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Modal Analysis of Adhesively Bonded Joints of Different Materials

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Abstract: *It is important to study the modal analysis (natural frequency and mode shape) of the single lap adhesive joint to understand the dynamic nature of the systems, and also in design and control. In this work modal analysis of bonded beams with a single lap epoxy adhesive joint of plates are investigated. The three specimen are used which consist of Al-Al plates, Cu-Cu plates and Ms-Ms plates. ANSYS 11.0 finite element software is use for modal analysis of single lap adhesive joint. The results show that the natural frequencies are directly proportional to the Young's modulus and Density ratio.*

I. Introduction

In the 1940s, adhesive bonding become importance in structural bonding in aircraft industry. The subject of adhesives became even more interesting to scientists when the application of synthetic resins as adhesives for wood, rubber, glass and metals were discovered. Adhesive bonding as an alternative method of joining materials together has many advantages over the more conventional joining methods such as fusion and spot welding, bolting and riveting. Adhesive bonding is gaining more and more interest due to the increasing demand for joining similar or dissimilar structural components, mostly within the framework of designing light weight structures. The current trends are to use viscoelastic material in the joints for passive vibration control in the structures subjected to dynamic loading. These components are often subjected to dynamic loading, which may cause initiation and propagation of failure in the joint. In order to ensure the reliability of these structures, their dynamic response and its variation in the bonded area must be understood.

In adhesive joint the major function of adhesive is to transmit loads from one member of joint to another. It allows a more uniform stress distribution than is obtained by another mechanical joining process such as welding, bolting, riveting, etc. Thus, adhesive often permit the fabrication of structures that are mechanical equivalent or superior to conventional assembles and furthermore cost and weight benefits. 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 joint 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. In adhesive joining process you do not need to create the hole in the plate or there is no localized heating take place. Thus adhesive bonding gaining more importance in joining process where you have to avoid stress concentration and avoid localized heating. In addition adhesive can produce joints with high strength, rigidity, dimensional precision in the light metals, such as aluminum and magnesium, which may be weakened or distorted by welding. Adhesive can also prevent electrochemical corrosion between dissimilar metals.

II. Adhesive Bond

2.1Adhesive Bonding:

Adhesive bonding is a material joining process in which an adhesive, placed between the adherend surfaces, solidifies to produce an adhesive bond (Figure1). When we bond components together the adhesive first thoroughly wets the surface and fills the gap between, then it solidifies. When solidification is completed the bond can withstand the stresses of use. The strongest adhesives solidify through chemical reaction and have a pronounced affinity for the joint surfaces. Adhesives come in several forms thin liquids, thick pastes, films, powders, pre-applied on tapes, or solids that must be melted. Adhesive can be designed with a wide range of strengths, all the way from weak temporary adhesives for holding papers in place to high strength structural systems that bond cars and airplanes. Now a day's adhesive compete with mechanical fastening systems such as nuts, bolts, and rivets, or welding and soldering.

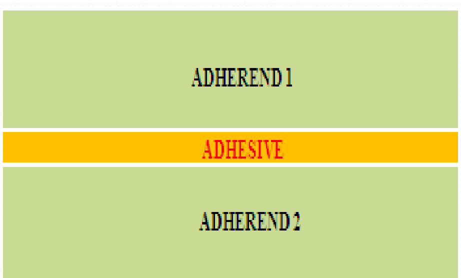


Figure 1: Adhesive Bond.

2.2. Epoxy adhesive:

Epoxy adhesives consist of an epoxy resin plus a hardener. Upon cure, epoxies typically form tough, rigid thermo-set polymers with high adhesion to a wide variety of substrates and superior environmental resistance. When using a one-part heat-cure system, the resin and a latent hardener are supplied already mixed and typically need to be stored refrigerated or frozen. By heating the system, the latent hardener is activated causing cure to initiate. The epoxy will normally start to cure rapidly at temperatures of 100 to 125°C (212 to 257°F) and cure times of 30 to 60 minutes are typical. Heat curing also generally improves bond strengths, thermal resistance and chemical resistance. When using a two-part system, the resin and hardener are packaged separately and are mixed just prior to use. This allows more active hardeners to be used so that the two-part epoxies will rapidly cure at ambient conditions.

III. Problem Definition

Natural, free vibration is a manifestation of the oscillatory behavior in mechanical systems, as a result of repetitive interchange of kinetic and potential energies among components in the system. Proper design and control are crucial in maintaining high performance level and production efficiency, and prolonging the useful life of machinery, structures, and industrial processes. Before designing or controlling an engineering system for good vibratory performance, it is important to understand, represent (model), and analyze the vibratory characteristic of the system.

An engineering system, when given an initial disturbance and allowed to execute free vibrations without a subsequent forcing excitation, will tend to do so at a particular "preferred" frequency and maintaining a particular "preferred: geometric shape. This frequency is termed a "natural frequency" of the system, and the corresponding shape of the moving parts of the system is termed a "mode shape". Any arbitrary motion of a vibrating system can be represented in terms of its natural frequencies and mode shapes. The subject of modal analysis primarily concerns determination of natural frequencies and mode shapes of a dynamic system. Once the modes are determined, they can be used in understanding the dynamic nature of the systems, and also in design and control. Therefore modal analysis is extremely important in vibration engineering.

Vibration testing is useful in a variety of stages in the development and utilization of a product. In the design and development stage, vibration testing can be use to design, develop, and verify the performance of individual components of a complex system before the overall system is assembled and evaluated.

IV. Methodology

In this work modal analysis of bonded beams with a single lap epoxy adhesive joint of plates are investigated. The three specimen are used which consist of Al-Al plates, Cu-Cu plates and Ms-Ms plates. The two sets of adherends use are aluminium plates of dimension 140 mm long, 38 mm wide, 5mm thickness; copper plates of dimension 140 mm long, 38 mm wide, 5mm thickness and mild steel plates of dimension 140 mm long, 38 mm wide, 5mm thickness. The araldite epoxies adhesive is use which consists of hardener and strainer. Both hardener and resin mixed with equal volume to form the adhesive paste which is use for preparation of specimen.

V. Modal Analysis

If the structural vibration is of concern in the absence of time-dependent external loads, a modal analysis is performed. Modal analysis determines the vibration characteristics of structure or machine components while it is being designed. The vibration characteristics (natural frequencies and mode shapes) are important in the design of the structure for dynamic loading conditions.

5.1Result and Discussion:

In this work modal analysis of bonded beams with a single lap epoxy adhesive joint of plates are investigated. The three specimen are used which consist of Al-Al plates, Cu-Cu plates and Ms-Ms plates. For present study the overlap length of 15mm is use for single lap adhesive joint. The Modal analysis had been done by using ANSYS 11.0 FEA software. The first five natural frequencies corresponding to different materials of single lap epoxy adhesive joints are shown in Table 1. The comparisons of frequency with respect to mode shapes are shown by Figure2.

Table 1: Comparative Table of Single Lap Adhesive Joint

Frequency Hz			
Mode shape	Cu-Cu	Al-Al	Ms-Ms
First	42.062	59.002	58.203
Second	260.68	366.40	358.80
Third	299.55	422.32	415.41
Fourth	553.95	788.39	783.35
Fifth	734.11	1029.3	1016.5

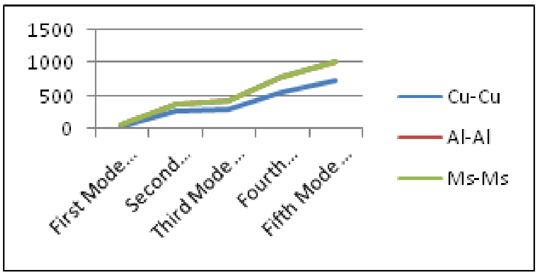
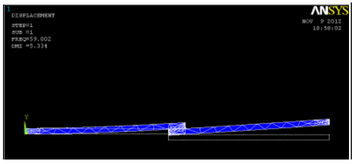
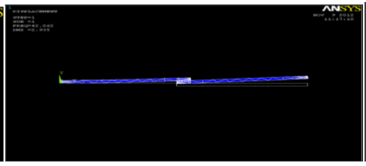


Figure2 Comparison of Frequency With Respect To Mode

The result show that natural frequencies are changing as the materials are changing of single lap adhesive joint. The result shows that the natural frequencies are depend on Young's modulus (E) and Density (ρ) ratio. The Young's modulus (E) and Density (ρ) ratio of Al-Al single lap adhesive joint is 0.025. The Young's modulus (E) and Density (ρ) ratio of Cu-Cu single lap adhesive joint is 0.013. The Young's modulus (E) and Density (ρ) ratio of Ms-Ms single lap adhesive joint is 0.025. As the ratio of the Young's modulus (E) and Density (ρ) of Al-Al single lap adhesive joint and Ms-Ms single lap adhesive joint are same therefore their natural frequencies are nearby same which is shown by Table 1 and Figure2. The Young's modulus (E) and Density (ρ) ratio of Cu-Cu single lap adhesive joint is different from Al-Al single lap adhesive joint and Ms-Ms single lap adhesive joint therefore the natural frequencies of Cu-Cu single lap adhesive joint are different than the Al-Al single lap adhesive joint and Ms-Ms single lap adhesive joint. The Fig.3- 5 shows the mode shapes for different material of single lap adhesive joint. The inspection of mode shapes shows that most of the mode shapes are similar for different material of single lap adhesive joint.


First Mode Shape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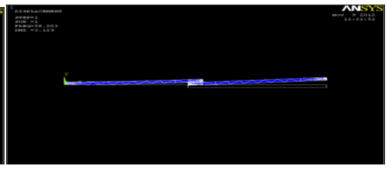
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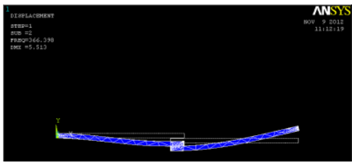
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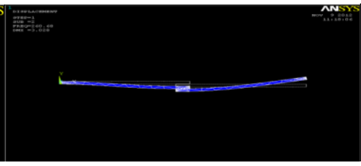
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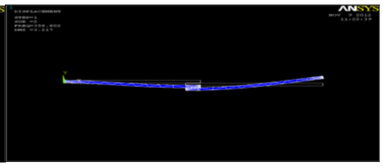
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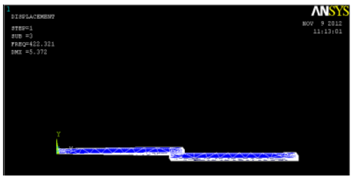
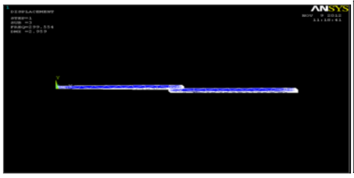

Third Mode Shape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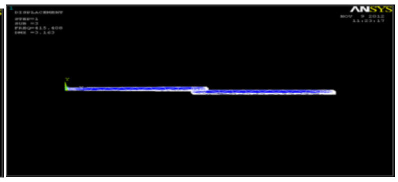
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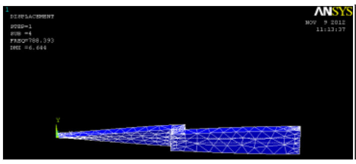
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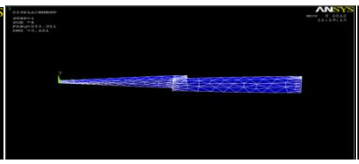
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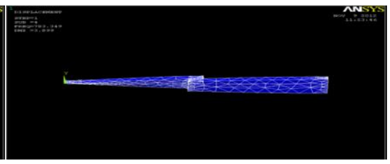
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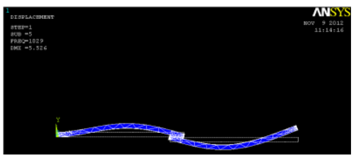
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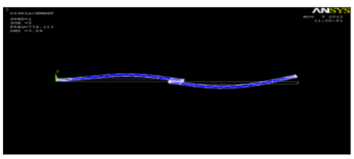
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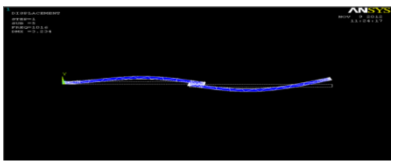
Fifth Mode Shape

Figure 3 Mode Shapes of Al-Al Single Lap Adhesive Joint.

Figure 4 Mode Shapes of Cu-Cu Single Lap Adhesive Joint.

Figure5 Mode Shapes of Ms-Ms Single Lap Adhesive Joint.

VI. Conclusion

Adhesive bonding as an alternative method of joining materials together has many advantages over the more conventional joining methods such as welding, bolting and riveting. For example, adhesives can be used to bond dissimilar materials, adhesive joints have a high stiffness to weight ratio and the stress distribution within the joint is much improved. Corrosion and vibration stress associated with mechanical fasteners and welds can be reduced or eliminated by forming continuous adhesive joint. It is important to study the modal analysis (natural frequency and mode shape) of the single lap adhesive joint to understand the dynamic nature of the systems, and also in design and control. The results show that the natural frequencies are directly proportional to the Young's modulus and Density ratio. If this ratio is increasing the natural frequencies are increasing for respective mode shapes.

The natural frequencies and mode a shape gives designer/engineers an idea of how the design will respond to different types of dynamic loads. This allows to designer/engineer to change the design to avoid resonant vibrations or to vibrate at a specified frequency. Also helps in calculating solution controls (time steps, etc.) for other dynamic analyses. It is conclude that the FEA of dynamic response of the bonded beams with a single lap joint will help future applications of adhesive bonding by allowing different parameters to be selected to give as large as a process window as possible for bonded beams vibration analysis.

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