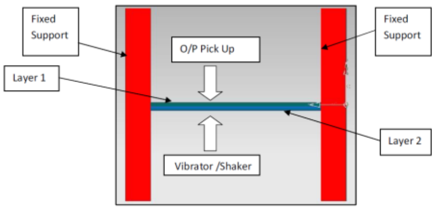


Fig 3: Fixed- Fixed Welded Joint Beam

2.1 Test Specimen Specifications

Above figures show schematic setup for fixed and cantilever beams. For respective materials which are widely used in structures and automotive, robotics etc., which are mild steel (MS) and aluminium (Al). So our main motive of finding damping in welded joints move around these metals.

Table 1: Specimen specification for Aluminium (Al) for layer variations

Note: ALL LENGTH DIMENSIONS IN MM.
As shown above table (1), l/d ratio is maintained as 10.00. So, we can apply “Euler Bernoulli beam theory (Thin beam theory)”.
Experiments are carried out on both metals joints in cantilever as well as in fixed beam support case to find out damping parameters and damping response of welded joints.

Fig 4: M.S. (L) and Aluminium (R) Specimen

Fig (4) shows some of specimens which are used for experimental analysis purpose. On left of fig (4) mild steel where as on right hand side aluminum specimens are placed.

2.2 Set Up Preparation:

The biggest obstacle of experimental work was preparing set up for experimentation. For that sake, initially we prepared 3D conceptual design for set up. After confirming its all merits and demerits, we finalized design. In below fig (5), the 3D modeling of set up is shown. The 3d modeling was prepared using UniGraphics NX 6 CAD software.

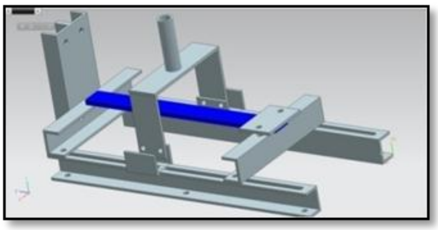


Fig 5: Conceptual 3D Drawing of Set up

As all things got cleared in set up design, we started fabricating it. The final sets up views are shown below in fig (6), (7).

Fig 6: Isometric view of set up

Fig 7: Front view of set up

2.3 Testing Procedure:

In order to find out the damping capacity of jointed beams experimentally and compare it with the theoretical results, an experimental set-up is used to compare the theoretical value with the experimental value. For this some experiments are conducted on the prepared specimens. The various measurement techniques used for the calculation of the value of the Young's modulus of elasticity, loss factor, damping ratio and quality factor. Once, vibration response graphs of the specimen materials are determined, tests are further conducted on the same set of specimens for evaluating the damping capacity. 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.

Half power bandwidth method is preferred using frequency domain results and loss factor (η) by frequency domain result. However, the other nomenclatures such as damping ratio (ζ) and quality factor (Q) are calculated. So if damping ratio (ζ) raises, damping of structure increases and vice versa.

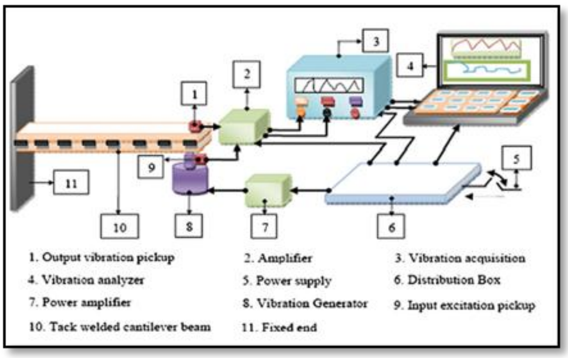


Fig 8: Experimental setup [6]

Fig. (8), shows conceptual experimental set up for measuring damping of beams, here in cantilever support. Distribution box is nothing but signal conditioning unit i.e. FFT analyzer.

After setting up set up, while taking readings for beams, there should be some clearance provided in order to let vibrate beam model under free vibrations after initial excitation.

Fig 9: Test procedure

In fig (9), visualises clearance "X" in between rod and beam but at same time equal clearance must be provided in dial gauge for precise measurement of excitation amplitude.

III. EXPERIMENTAL ANALYSIS

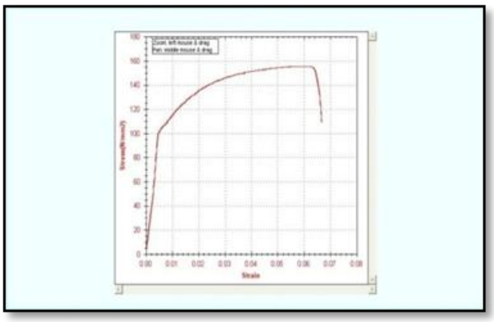
For initial input in CAE simulation of cases we generally require software like Ansys or Hypermesh. As Ansys11.0 s APDL has been used for simulation purpose. Basic three parameters are needed listed below:

1. Poisson's ratio, which is taken as 0.3;
2. Density, as per design data book standard or by measuring mass and calculating density respectively.
3. Young's Modulus (E) calculated by performing uni axial tensile test on UTM.

3.1 Measurement of Young's Modulus:

The Young's modulus of elasticity (E) of the specimen material is found out by conducting static deflection tests. For this purpose, few samples of solid specimen beams are selected from the same stock of mild steel flats. These specimens are mounted on the same experimental set-up rigidly so as to ensure perfect boundary conditions for fixed-fixed beam.

Static loads (W) are applied at the mid-span and the corresponding deflections (Δ) are recorded. The Young's modulus for the specimen material is then determined using the expression $E=WL^3/ 192I\Delta$, where L and I are the free length and moment of inertia of the fixed-fixed specimen. The average of some readings is recorded from the tests from which the average value of Young's modulus for different material is evaluated and is found. For obtaining young's modulus, we have taken tensile tests on UTM (Universal Testing Machine). And graphs are recorded, and stored.



Graph 1: Stress Vs Strain graph for Aluminium specimen

From above graph (1),

Young's Modulus i.e. value of "E" for Aluminium can be found out using Hooke's formula:

Young's Modulus (E) = (Stress / Strain) in elastic limit

= 75Gpa.

Experimental results of vibrations on beams are taken with help of FFT analyzer. Using spring loaded dial gauge appropriate exciting deflection is provided and beam is set to vibrate freely on free vibrations. And vibrations are recorded on computer which rectifies signals sent by accelerometer which is attached to beam. Accelerometer measures accelerations respective of point of sensor. Specifications of FFT analyzer are listed as below:

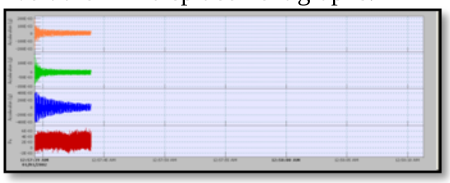
FFT analyser: OROS 4-channel FFT analyser

Sensor: Single magnetic Accelerometer- 3axis measurement

Sensitivity: X axis-98.6mv; Y axis- 99.7mv; Z axis-101mv

Software: NV Gate-3.0

By using this we get accelerations in time domain as well as frequency domain. For damping measurement purpose we had to convert them in displacement graphs.



Graph 2: 3 axis (X, Y, Z) & 1 microphone vibration graph

Graph (2) shows variation of accelerations in different axis in time. The last bar shows acoustic pressure change with time. And acceleration graph in frequency domain are needed to convert into displacement vs. Frequency for ease of operation.

Damping ratio is measured by two methods. Selection of either method is based on output form of measurement. If measurement is taken in terms of time domain graphs, logarithmic decrement preferred. Or else use "half-power bandwidth" concept in frequency domain. [11]

In the present study, damping has been measured using the half power bandwidth method based on frequency domains. See fig. (10).

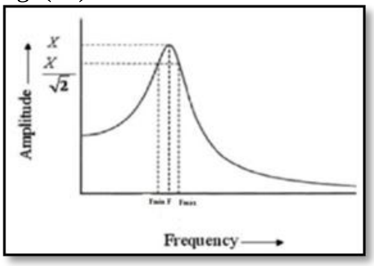


Fig 10: Half-power bandwidth method

Half power bandwidth method measures loss factor, quality factor and damping ratio simultaneously by formula, which is also known as 3db method. [12]

Damping is nothing but energy dissipation mode. So we can calculate energy loss in propagation of vibration i.e. damping of medium. This loss of energy is measured using loss factor formula, as follows:

Loss factor (η),

$\eta = (F_{max} - F_{min}) / F$

From value of loss factor damping ratio () is measured by following formula,

Damping ratio (ξ),

$2\xi = (F_{max} - F_{min}) / F$

$2\xi = \eta$

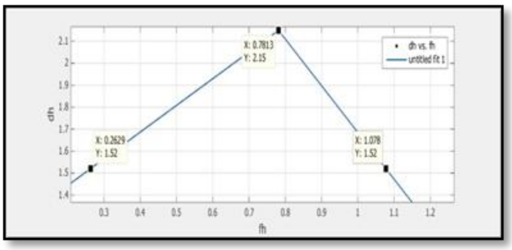
And amplification factor which is commonly known as quality factor (Q), calculated by formula

$(1/Q) = 2\xi$

Hence;

$\eta = 2\xi = (1/Q)$

Where, η- Loss factor, ξ – Damping ratio, Q- Quality factor [12]



Graph 3: Curve fitting to find vibration parameters (ξ**)** using MatLab

Graph (3) depicts at 0.78Hz frequency displacement becomes 2.15mm. And damping ratio can be calculated by half power bandwidth method as;

X_{max}= 2.15m;

$X_{max}/\sqrt{2}$ = 1.52mm

Therefore respective F_{max} = 1.078Hz and F_{min}=0.2629Hz

$2\xi = (1.078Hz-0.2629Hz) / 0.7813Hz$

$2\xi = 0.8151Hz / 0.7813Hz$

$2\xi = 1.043$

$\xi = 0.5215$

Here, ξ =0.5215 < 1 means it is under damped vibrations. Likewise we need to find for each wave damping ration in each case. For ease of operations we selected peak wave.

And additionally we must select peak in same range of frequency for all signals. To obtain damping variations it is strictly to provide controlled vibrations. [12]

For cantilever case, excitations provided in 5 discrete unit steps 1mm, 2mm, 3mm, 4mm and 5mm. And for fixed ends case, excitations provided in 5 discrete steps 1mm, 2mm and 3mm.

3.2 Effects of layers, material, support on damping of structures:

Considering net thickness of 6mm, and dividing thickness into number of layers keeping thickness ratio 1.00 in both aluminium as well as mild steel under fixed ends and cantilever support, we can estimate results of damping under influence of layers, material and support.

3.2.1 Aluminium (Al):

Aluminium specimens specified in table (1) are tested under both cantilever and fixed ends case under specified excitations.

3.2.1.1 Aluminium in Cantilever Case:

Table which is shown below depicts parameters, which signifies damping of Aluminium structure when 1mm of amplitude excitation.

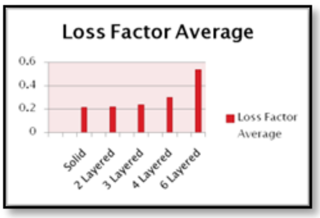
Table 2: Parameters calculations of Aluminium (Al) in cantilever case with 1mm excitation

Specimen	Fmax	Fmin	F	Loss Factor	Damping Ratio	Quality Factor
Half Solid	10.93	9.785	9.375	0.122133333	0.061066667	8.187772926
Solid	20.87	18.35	18.75	0.1344	0.0672	7.44047619
2 Layered	17.05	14.94	15.63	0.134996801	0.067498401	7.407582938
3 Layered	20.82	17.8	18.75	0.161066667	0.080533333	6.208609272
4 Layered	19.43	16.38	17.19	0.177428738	0.088714369	5.636065574
6 Layered	18.21	14.35	17.21	0.224288205	0.112144102	4.458549223

In all readings of table (2), it has been observed that a lot of variations in damping parameters appeared. So the problem is clarified by taking average of all characteristics to draw final conclusions, as shown in table (3).

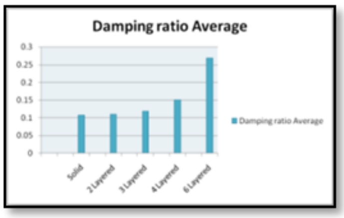
Table 3: Parameters average of aluminium (Al) in cantilever case with all (1mm, 2mm, 3mm) excitation

Specimen	Loss Factor Average	Damping ratio Average	Quality Factor Average
Solid(6mm)	0.213998414	0.106999207	6.13800368
2 Layered	0.218597774	0.109298887	6.050840453
3 Layered	0.237500556	0.118750278	5.387207593
4 Layered	0.3014426	0.1507213	4.23961131
6 Layered	0.53711934	0.26855967	2.222167309



Graph 4: Loss factor average Vs layered specimens of aluminium (Al) in cantilever beam

Above graph (4), shows the variation of average of loss factor against multi layered aluminium specimens under cantilever support.

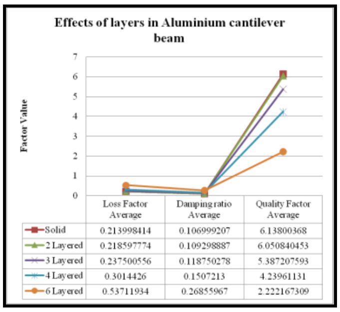


Graph 5: Damping ratio factor average Vs layered specimens of aluminium (Al) in cantilever beam

Above graph (5), shows the variation of average of damping ratio against multi layered aluminium specimens under cantilever support.

Graph 6: Quality factor average Vs layered specimens of aluminium (Al) in cantilever beam

Graph (6), shows the variation of average of quality factor of multi layered aluminium specimens under cantilever support.



Graph 7: Effects of no. of layers in aluminium (Al) cantilever beam

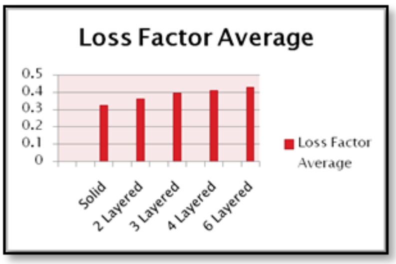
Graph (7), explains the variation of all three damping parameters i.e. loss factor, damping ratio and quality factor. Compared to value of quality factor, loss factor and damping ratio values are closer and small.

3.2.1.1 Aluminium in fixed ends Case:

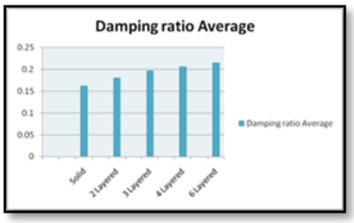
Table 4: Parameters average of aluminium (Al) in fixed ends case with all excitations

Specimen	Loss Factor Average	Damping ratio Average	Quality Factor Average
Solid	0.3238	0.1619	8.904970275
2	0.3611012	0.1805506	8.847190

Layered	16	08	308
3 Layered	0.3937675 37	0.1968837 68	8.836182 726
4 Layered	0.41148	0.20574	8.552406 037
6 Layered	0.4293300 47	0.2146650 24	7.081236 296



Graph 8: Loss factor average Vs layered specimens of aluminium (Al) in fixed beam

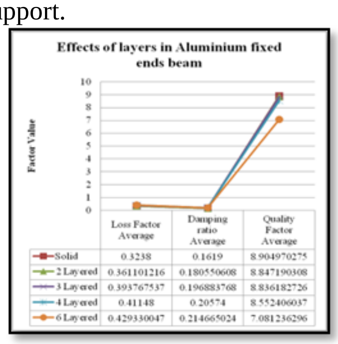


Graph 9: Damping ratio average Vs layered specimens of aluminium (Al) in fixed beam

Above graph (8) & (9), shows the variation of average of loss factor and damping ratio against multi layered aluminium specimens under fixed support.

Graph 10: Quality factor average Vs layered specimens of aluminium (Al) in fixed beam

Above graph (10), shows the variation of average of quality factor average against multi layered aluminium specimens under fixed support.



Graph 11: Effects of no. of layers in aluminium (Al) fixed beam

Graph (11), explains the variation of all three damping parameters i.e. loss factor, damping ratio and quality factor in both ends fixed beam case.

Compared to value of quality factor, loss factor and damping ratio values are closer and small.

IV. CAE ANALYSIS

CAE analysis of beams under vibration influence is studied using Ansys 11.0 APDL.

Basic three parameters

For aluminium (Al)-

1. Poisson's ratio= 0.3;

2. Young's modulus=75Gpa=7.5 tonnes/mm^2.

3. Density = 2780kg/mm^2 = 2.78 E-9 tonnes/mm^3.

Other specifications while analysis on Ansys 11.0;

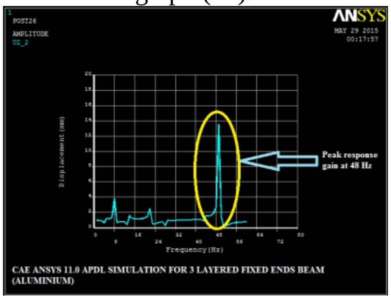
Element type: Shell63- 4 nod elastic

Analysis mode: Harmonic analysis

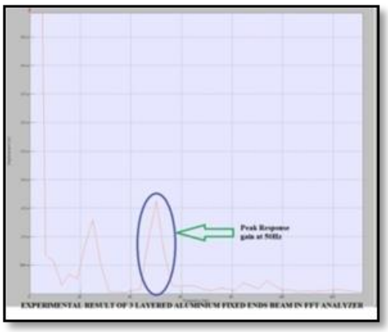
Frequency range: 0Hz-100Hz

Graph type: Both Linear and Logarithmic of Displacement Vs Frequency.

As shown below graph (12) of Displacements Vs Frequency are obtained in Ansys 11.0. Though these graphs does not match original graph result (13) obtained using FFT exactly, but peak values in FFT experimental results are matched convincingly. As experimental data may get influenced by support quality, parallax error, human error, random errors as well as systematic errors related to set up. But at end in overall results about 75% to 80% results of experimentation and software are found matched quite convincingly as shown in graph (14).

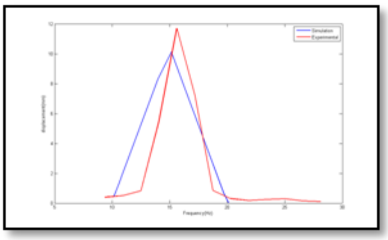


Graph 12: CAE simulation of 3 layered aluminium fixed beam with 1mm initial actuation



Graph 13: Experimental result of 3 layered aluminium fixed beam with 1mm initial actuation

Hence it could be claimed that the results prepared using Ansys 11.0 APDL supports experimental results by FFT analyser. So vice versa it also could be said that experimental results are convincingly correct to best of knowledge.



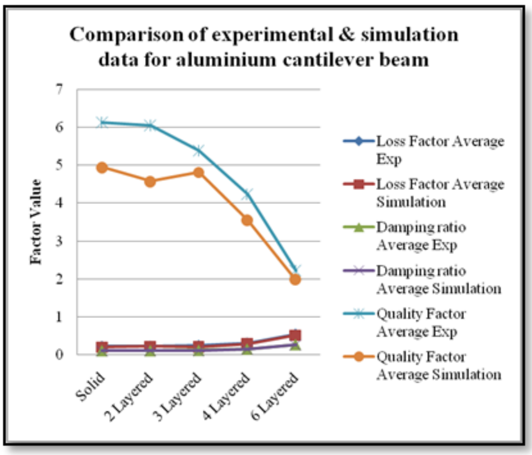
Graph 14: Superimposition of simulation and experimental result of 3 layered aluminium fixed beam with 1mm initial actuation

V. Comparison And Validation of Data

For validation of experimental data it is must to carry out CAE simulation work and comparison of both data simultaneously.

Table 5: Experimental & simulation data for aluminium cantilever beam

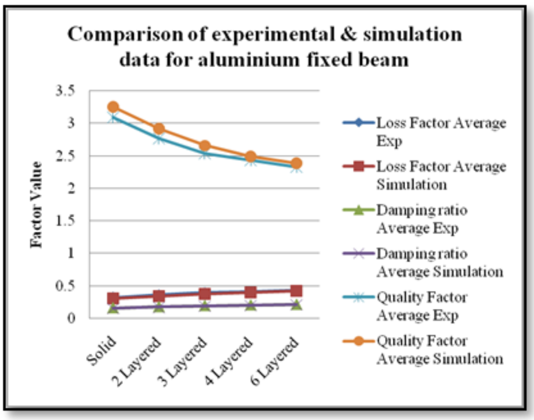
	Loss Factor Average		Damping ratio Average		Quality Factor Average	
Specimen	**Exp**	**Simulation**	**Exp**	**Simulation**	**Exp**	**Simulation**
Solid	0.213998	0.201998414	0.106999	0.100999207	6.138004	4.950533921
2 Layered	0.218598	0.218597774	0.109299	0.109298887	6.05084	4.57461201
3 Layered	0.237501	0.207500556	0.11875	0.103750278	5.387208	4.81926419
4 Layered	0.301443	0.2814426	0.150721	0.1407213	4.239611	3.553122381
6 Layered	0.537119	0.50711934	0.26856	0.25355967	2.222167	1.971922429



Graph 15: Comparison of experimental & simulation data for aluminium cantilever beam

Table 6: Experimental & simulation data for aluminium fixed beam

	Loss Factor Average		Damping ratio Average		Quality Factor Average	
Specimen	**Exp**	**Simulation**	**Exp**	**Simulation**	**Exp**	**Simulation**
Solid	0.3238	0.3078	0.1619	0.1539	3.088326	3.248862898
2 Layered	0.361101216	0.3432012	0.180551	0.171600608	2.769307	2.913742593
3 Layered	0.393767537	0.3767675	0.196884	0.188383768	2.539569	2.654156483
4 Layered	0.41148	0.40248	0.20574	0.20124	2.430252	2.484595508
6 Layered	0.429330047	0.4200474	0.214665	0.210023701	2.32921	2.380683691



Graph 16: Comparison of experimental & simulation data for aluminium fixed beam

It has been observed that experimental results and calculated factors i.e. loss factor, damping ratio, quality factor matches values with those values obtained by CAE simulation. Values resulted from experiment differs by 15-20% respective to simulation results. As results are convincingly validated, so it could be concluded that results calculated results are precise, reliable.

VI. Conclusion

In the present work, experimental analysis has been carried out to investigate mechanism of dynamic slip, which results in damping of structure. CAE simulations are conducted to validate experimental results. The results plotted in tables and graphs shows coherence in between experimental data and simulation data. From analysis, it is inferred damping capacity of structure can significantly enhanced by application of multi layered, multi joined welded joints.

1. Finally, it is established that the damping capacity of the layered and jointed welded structures can be improved largely by fabricating the same with tack welds instead of continuous welds.
2. Moreover, more relative spacing between the consecutive tack welds with less no. of tack joints under smaller amplitude of excitation will enhance the damping capacity substantially.
3. The results plotted in the figures and table show the coherence between the experimental and finite element analysis. As a result, it is found that CAE analysis brings validation to experimental results.
4. Though continuous weld shows high damping compared to tack weld joints, but mass as well as properties of structure are changed.
5. Fixed support case damping is quicker than cantilever case damping, because of support characteristics.

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