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Review on Vibration Analysis of Adhesively Bonded Single Lap Joint for Different Materials

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ABSTRACT

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 pre-dominantly 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 visco-elastic material in the joints for passive vibration control in the structures subjected to dynamic loading. There are many joints used in aerospace structures such as lap joint, double-strap joint etc. In this work Vibration analysis of adhesively bonded lap joint is done by means of ANSYS software and comparison is done by means of experimental analysis. Rubber is used as visco elastic material. By changing the thickness of rubber & overlap ratio different natural frequencies are obtained. Experimental analysis is done by preparing lap joint with different materials and rubber material. Locktite is used as an adhesive. Analysis is done by using FFT analyzer. Damping ratio is also calculated for different joints. The effect of thickness of rubber and overlap ratio on natural frequency is also carried out.

Keyword: Adhesive bonding, damping ratio, Viscoelastic material, natural frequency

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I. INTRODUCTION

In recent years, adhesives have been widely used to bond dissimilar material members particularly in aircraft and automobile structures. If the adhesive layer is very small compared with adherents, a more refined mesh model is needed for FEA modeling. 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. Whereas adhesively bonded joints and bonded repairs made to cracked metallic structures have been continuously receiving attention in the aerospace industry for the purpose of enhancing fatigue resistance and restoring the stiffness and strength of damaged/cracked structures, the effective use of adhesive bonding technology in primary structural members is still in it.

Boeing 747 aircraft has 62% of its surface are constructed with adhesive bonding, while LockheedC-5A aircraft has 3250 m2 of bonded structure. Features which make adhesive bonding attractive include improved appearance, good sealing high strength to weight ratio, low stress concentration, low cost corrosion resistance and fatigue resistance. The rapid development of structural adhesives has led to the wide-spread use of adhesive joining technique in defense, 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 prima-ry load bearing structures, especially aerospace and military applications, makes it important to under-stand their failure mechanisms under transverse and in plane l.

II. LITERATURE SURVEY

1st Yu Du 2nd Lu Shi (1) He studies on developing models and theories describing the static strength of adhesive joints as a function of the fatigue loading, there is lack of understanding on how the fatigue of the adhesive joint affects dynamic modal properties of the bonded structure. In applications such as automobile components, modal properties are critical in determining their dynamic performances. To investigate the relationship between modal properties of single lap joints (SLJs) and the cyclic-vibration-peel loading, this study first carries out vibration fatigue tests and subsequent modal response measurements using steel-aluminum SLJ specimens. It is experimentally demonstrated that modal frequencies of the SLJ structure tend to decrease with increasing vibration fatigue cycles. Furthermore, it is also shown that this trend is related to the fatigue characteristics of the adhesive layer. The fatigue degradation effects of Young's modulus and contact area between the adhesive and the adherends on modal frequencies are then investigated using a finite element model. Simulation results reveal that dramatic reductions in modulus and contact area values are required to result in the modal frequency shifting observed in experiments, which may not be always realistic. Although the findings in this study are informative, more research effort is needed to further identify then critical reason(s) for the experimental trend of decreasing modal frequencies with increasing vibration fatigue cycles.

1st Weidong Li 2nd Kunyue Wu 3rd Yu Du Last Ping Hu (2) ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference .The dynamic loads due to vibration motions are therefore one of the primary causes for structural damage, especially when the outside cyclic stir vibration frequency is adjacent to the natural frequencies of the adhesive joint frame. This is so called the vibration fatigue. In this paper, the fatigue behavior of adhesively bonded single lap joint (SLP) subject mainly to normal stresses induced by vibration excitations is investigated. Combining with static tests, the NI PXI-1045 vibration measurement and analysis system are used to analyze the effect of vibration loading on the fundamental modal frequency with long-term fatigue cycle. Furthermore, a virtual fatigue analysis approach for the fatigue damage prediction of adhesive joints subject to vibration loads is performed in this study. It is found that the joint stiffness decreases with the cyclic durations under which the vibration loads are applied. As a result, a stable decrease of the fundamental resonance frequency of the joint structure is observed during the tests. The experimental data demonstrate a significant correlation between the shear strength of adhesive joints and the vibration cycling time. A gradual decrease in the shear strength with increasing load cycles is seen in vibration fatigue, the maximum shear strength of adhesively bonded joints drops about 12% after 1.35e8 cycles. Based on the test data, a new approach called virtual fatigue analysis modeling (VFAM) is proposed for the fatigue damage of the adhesive joints under vibration loads. The VFAM shows that the fatigue damage occurs first at the end of the overlap area of the adhesive layer. 1st Ping Hu 2nd Z. W. Shi 3rd X. X. Wang Last Xiao Han (3) Strength Degradation of Adhesively Bonded Single-Lap Joints in a Cyclic-Temperature Environment Using a Cohesive Zone Model. The Journal of Adhesion 91(8) • August 2015 . Adhesively bonded joints are widely used in automotive industry. Adhesively bonded joints permit to have more uniform stress distributions, join complex shapes, and reduce the weight of the structures. The requirement to reduce the weight of automobiles is also increasing the application of composites. In this article, CFRP (carbon fiber-reinforced plastics) composite was used in experimental tests. In many cases, adverse environments cause non-negligible degradation in joints mechanical performance. So a combined experimental–numerical approach was developed to characterize the effect of cyclic-temperature environment on adhesively bonded joints. Experimental tests were carried out on single-lap joints with CFRP and steel adherend in a cyclic-temperature environment. A cohesive zone model was taken into consideration to predict the results observed during the experimental tests and an environmental degradation model was developed. Scanning electron microscopy was utilized to investigate the fracture surfaces.1st Guoshuang Shui 2nd Xian Song 3rd Jingyu Xi 4th Yue-Sheng Wang (4)- Experimental Characterization of Impact Fatigue Damage in an Adhesive Bonding Using the Second Harmonics with Journal of Non destructive Evaluation 36(2):23 • February 2017 in Article .Adhesive bonding is widely used in various industrial applications. In this paper, an application of non-destructive evaluation (NDE) technique based on the second harmonics for experimental characterization of impact fatigue damage in an adhesive bonding is presented. Adhesively bonded specimens made from AZ31 magnesium–aluminium alloy were firstly subjected to impact fatigue loading; the ultrasonic harmonics generated due to impact fatigue damage within the adhesive layer were thereafter measured. The acoustic nonlinearity parameter (ANP) based on the fundamental and second harmonics was thus obtained. The experimental results show that the normalized ANP, which is an indicator of material properties, increases with the impact fatigue life. Further discussion based on a theoretical model with different interfacial compression and tension stiffness was also conducted. The experimental results consist well with the theoretical ones. The results in this paper demonstrate that the nonlinear ultrasonic method based on the second harmonic generation technique can be used to characterize the impact fatigue damage in an adhesive bonding. 1st Yu Du 2nd Lu Shi (4) Effect of Vibration Fatigue on Modal Properties of Single Lap Adhesive Joint . International Journal of Adhesion and Adhesives 53 • September 2014 in Article It studies focus on developing models and theories describing the static strength of adhesive joints as a function of the fatigue loading, there is lack of understanding on how the fatigue of the adhesive joint affects dynamic modal properties of the bonded structure. In applications such as automobile components, modal properties are critical in determining their dynamic performances. To investigate the relationship between modal properties of single lap joints (SLJs) and the cyclic-vibration-peel loading, this study first carries out vibration fatigue tests and subsequent modal response measurements using steel-aluminium SLJ specimens. It is experimentally demonstrated that modal frequencies of the SLJ structure tend to decrease with increasing vibration fatigue cycles. Furthermore, it is also shown that this trend is related to the fatigue characteristics of the adhesive layer. 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Blackman (5) A study of the impact properties of adhesively-bonded aluminium alloy based on impact velocity journal of Mechanical Science and Technology 29(2):493-499 • February 2015 In this study, an experiment and a simulation were carried out on colliding an adhesively-bonded tapered double cantilever beam (TDCB) at the impact velocities of 5 m/s, 7.5 m/s and 12.5 m/s. The analysis method of the corrected beam theory (CBT) was used to obtain the rate of energy release in the bonded area according to the crack progression, and a simulation was performed to determine the maximum strain energy during the impact analysis as a means to examine the mechanical properties of aluminium alloy. The experimental data were found to be higher than the simulation data. This is deemed to explicable by the fact that the adhesive strength was maintained even after the specimen separated in the experiment. Crack progression occurred, irrespective of the impact velocity, and high strain energy occurred at the end of the bonded region, thereby causing the strain energy to increase in the final stages. Also, the maximum load applied on the pin and the maximum strain energy in the bonded area were shown increase at higher impact velocities. The results of the experiment and simulation performed in this study are expected to serve as important data in developing a safety design for composite materials that can help prevent the progression of cracks caused by impact. 1st Raul Campilho 2nd A. M. G. Pinto 3rd M. D. Banea Last L.F.M. da Silva (6) Strength Improvement of Adhesively-Bonded Joints Using a Reverse-Bent Geometry with Journal of Adhesion Science and Technology January 2011 Adhesive bonding of components has become more efficient in recent years due to the developments in adhesive technology, which has resulted in higher peel and shear strengths, and also in allowable ductility up to failure. As a result, fastening and riveting methods are being progressively replaced by adhesive bonding, allowing a big step towards stronger and lighter unions. However, single-lap bonded joints still generate substantial peel and shear stress concentrations at the overlap edges that can be harmful to the structure, especially when using brittle adhesives that do not allow plasticization in these regions. In this work, a numerical and experimental study is performed to evaluate the feasibility of bending the adherends at the ends of the overlap for the strength improvement of single-lap aluminium joints bonded with a brittle and a ductile adhesive. Different combinations of joint eccentricity were tested, including absence of eccentricity, allowing the optimization of the joint. A Finite Element stress and failure analysis in ABAQUS was also carried out to provide a better understanding of the bent configuration. Results showed a major advantage of using the proposed modification for the brittle adhesive, but the joints with the ductile adhesive were not much affected by the bending technique. December 2011 1st Ping Hu 2nd Xiao Han 3rd Long Li Last Wei Dong Li (7) It significant Effect of Temperature on Shear Strength of Adhesively Bonded Joints for Automobile Industry effect on vehicle lightweight, adhesively bonded joint in structural components is widely adopted in automobile industry in recent years, which leads to the benefits in fuel economy, reduced emissions and driving safety. In this paper, the performances of adhesively bonded joints with three different adhesive types after different temperature treatments are investigated through joint shear Strength test.

III.EXPERIMENTAL MODAL ANALYSIS

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 Aluminum. As a first step aluminum beam are cut into pieces 150 mm long 30 mm wide & 5 mm thickness for the primary beam, The aluminum beams are the surface finished with the help of abrasive paper.

The damping material used for modal testing of joint is natural Rubber the damping material is a standard viscoelastic material 2mm, 3 & 5 mm thickness .In order to get a perfect bond between damping material & beam, a very thin layer of adhesive Locktite. 407 are applied. The viscoelastic layer is then correctly bonded in the overlap region the beam. The resulting joint specimen is the cured at room temperature for more than 24hoursunder a weight of 25 to 30kg.

B. Procedure to carry out Experimental Modal Analysis using FFT

The basic experimental modal setup is shown in fig4.1.The frequency response function (FRP) in terms of reacceptance ratio of displacement to forces was measured using the experimental setup .The double lap joint was fixed to the rigid fixture and tested at fixed-fixed boundary condition.

An impact with a force transducer is used as an excitation source (channel 1) and an accelerometer is used as the output (channel2). 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.

C. Test would be conducted as follows:

1. Mount an accelerometer on the joint and connect it to channel 2 of the analyzer.
2. Connect an instrumented force hammer tochan-nel1.
3. Impact the joint with few blows. These blow swill be needed to setup the analyzer for the test .This is often the most tedious part of the test.
4. Set the analyzers trigger level (channel 1).Set the input attenuation of channel 1 and channel2to avoid overload.
5. Choose a time window which shows preparing down of time domain output of system.
6. Average several blows.
7. View transfer function magnitude and phase.
8. The FRF data then transferred to modal analysis software to estimate modal parameters (Natural frequencies and damping ratios)
9. Use single degree of freedom form curve fitting routine over each modal peak to obtain modal parameters for that mode. This procedure is repeated for the remaining joints. Fig.1 shows the experimental setup.

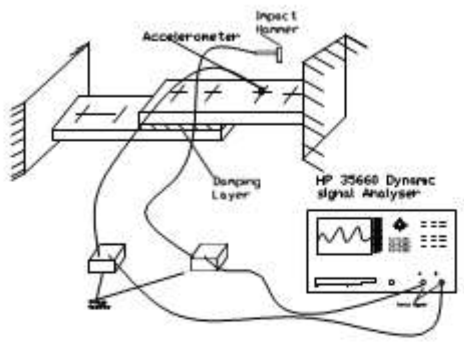

Fig.1. Experimental Set Up

IV. PROPRTIES 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	Aluminum	264870	0.675 x 10^5	0.260 x 10^5	0.34
2	Natural Rubber	1100	0.01-0.1	0.0006 x 10^6	0.48

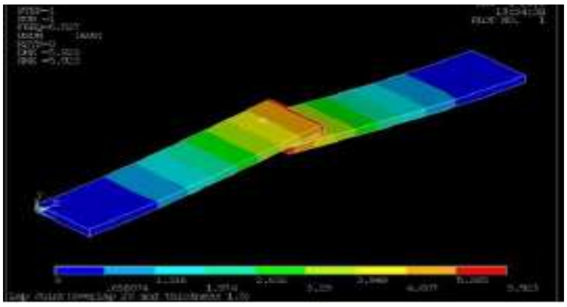
Fig. 2. Analysis of mode shapes

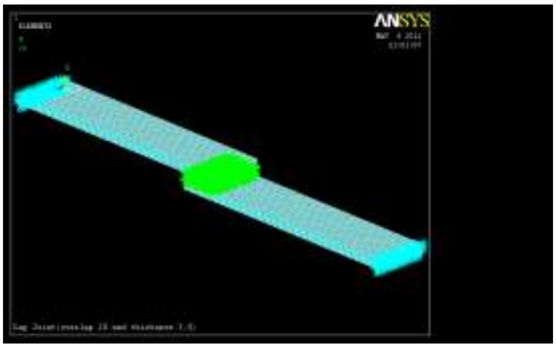

Fig 3.Meshing of Lap joint

V. FINITE ELEMENT ANALYSIS

Ansys is an integrated package of mechanical engineer-in software tools. Ansys mechanical family of products differs a full depth of analysis from concept simulation advanced analysis. The software provides simulation tools used widely across industry by designers to advanced analysis, providing a full complement of non-linear and linear elements laws ranging from metal to rubber and the most comprehensive set of solvers available .Element Used: For Finite Element Analysis of adhesively bonded lap joint 4 nodded Solid Brick element is used. The analysis of the joint is done by using fixed-fixed boundary condition.

VI. CONCLUSION

It is 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 .Increasing the share modulus of the adhesive layer will increase the stiffness of the joint but reduce the damping capacity. 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. The increase in the value of the damping ratio due to the presence of bonded Joints in the system do not appear to be very significant.

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