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Vibration Analysis of Adhesively Bonded Lap Joint

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ABSTRACT

Adhesively bonding is a high-speed fastening technique which is suitable for joining advanced light weight sheet materials that are dissimilar, coated and hard to weld. This joints are used recently because now a days we are going for light weight application and it is very important for us to build such joint which will not only decrease its weight as per requirement but will also help in damping the vibrations. In this project we can understand the effect of using neoprene rubber for joining two dissimilar metals, by making use of an industrial adhesive, which is very powerful. After making this joint we conduct a test on FFT Analyser and find natural frequencies. Also to validate the prediction by using ANSYS software. By changing the thickness of rubber & overlap length, different natural frequencies are obtained. Experimental analysis will be done by preparing lap joint with aluminium plates and Locktite.407 as adhesive, and for damping the vibration neoprene rubber used as viscoelastic material. The effect of thickness of rubber and overlap length on natural frequency will also be carrying out. Adhesive bonds find a large application in the field of aerospace and automotive industries. There are few aircrafts in market which makes use of adhesives for joining 60% of its body part. This joint ensures a firm structure with a better control over various modes of frequencies while on the other hand welded joints if used in place of elastic joint can add stiffness to the joint. The coordination of experimental and analytical techniques will makes it possible to find the efficient tool for studying the dynamic response of single lap joint.

***Keywords*— Adhesive, Viscoelastic material, Passive damping, Composites.**

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I. INTRODUCTION

An adhesively bonded joint has widespread applications in aeronautics, aerospace, automobile, semiconductor, and civil structure. Reliability of adhesively bonded joints not only depends on design, material and manufacturing methods but also on effective analysis of the characteristics of the joints. In recent years, adhesives have been widely used to bond dissimilar material members particularly in aircraft and automobile structures. In many applications adhesively bonded joints are more suitable than traditional joining techniques such as mechanical fastening, especially for components made from composite or polymeric materials, because they can provide uniform distribution of load, resulting in better damage tolerance and excellent fatigue life. Because of the involvements of many geometric, material and fabrication variables, and complex failure modes and mechanics present in the joints, a deep understanding of the failure behaviour of adhesively bonded joints, particularly under combined loading conditions, is needed in order to fully achieve the benefits of adhesive bonding.

Boeing 747 aircraft has 62% of its surface area constructed with adhesive bonding, while Lockheed C-5A aircraft has 3250 m2 of bonded structure. In many structures such as those for flight and space vehicles etc. adhesively bonded structures have often been used recently, because of great advances in adhesive bonding techniques. Many aerospace structures such as truss system of space telescope & space station are constructed using predominantly composites beams, plates & bonded joints. These structures should possess sufficient inherent damping capacity to keep vibration & acoustics response caused by external disturbances within acceptable limits. The current trend is to use viscoelastic material in the joints for passive vibration control in the structures subjected to dynamic loading.

The rapid development of structural adhesives has led to the widespread use of adhesive joining technique in defence, aerospace, rail, ground transportation applications. In these applications the joints are designed to carry in plane roads, although they are also prone to transverse loading from crashes, bullets, fragments, tool drops, or flying debris. The usage of bonded joints in primary load bearing structures, especially aerospace and military applications, makes it important to understand their failure mechanisms under transverse and in plane loading.

II. PROBLEM STATEMENT

Result of the trend towards lightweight construction in manufacturing, there has been a significant increase in the use of adhesively bonded joints in engineering structures and components [2].The conventional joining process increase the weight of the structure by adding extra material such as bolt, screws, extra filler material. If you want to join two plate by bolting then hole is created in the plate which result in stress concentration or if you joint by weld then there is localized heating of the component take place which alter its mechanical properties [9].

In the design of mechanical systems, for minimum vibration response, a specific knowledge of the damping capacity of the joints is important [2].To overcome those problems we can use adhesively bonded single-lap joints and prediction of its dynamic response, in future application of adhesively bonding by allowing different parameter to be selected to give as large process window as possible for bonded beam vibration analysis.

III.METHODOLOGY

In this work neoprene rubber is used as viscoelastic material and Locktite.407 is as adhesive. The two adherends used were aluminum plates of dimension 150mm long, 25mm wide, 2.5mm thickness. By changing the overlap length and rubber thickness modal analysis is carried on FFT analyser. The effect of thickness of rubber and overlap length on natural frequency is also carried out. Also we can simulate the lap joints on ANSYS and find the natural frequencies and mode shapes of the lap joints.Compared it with the natural frequency that we get from FFT analyser.

TABLE I

Properties of Material

Sr. No.	Material	Density Kg/m^3	Young's Modulus (E) N/mm^2	Modulus of rigidity (G) N/mm^2	Poisson's ratio(μ)
1	Aluminium	264870	0.675 x 10^5	0.260 x 10^5	0.34
2	Neoprene Rubber	1.23-1.25	0.0007-0.0002	0.0006 x 10^6	0.499

IV. EXPERIMENTATION

Experimental modal analysis also known as modal analysis or model testing deals with determination of natural frequencies, damping ratio and mode shapes through vibration testing.

A. Preparation of Lap Joint

The preparation of lap joint Specimen is the first step in the modal testing .The material used for primary beams is Aluminium. As a first step aluminium beam are cut into pieces 150 mm long 25 mm wide & 2.5 mm thickness for the primary beam, The aluminium beams are then surface finished with the help of abrasive paper.

The damping material used for modal testing of joint is Neoprene Rubber the damping material is a standard viscoelastic material 2mm, 3mm & 5mm thickness. In order to get a perfect bond between damping material & beam, a very thin layer of adhesive Locktite.407 are applied. Then two aluminium plates are joint in a lap section with a rubber material of variable thickness in between joints and an adhesive for making a tight bond. The viscoelastic layer is then correctly bonded in the overlap region of the joint. The resulting joint specimen is the cured at room temperature for more than 24 hours under a weight of 25 to 30 kg.

B. Procedure to carry out Experimental Modal Analysis using FFT

The basic experimental modal setup is shown in fig.1.The frequency response function (FRP) in terms of reacceptance ratio of displacement to forces was measured using the experimental setup. The lap joint was fixed at one end as like cantilever condition. An impact with a force transducer is used as an excitation source (channel 1) and an accelerometer is used as the output (channel 2).The point of impact and position of the accelerometer are chosen such a way that the natural frequencies of the system can be easily determined by locating peaks of transfer function.

Fig.1 Photograph Showing the Experimental Setup for lap joint

V. FINITE ELEMENT ANALYSIS

NSYS is comprehensive general purpose finite element analysis software which capable of performing structural, heat transfer, fluid flow, electromagnetism and biomedical analysis. The ANSYS version has multiple windows incorporating Graphics users interface, pull down menus, dialog box and tool bar.

Finite Element Analysis by ANSYS

ANSYS, Inc. has developed product lines that allow you to make the most of your investment and choose which product works best in your environment. ANSYS is a finite element analysis (FEA) code widely used in the computer-aided engineering (CAE) field. ANSYS software allows engineers to construct computer models of structures, machine components or systems; apply operating loads and other design criteria; and study physical responses, such as stress levels, temperature distributions, pressure, etc. It permits an evaluation of a design without having to build and destroy multiple prototypes in testing. The ANSYS program has a variety of design analysis applications, ranging from such everyday items as dishwashers, cookware, automobiles, running shoes and beverage cans to such highly sophisticated systems as aircraft, nuclear reactor containment buildings, bridges, farm machinery, X-ray equipment and orbiting satellites.

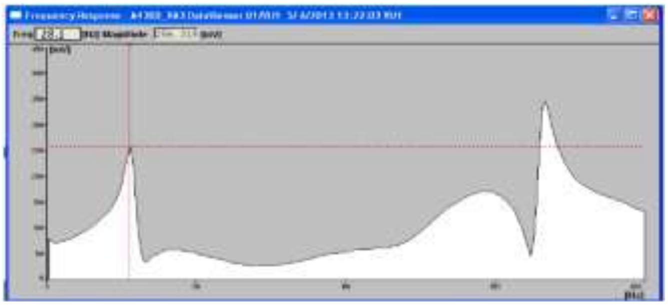

Fig.2Fundamental frequency for lap joint with 2mm bonding Thickness and 30mm overlap

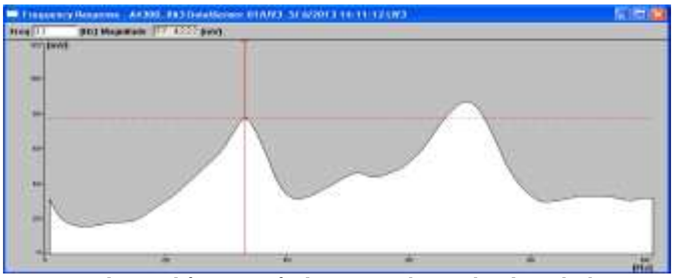

Fig.3 Fundamental frequency for lap joint with 2mm bonding Thickness and 50mm overlap

These readings were taken from ANSYS software. We made use of APDL programming. We can see that how fundamental frequency remains same with the increase in thickness of rubber but at the same time second mode frequency do not show much difference because here damping is increased. This readings are well matching to the FFT readings.

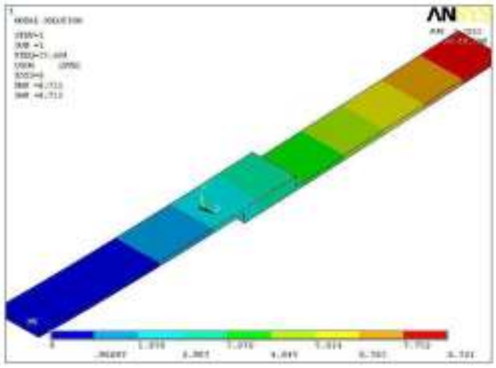

Fig.4 Nodal Solution

VI. RESULTS & DICUSSION

The specimens were prepared by bonding two similar beams over the desired using an adhesive much care was taken to obtain a good bond by properly curing the joint system in an oven.The dimensions of the unbounded beams are having length 150mm width 25mm and thickness 2.5mm. These dimensions and material properties were input to software to predict the natural frequencies and mode shapes. An impact hammer with an attached force transducer was used to excite the specimen and the response was measured by accelerometer. The frequency response was immediately computed and recorded on FFT analyzer. This work is carried out for various overlap and rubber thickness. From table it is seen that there is good agreement between the predicted values of natural frequency and experimental data. The percentage difference between the two results is in the range of three to nine percent. Comparisons of FEM and experimental work is shown below,

TABLE III
FOR OVERLAP OF 30MM (FUNDAMENTAL FREQUENCY)

Sr. No.	Bonding Thickness	Experimental Reading Natural Frequency (Hz)	FEM Reading Natural Frequency (Hz)
1	2mm	28.1	27.694
2	3mm	37	35.605
3	5mm	69	68.578

TABLE IIII
FOR OVERLAP OF 50MM (FUNDAMENTAL FREQUENCY)

Sr. No.	Bonding Thickness	Experimental Reading Natural Frequency (Hz)	FEM Reading Natural Frequency (Hz)
1	2mm	33	31.590
2	3mm	37	40.504
3	5mm	78.2	78.662

VII. CONCLUSION

In this dissertation work vibration analysis of adhesively bonded lap joint is done by using FEA and experimental method. By observing the results obtained in both methods it concludes that:

1. FFT can be used to predict natural frequencies and mode shapes of bonded lap joint system. The modal analysis can also be used to predict system modal damping values by properly choosing material damping values of the beam and the adhesive.
2. Increasing the shear modulus of the adhesive layer will increase the stiffness of the joint but reduce the damping capacity.
3. The damping capacity of the joint appears to be sensitive to changes in the adhesive thickness up to certain limit. Furthermore increasing thickness beyond a certain limit will not yield additional benefits. An increasing the overlap ratio will increase the stiffness of the joint.
4. If bonding thickness is 2mm the fundamental frequency is 28 Hz, for 3mm its 37Hz and for 5mm its 69Hz and second mode frequency varies as 167, 198, 206Hz respectively. Now we can see that though fundamental frequency show considerable change and second mode is getting closer to previous value. So we can say that damping coefficient increases with increases with increase in thickness.The percentage difference betweenthe two results is in the range of three to nine precents.
5. Beyond 5mm bonding thickness stiffness will increase and can lead to failure of joint under high impact.
6. It is very important to keep the value of rubber thickness to a optimum value in order to get the required damping.

Future scope: More work can done for various joints likedouble strap joint, corner joint, double lap joint etc. A finite element thermal stress analysis is also conducted in order to investigate the behavior of adhesively bonded joints. The current trend is to use viscoelastic material in the joints for passive vibration control in the structures subjected to dynamic loading.

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REFRENCES

[1] Goland M., and Reissner, E.,"The Stresses in Cemented Joints, "ASME Journal of Applied Mechanics, 1944, Vol. 11, pp. A17-A27.

[2] Xiaocong He, “Numerical and experimental investigations of the dynamic response of bonded beams with a single-lap joint”, Adhesion and Adhesives,37, (2012) 79-85.

[3] Yu Du*, Lu Shi, “Effect of vibration fatigue on modal properties of single lap adhesive joints”, Adhesion and adhesives,53,(2014) 72-79.

[4] Xiaocong He, “Finite element analysis of torsional free vibration of adhesively bonded single-lap joints”, Adhesion and Adhesives,48,(2014),59-66.

[5] XiaocongHe,“A review of finite element analysis of adhesively bonded joints” Adhesive and Adhesions ,31 (2011), 248-264.

[6] Menq,D.J.,Modelling& vibration Analysis of Friction joints, ASME journal vibration & Acoustic,1989,vol.111, pp.71-76.

[7] Miles, R. N., and Reinhall, P. G., 1986, "An Analytical Model for the Vibration of Laminated Beams including the Effects of Both Shear and Thickness deformation in the Adhesive Layer," Journal of vibration & Acoustic, Vol. 108, pp. 56-64.

[8] Saito, H., and Tani, H., "Vibrations of Bonded Beams with a Single Lap Adhesive Joint," Journal of Sound and Vibration, 1984, Vol. 92, No. 2, pp 299-309.

[9] Y. B. Patil, R. B. Barjibhe, “Madal analysis of adhesively bonded joints of different materials”, IJMER,Vol.3,Issue.2, (2013), pp-633-636.

[10] Prucz, J.,"Analytical and Experimental Methodology for Evaluating Passively Damped Structural Joints," 1985,Ph.D. Dissertation, Georgia Institute of Technology, Atlanta, GA.

