Vibration Analysis of Adhesively Bonded Single Lap Joint

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Abstract : Adhesively bonding is a very pace fastening method that's convenient for joining superior lightweight sheet substances which can be varied and tough to weld. This joint is used recently because now a day we are going for lightweight application and it is very important for us to build such joint which will not only reduce its weight as per requirement but will also help in damping the vibrations. In this project we can grasp the effect of using neoprene rubber for joining two dissimilar metals, by making use of an industrial adhesive, which is very powerful. Adhesive bonds discover a large application in the field of aerospace and automotive industries. The natural frequency of the adhesively bonded lap joint increases with the increase in the overlap length. This tendency is logical because of the joint system to become rigid with increasing the overlap length. This particular truth can be used as a design tool to avoid resonant vibrations.

***Index Terms* - Adhesive bond, Neoprene rubber, Lap joint, Vibrations.**

I. INTRODUCTION

An adhesively bonded joint has broad scale applications in aeronautics, aerospace, automobile, semiconductor, and civil structure. The credibility of adhesively bonded joints doesn't only depend on design, material and manufacturing methods but also for effective analysis of the characteristics of the joints. In the last years, adhesives have been usually used to bond dissimilar material members, particularly in aircraft and automobile structures. In many applications adhesively bonded joints are more allowable than existing 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 outstanding fatigue life. Because of the involve of many geometric, material and fabrication variables, and complex failure modes and mechanics present in the joints, a deep understanding of the failure behavior of adhesively bonded joints, especially 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 build with adhesive bonding. In many structures such as flight and space vehicles, etc. adhesively bonded structures have often been used in these days, because of significant advances in adhesive bonding techniques. Many aerospace structures such as a truss system of space telescope space station are created using predominantly composites beams, plates & bonded joints. These structures should control sufficient inherent damping capacity to keep vibration & acoustic response caused by external disturbances within acceptable limits. The present trend is to use viscoelastic material in the joints for passive vibration control in the structures subjected to dynamic loading.

The fast development of structural adhesives has led to the universal use of adhesive joining technique in defense, aerospace, rail, ground transportation applications. In these applications the joints are developed 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, particularly aerospace and military applications, makes it important to understand their failure mechanisms under the transverse and in plane loading.

Xiaocong He [1] developed an efficient numerical technique for the prediction of the dynamic response of bonded beam. The frequency response functions, natural frequencies, and mode shapes of the joints of different adherent widths and of different adhesive layer thickness were measured.

Yu Du [2] investigated the connection between modal properties of single lap joints and the cyclic vibration peel loading this study first carries out vibration fatigue tests and subsequent modal response measurements using steel aluminum single lap joint specimens.

Xiaocong He [3] has shown that torsional natural frequency and torsional natural frequency ratio of adhesively bonded single lap joints increases as Young's modulus of the adhesives increases, but only slight changes are encountered for vibrations of Poisson's ratio. Xiaocong He [4] worked on finite element analysis of adhesively bonded lap joints in terms of static loading analysis, environmental behaviors, fatigue loading analysis and dynamic characteristics of the adhesively bonded joints.

F. Heidarpour [5] showed the robust design of the joints in the engineering structures, it is necessary to determine the stress and strain under a certain load and predict the failure potential. Y. B. Patil [6] showed the natural frequencies are directly proportional to the Young's modulus and density ratio. The specimen is used which consist of Al-Al plates, Cu-Cu plates, and Ms-Ms plates. Recep Gunesa [7] carried out the three-dimensional free vibration and stress analyses of an adhesively bonded single lap joint.

The lightweight construction in manufacturing, there has been a significant increase in the use of adhesively bonded joints in engineering structures and components. The regular joining process increases the weight of the structure by adding extra material such as bolt, screws, extra filler material. If you want to join two plates by bolting then the hole is generated 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 change its mechanical properties. In the design of mechanical systems, for minimum vibration response, a particular knowledge of the damping capacity of the joints is important. To get over those problems we can use adhesively bonded single-lap joints and prediction of its dynamic response, in the future application of adhesive bonding by allowing different parameter to be chosen to give as large process window as possible for bonding beam vibration analysis.

To understand the effect of neoprene rubber for joining two similar metals, by making use of an industrial adhesive. To find two frequencies, i.e. Fundamental Frequency and second mode frequency, mode shapes. To determine the effect of thickness of rubber and overlap length on natural frequencies, mode shapes. To find the optimum rubber thickness and overlap length for adhesive joint.

II. METHODOLOGY

In this work neoprene rubber is used as viscoelastic material and Locktite is as an adhesive. The two adherents used where aluminum plates of dimension 150 mm long, 25mm wide, and 2.5 mm thickness. By changing the overlap length and rubber thickness modal analysis is carried on FFT analyzer. The effect of rubber thickness and overlap length on natural frequency is also carried out. Also, we can imitate 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 analyzer.

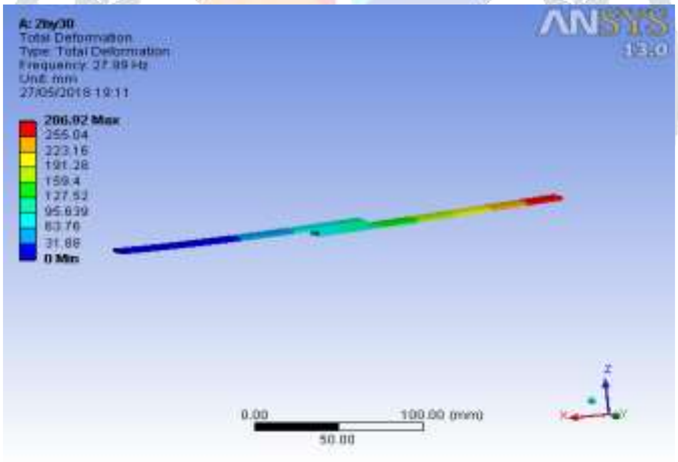
III. FINITE ELEMENT ANALYSIS

ANSYS is pervasive general purpose finite element analysis software which useful for performing structural, heat transfer, fluid flow, electromagnetism and biomedical analysis. ANSYS is a finite element analysis (FEA) code, mainly used in the computer-aided engineering (CAE) field. ANSYS software allows engineers to build computer models of structures, machine elements or systems; apply operating loads and other design criteria; and study physical responses, such as stress levels, temperature distributions, pressure, etc. By using the ANSYS software we find out the natural frequencies of different bonding thickness and different overlaps ratio of aluminum plates with the lap joints. The material properties are shown below.

Table 1: Material Properties

Material	Young's Modulus (E), MPa	Density (ρ), ton/mm3	Poisson's Ratio (µ)
Aluminum	71000	2.77E-09	0.33
Neoprene Rubber	2	1.25E-09	0.49

The results for the lap joint with 2 mm, 3 mm, 5 mm bonding thickness and 30 mm, 50 mm overlap are shown below.



A: 2by30
Total Deformation
Type: Total Deformation
Frequency: 27.99 Hz
Unit: mm
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Fig. 1. First mode of vibration of 2 mm bonding thickness and 30 mm overlap is 27.99 Hz

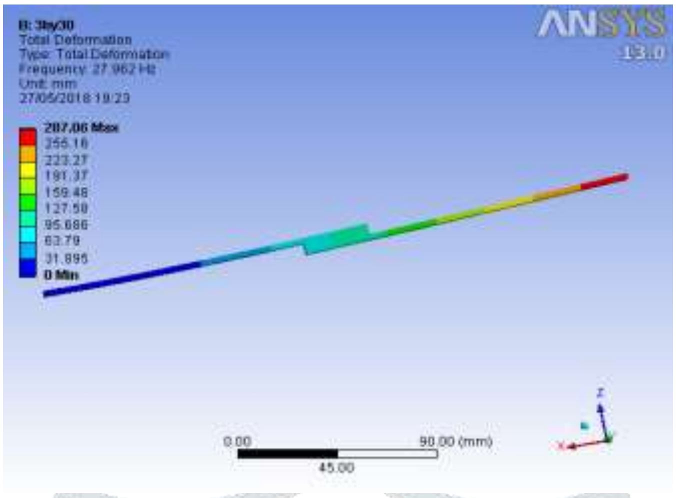

Fig. 2. First mode of vibration of 3 mm bonding thickness and 30 mm overlap is 27.96 Hz

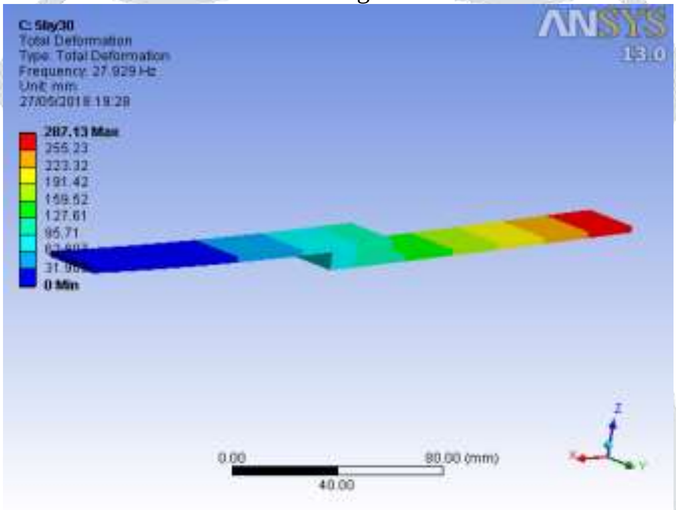

Fig. 3. First mode of vibration of 5 mm bonding thickness and 30 mm overlap is 27.92 Hz

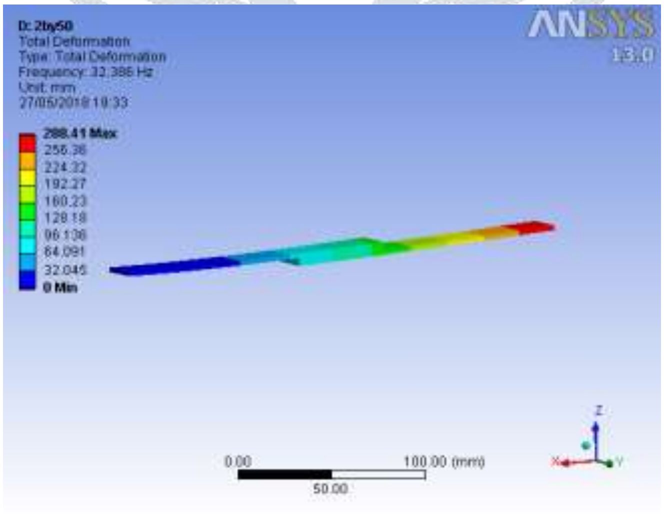

Fig. 4. First mode of vibration of 2 mm bonding thickness and 50 mm overlap is 32.38 Hz

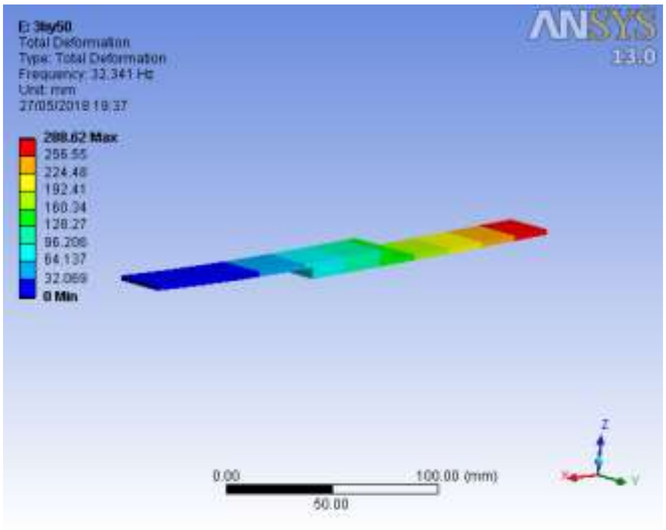

Fig. 5. First mode of vibration of 3 mm bonding thickness and 50 mm overlap is 32.34 Hz

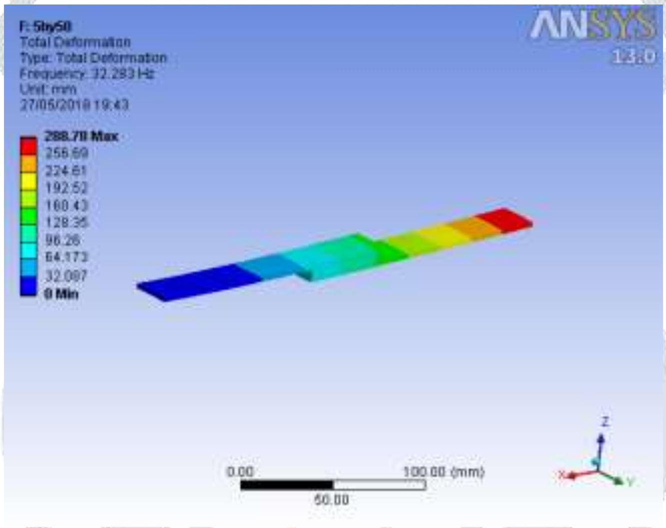

Fig. 6. First mode of vibration of 5 mm bonding thickness and 50 mm overlap is 32.28 Hz

The natural frequency of different thickness and different overlap length for first mode are shown in above figures

IV. EXPERIMENTATION

Experimental modal analysis, also known as modal analysis or model testing deals with finding of natural frequencies, damping ratio and mode shapes through vibration testing. The preparation of lap joint specimen is the initial step in the modal testing. The material used for primary beams is aluminum. As a first step aluminum beam is cut into pieces 150 mm long, 25 mm wide & 2.5 mm thickness of the primary beam. The aluminum beams are then surface finished with the use of abrasive paper. The damping material used for modal testing of joint is neoprene rubber the damping material is a standard viscoelastic material 2 mm, 3 mm and 5 mm thickness. In order to get a perfect bond between damping material & beam, a very thin layer of adhesive Loctite are applied. Then two aluminum plates are join 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 accurately bonded in the overlap region of the joint. The necessary equipment for measurement of vibration hardware requires: Impact Hammer, Accelerometer, Multi-channel Vibration Analyzer (DEWESoft-DEWE-43), A PC or a laptop loaded with software for modal analysis, test specimen (A cantilever held in a fixture), power supply for the PC and vibration analyzer, connecting cables for the impact hammer and accelerometer, fasteners and spanner to fix the specimen in the fixture, and adhesive wax to fix the accelerometer). The experimental setup for lap joint is shown in below figure 7.

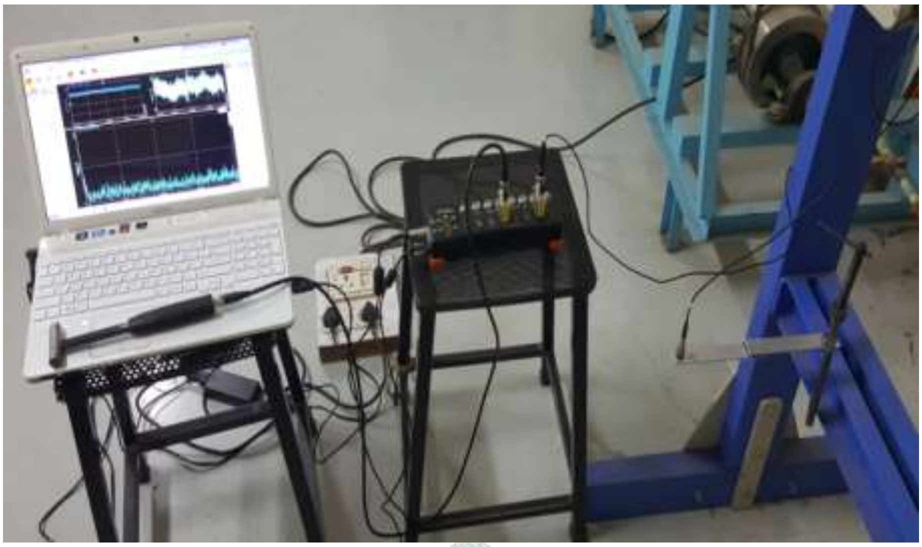

Fig.7. Experimental setup for Lap Joint

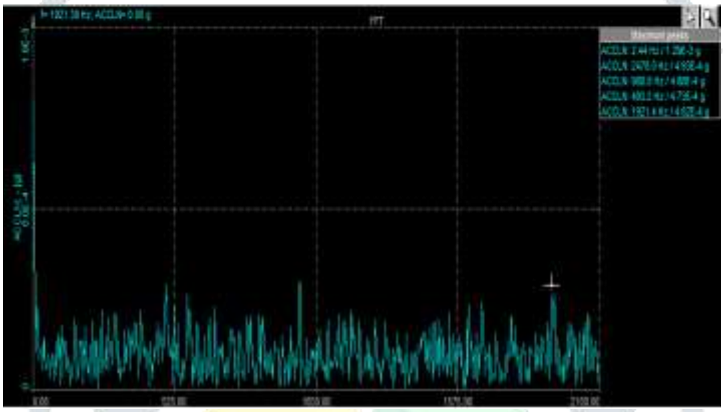

Fig. 8. Natural frequency for lap joint with 3mm bonding Thickness and 30mm overlap

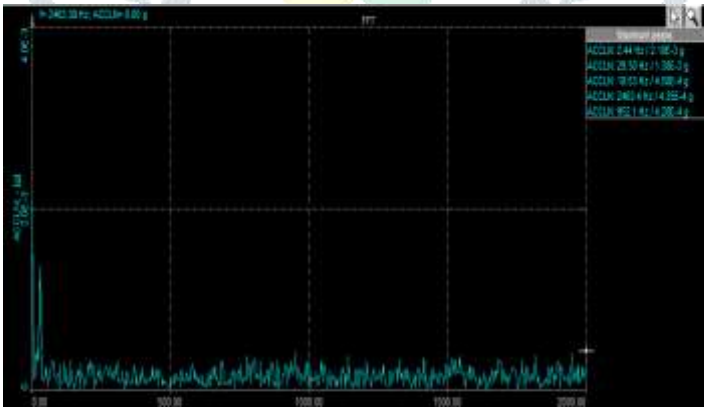

Fig. 9. Natural frequency for lap joint with 3mm bonding Thickness and 50mm overlap

The figure 8 and 9 shows the results of the natural frequency for lap joint with 3 mm bonding thickness and 30 mm overlap and 3 mm bonding thickness and 50 mm overlap plates, that are got from the experimental test which is conducted on the FFT analyzer.

V. RESULTS AND DISCUSSION

The modal analysis of lap joint with different rubber thickness such as 2 mm, 3 mm and 5 mm also the different overlap length such as 30 mm and 50 mm is done with the help of ANSYS software. In modal analysis, mode shapes and natural frequencies are extracted. We compare these results with results that are got from the experimental test which is conducted on the FFT analyzer.

The comparison of modal analysis natural frequency and experimental natural frequency for lap joint with different rubber thickness and different overlap length are shown in tables below.

Table 2: For Overlap of 30mm (Fundamental Frequency)

Sr. No.	**Bonding Thickness**	**Experimental Reading (Natural Frequency Hz)**	**FEM Reading (Natural Frequency Hz)**
1	2 mm	31.5	27.99
2	3 mm	26.86	27.96
3	5 mm	24.41	27.92

Table 3: For Overlap of 50mm (Fundamental Frequency)

Sr. No.	**Bonding Thickness**	**Experimental Reading (Natural Frequency Hz)**	**FEM Reading (Natural Frequency Hz)**
1	2 mm	26.86	32.38
2	3 mm	31.74	32.34
3	5 mm	26.86	32.28

Results of modal analysis of lap joint with different rubber thickness and different overlap length are shown in the above tables. There is good agreements have been obtained between experimental natural frequency and natural frequency predicted by ANSYS. The results show that the natural frequency of the system increases with the increase in the overlap length of the joint of 2 mm, 3 mm and 5 mm thickness of the rubber.

VI. CONCLUSION

The natural frequency of the adhesively bonded lap joint increases with the increase in the overlap length of the joint. This tendency is logical because of the joint system to become rigid with increasing the overlap length. This particular truth can be used as a design tool to avoid resonant vibrations. The maximum displacement decreases with increase in rubber thickness for all modes. Also damping capacity of the joint appears to be sensitive to changes in the rubber thickness up to 3 mm.

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