ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 6, June 2016

Validation of Double Lap Adhesive Joint for Al-Al Plates

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Abstract— Now a days many joints used in Automobiles, Aerospace, Marine structures etc. such as lap joint, double-strap joint, rivet joints and adhesive joints etc. The failures in adhesively bonded joints are mainly of two types, adhesive and cohesive; occurring mainly due to interfacial (adhesive) cracking, also called de-bonding, at geometric boundaries due to stress concentrations, or resulting from faulty joining in fabrication. In this work vibration analysis or modal analysis of adhesively bonded double lap joint is done by means of finite element Modeling and comparison is done by means of experimental analysis. 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. Rubber is used as visco-elastic material. The modal can also be used to predict system modal damping values by properly choosing material damping values of the beam and the adhesive. By changing Overlap Ratio and Surface Roughness different natural frequencies are obtained. Experimental analysis is done by preparing double lap joint with aluminum material. Araldite (Epoxy adhesive) is used as an adhesive.

Index Terms— Adhesive, Visco-elastic material, Passive damping, Composites.

I. INTRODUCTION

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 behavior of adhesively bonded joints, particularly under combined loading conditions, is needed in order to fully achieve the benefits of adhesive bonding. There are several typical failure modes associated with adherence and adhesive in adhesively bonded composite repairs including substrate yielding, patch fiber breaking in tension, fiber failing in compression, adhesive shearing, substrate-adhesive peeling, patch-adhesive peeling, patch inter-laminar peeling, and patch inter-laminar shearing. Since substrate yield is not a catastrophic failure mode, an optimal design will focus on other failure modes associated with the patch and adhesive.[1].

The failures in adhesively bonded joints are mainly of two types, adhesive and cohesive; occurring mainly due to interfacial (adhesive) cracking, also called de-bonding, at geometric boundaries due to stress concentrations, or resulting from faulty joining in fabrication. Well-bonded joints should fail within the adhesive (cohesive) or within the adherends (inter-laminar failure) when broken apart. Failure at the adherend-adhesive interface (interfacial failure) generally indicates that the bond was not performed properly. Adhesive bonding usually requires curing of adhesive at temperature higher than applied condition. Joints and fasteners often have a significant effect on the dynamical behavior of assembled mechanical structures and the analytical prediction of structural responses therefore depends upon the accuracy of joint modeling. Detailed constitutive models that fully describe the behavior of frictional interfaces are often unduly complicated; in which case simpler phenomenological models having parameters identified from vibration tests may be preferable. Unfortunately the direct measurement of forces transmitted between two contacting surfaces and their relative displacements are not possible in practice and it is therefore necessary to rely on measurements remote from joints. In this paper, the parameters of an assumed nonlinear joint model are identified by force-state mapping from time-domain acceleration records in response to single-frequency excitation close to the first natural frequency. The problem of lack of accessibility for measurement at the joint is overcome by casting the governing equation of the system in modal coordinates so that modal parameters are identified to represent the nonlinear behavior of the joint. A particular result from the experimental program is the identification of viscous damping coefficients dependent upon displacement amplitude. The significance of this result is that the complex phenomenon of energy dissipation in lap joints can be represented by a simple analytical model capable of producing accurate results.[2].

Various types of double-lap specimens with different overlap lengths and adhesive thicknesses were used in the experimental program to investigate the effect of bonding dimensions on fatigue strength. Experimental results indicate that under the fixed average shear stress condition, the larger adhesive thickness detrimentally affects fatigue strength. Similarly, the fatigue resistance decreases as the overlap increases except for the specimens with an adhesive thickness of 0.5 mm. The finite element method was adopted herein to obtain the local stress states at the interface between the adhesive and the adhered. Three selected parameters based on the simulated interfacial stresses were considered to correlate with the fatigue life data of all specimens with various adhesive dimensions. These parameters are maximum interfacial peeling stress, maximum interfacial shear stress and a linear combination of interfacial peeling stress and shear stress. These three interfacial parameters yield much better correlation results than the bulk average stress parameter. The evaluation results demonstrate that peeling stress and the linear combination of interfacial peeling stress and shear stress provide better correlation results than the interfacial shear parameters, revealing that the interfacial peeling Stress is the main driving force of the fatigue failure of the single-lap joints.[1].

II. ADHESIVE JOINT

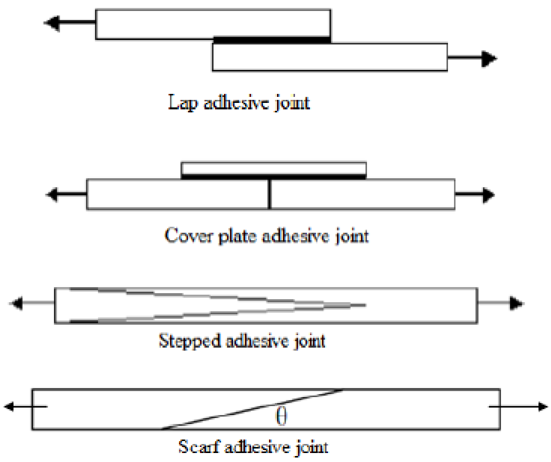


Fig. 01 Types of adhesive joints

-Continuous bond: On loading, there is more uniform distribution of stresses over the bonded area. The local concentrations of stresses present in spot welded or mechanically fastened joints are avoided. Bonded structures can consequently offer a longer life under load.

-Less weight: Low weight of joint in comparison with other types of joint is one of the great advantages of adhesive joint. Adhesive joint gives high strength to weight ratio.

It is very important to understand types of loading stresses involved in adhesively bonded joints. Strength of adhesive joints mainly depends on two major parameters i. e. material involved in the adhesive joint and types of loading stresses involved within the joint. The basic types of stresses involved in the adhesive joints are tension, compression, shear, cleavage and peel stresses as shown in Fig.02

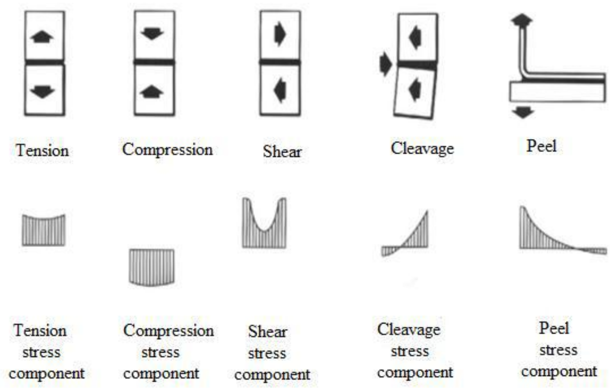


Fig.02 Types of loading stresses in adhesive joint

When failure of adhesive joint happens by failure of adhesive itself is called as cohesive failure. It is shown in fig. 1.3. Since failure is taking place within the adhesive layer, bond strength is greater than adhesive strength. Hence the joint which fails by cohesive failure is generally higher than those fails by adhesive failure.03

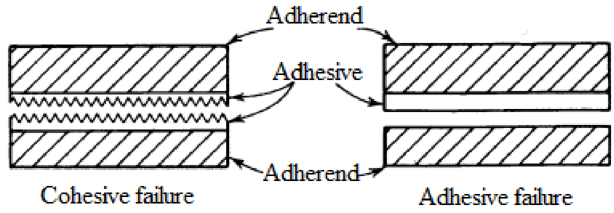


Fig.03 Basic modes of failure in adhesive joint

III. FFT ANALYSIS

The basic experimental modal setup is shown in fig 5.1. 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 cantilever boundary 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.

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 to channel 1.
3. Impact the joint with few blows. These blows will 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 channel 2 to 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. View the coherence display. A value near 1.0 indicates a good test.
9. The FRF data then transferred to modal analysis software to estimate modal parameters (Natural frequencies and damping ratios)
10. 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.04 shows the experimental set up.

Fig.04 Experimental set up

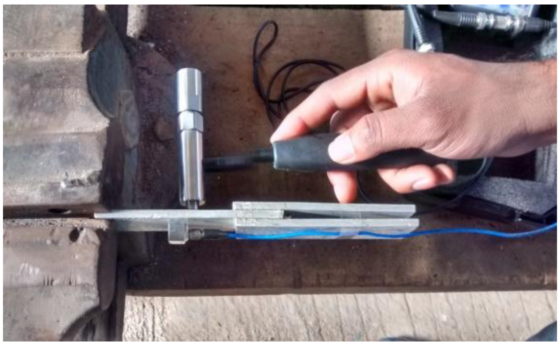


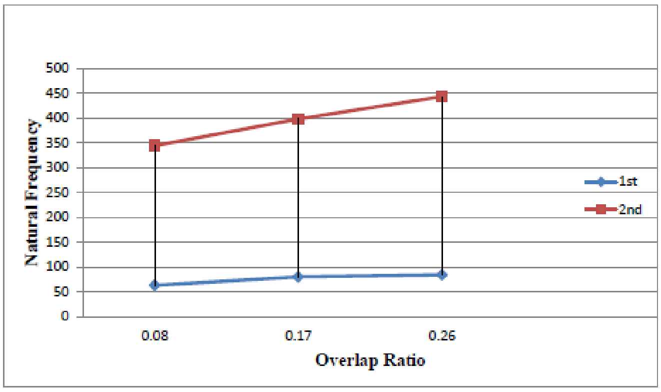
Fig.05 Photograph showing Experimental procedure

Experimental analysis:

A. For 30mm plate:

Table 01 Effect of overlap ratio on natural frequency

Overlap	Natural Frequency (Hz)		Breaking Strength (Mpa)
	1	2	
0.08	63	344	2.254
0.17	80	398	
0.26	84	443	



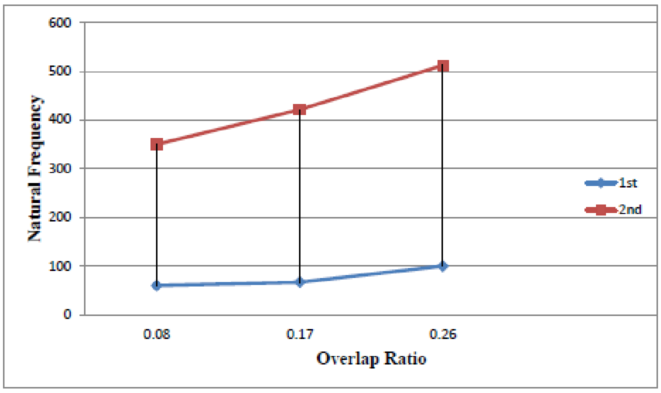
Graph 01: Graph of Overlap Ratio Vs Natural Frequency for Zero Surface Roughness

Table 01 and Graph 01 shows the effect of Overlap ratio on natural frequency for 30mm plate width, with the increase in overlap ratio natural frequency increases. With FFT analyzer only two natural frequencies are obtained for adhesive joint.

B. For 30mm plate with 1 mm rubber thickness:

Table 02 Overlap ratios and their Natural Frequency for 1mm Rubber thickness

Overlap Ratio	Rubber Thickness (mm)	Natural Frequency (Hz)		
		1	2	3
0.08	1	60	350	---
0.17	1	67	421	---
0.26	1	79	512	---



Graph 02: Graph of Overlap Ratio Vs Natural Frequency for 1mm Rubber Thickness

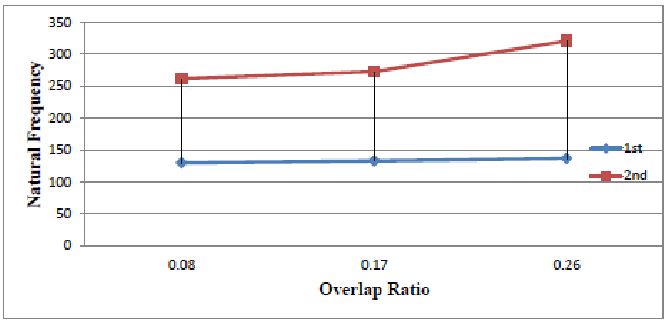
Table 02 and Graph 02 shows the effect of the Overlap ratio of the natural frequency of 30mm plate width, with the increase in the overlap ratio natural frequency increases, but due to the addition of 1mm rubber thickness natural frequencies are reduced by some Hertz . It may be because vibration damping due to rubber.

EXPERIMENTAL ANALYSIS FOR RIVETTED JOINT

For 30mm plate:

Table 03 Overlap ratio Vs Natural Frequency for 30mm Plate Width

Design of Experiment (30 mm width plate)				
Sr. No.	Overlap Ratio	Natural frequency(Hz)		Breaking Strength (Mpa)
		1	2	
1	0.08	130	262	1.699
2	0.17	133	273	
3	0.26	137	321	



Graph 03: Graph of Overlap Ratios Vs Natural Frequency for 30mm Plate Width

Table 03 and Graph 03 show the effect of overlap ratio on natural frequency for 30mm plate width with riveted joints, it is clearly observed that with the increase in overlap ratio natural frequency increases. With FFT analyzer only two natural frequencies are obtained for riveted joint also. The large amount of difference is obtained in natural frequencies for adhesive and riveted joint for first and second mode shapes.

IV. FINITE ELEMENT ANALYSIS

Element Used: For Finite Element Analysis of adhesively bonded Double lap joint Solid 92 element is used. The analysis of the joint is done by using Cantilever boundary condition.

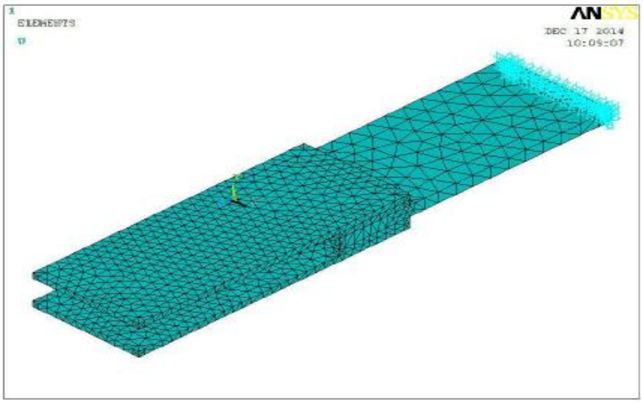


Fig 06 Meshing of Double Lap joint

Table 04 ANSYS RESULT IN TABULAR FORM

Design of Experiment (30 mm width Plate)					
Sr. No.	Overlap Ratio	Rubber Thickness	Natural Frequency(Hz) 1	2	3
1	0.08	0	65.52	362.94	382.14
4	0.17	0	72.29	419.07	441.83
7	0.26	0	80.32	461.97	549.43
Sr. No.	Overlap Ratio	Rubber Thickness	Natural Frequency(Hz) 1	2	3
10	0.08	1mm	62.59	361.54	480.44
11	0.17	1mm	68.68	441.16	523.82
12	0.26	1mm	75.72	548.80	573.24

Finite Element Analysis For Adhesive Joint:
For 30mm Width Plate:

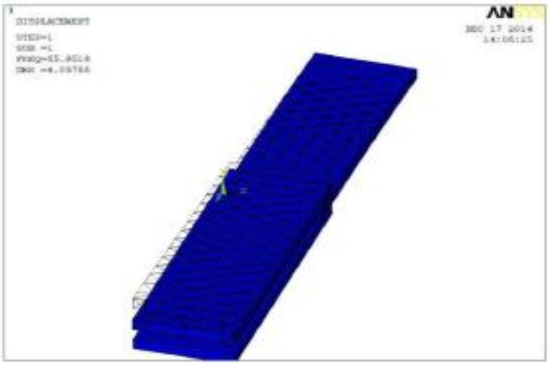


Fig 071st Mode Shape for 0.08 Overlap Ratio

Fig 08 2nd Mode Shape for 0.08 Overlap Ratio

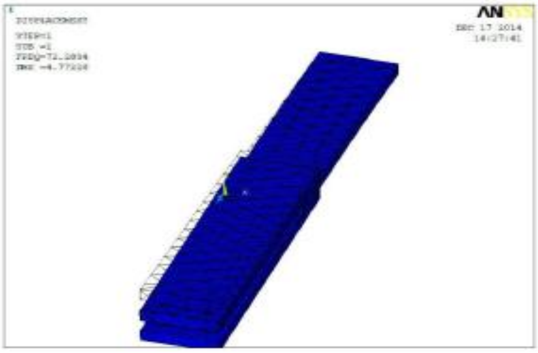


Fig 09 1st Mode Shape for 0.17 Overlap Ratio

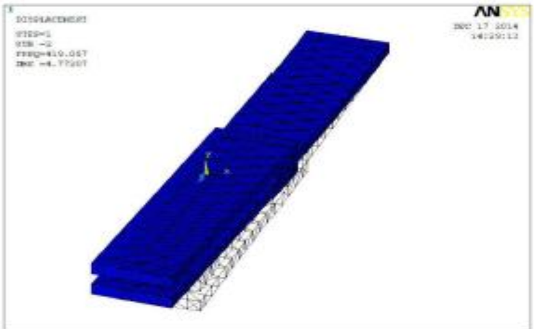


Fig 10 2nd Mode Shape for 0.17 Overlap Ratio

From the above figure it is observed that the in the Second mode shape for 0.17 overlap ratio and 30mm width plate the Frequency of vibration for adhesively bonded joint is 419.05Hz

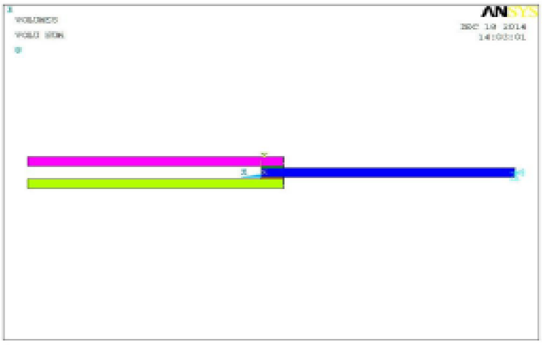


Fig 11 30mm width plate with 1mm rubber thickness

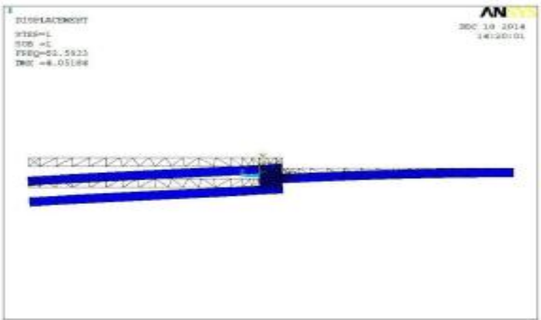


Fig 12 Basic Model of Double Lap adhesive joint with 1mm Rubber Thickness

From the above figure it is observed that the in the First mode shape for 0.08 overlap ratio and 1mm rubber thickness for 30mm width plate the Frequency of vibration for adhesively bonded joint is 62.59 Hz.

Finite Element Analysis For Rivetted Joint:
For 30mm Width Plate:

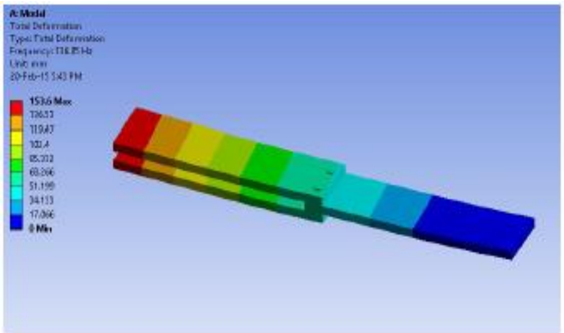


Fig 13 1st Mode Shape for 0.08 Overlap Ratio

From the above figure it is observed that the in the first mode shape for 0.08 overlap ratio for 30mm width plate the Frequency of vibration for riveted joint is 136.05 Hz

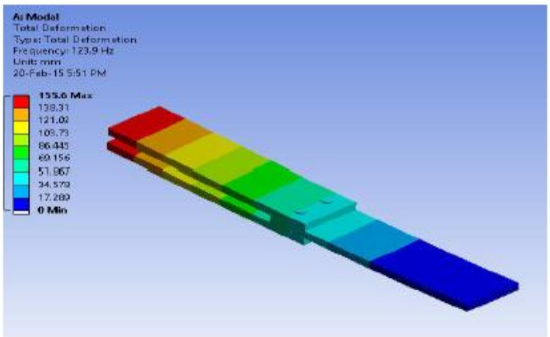


Fig 14 1st Mode Shape for 0.17 Overlap Ratio

From the above figure it is observed that the in the first mode shape for 0.17 overlap ratio for 30mm width plate the Frequency of vibration for riveted joint is 123.09 Hz

V. CONCLUSION

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

It is used to predict the natural frequencies and mode shapes of bonded lap joint system. The modal can also be used to predict system modal damping values by properly choosing material damping values of the beam and the adhesive.

The results obtained from Finite element modeling and experimentation has found good agreement. the variation in results can be observed from Minimum 2% to maximum 11%.

ACKNOWLEDGMENT

I would like to express my sincere thanks and gratitude Prof. Gaikwad M.U. Project guide (Mechanical – Design Engg) for their valuable help and guidance and Prof. Shitole J. S. HOD Mechanical Dept. I wish to express my gratefulness for the most cooperative attitude of Prof. Gaikwad M.U. for their able guidance thoughtful suggestions and the constant moral support.

REFERENCES

[1] R.A. Deshmukh, S.A. Sonawane, “Vibration Analysis of Adhesively Bonded Lap Joint”, Proc. of Int. Conf. on Advances in Robotic, Mechanical Engineering and Design 2011, Vol.5, Issue.1, March-April. 2009 pp-251-256

[2] Y. B. Patil, R. B. Barjibhe, “ Modal Analysis of Adhesively Bonded Joints of Different Materials”, International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.2, March-April. 2013 pp-633-636

[3] Solyman Sharifi, and Naghdali Choupani, “Stress Analysis of Adhesively Bonded DoubleLap Joints Subjected to Combined Loading”, World Academy of Science, Engineering and Technology Vol:2 2008-05-24

[4] Hamid Ahmadian, Hassan Jalali, “Identification of bolted lap joints parameters in assembled structures” Mechanical Systems and Signal Processing 21 (2007) 1041–1050, Received 30 April 2005; received in revised form 30 July 2005; accepted 11 August 2005 Available online 30 September 2005

[5] M D Banea, L F M Da Silva, “Adhesively bonded joints in composite materials: an overview" Journal of material design and applications, Vol. 223, 2009.

[6] M. Lusic, A Stoic, J Kopac “Investigation of aluminium single lap adhesively bonded joints”, Journal of Achievements in materials and manufacturing Engineering, Vol 15, 79-87, 2006.

[7] MohdAfendi, Toru Nakajima , “Study on strength of V-shaped epoxy adhesive joint”, International conference on applications and design in mechanical engineering, 2012.

[8] MohdAfendi, TokuoTeramoto, "Fracture toughness test of epoxy adhesive dissimilar joint with various adhesive thicknesses", Journal of solid mechanics and materials engineering, Vol. 4, no.7, 999-1010, 2010.

[9] HE Dan, TashiyakiSawa, Atsushi Karami " Stress analysis and strength evaluation of scarf adhesive joints wih dissimilar adherends subjected to static bending moments", Acian pacific conference for materials and mechanics, 2009.

[10] K.N. Anyfantis, N.G. Tsouvalis, "Experimental parametric study of single-lap Adhesive joints between dissimilar materials", 15th European conference on composite materials, 2012.

[11] Araldite standard technical data sheet.

[12] Product data sheet for Araldite_420A/B

[13] Mohd Afendi1, Nur Athirah1, M.S. Abdul Majid1, R. Daud and Tokuo Teramoto, “Experimental and numerical investigation of v-shaped epoxy adhesive joint”,International Conference on Mechanical Engineering Research (ICMER2013), 1-3 July 2013

[14] Xiaocong He, “effect of mechanical properties of adhesives on stress distributions in structural bonded joints” Proceedings of the World Congress on Engineering 2010 Vol II WCE 2010, June 30 - July 2, 2010, London, U.K.

[15] Lijuan Liao, Chenguang Huang , Toshiyuki Sawa, “Effect of adhesive thickness, adhesive type and scarf angle on the mechanical properties of scarf adhesive joints”, International Journal of Solids and Structures.

[16] Hiroko Nakano , Yasuhisa Sekiguchi , ToshiyukiSawa, “FEM stress analysis and strength prediction of scarf adhesive joints under static bending moments”, International Journal of Adhesion and Adhesives 44 (2013) 166–173

[17] Yi-Ming Jen, “Fatigue life evaluation of adhesively bonded scarf joints”, International Journal of Fatigue 36 (2012) 30–39,

[18] Andrew J. Gunnion, Israel Herszberg, “Parametric study of scarf joints in composite structures”, Composite Structures 75 (2006) 364–376

[19] Mohd Afendi , TokuoTeramoto, HairulBinBakri, “Strength prediction of epoxy adhesively bonded scarf joints of dissimilar adherends” International Journal of Adhesion and Adhesives 31 (2011) 402–411
[20] Mohd Afendi, Abdul Majid M.S., Daud R., Ishino Y. and Teramoto T.” Stress Analysis and Failure Characterizations of V-shaped Epoxy Adhesively Bonded Joint”, Advanced Materials Research Vol. 795 (2013) pp 290-293
[21] He Dan, ToshiyukiSawa , Takeshi Iwamoto, Yuya Hirayama, “Stress analysis and strength evaluation of scarf adhesive joints subjected to static tensile loadings”, International Journal of Adhesion and Adhesives 30 (2010) 387–392
[22] Hamit Adin,” The effect of angle on the strain of scarf lap joints subjected to tensile loads”, Applied Mathematical Modelling 36 (2012) 2858–2867
[23] Sinan AYDIN, Murat Yavuz SOLMAZ and Aydin TURGUT, “The effects of adhesive thickness, surface roughness and overlap distance on joint strength in prismatic plug-in joints attached with adhesive”, International Journal of the Physical Sciences Vol. 7(17), pp. 2580 – 2586
[24] Hamit Adin, “The investigation of the effect of angle on the failure load and strength of scarf lap joints”, International Journal of Mechanical Sciences 61 (2012) 24–31
[25] Jaroslav Mackerle, “Finite element analysis and simulation of adhesive bonding, soldering and brazing: A bibliography” Modelling Simul. Mater. Sci. Eng. 5 (1997) 159–185.
[26] Rohan P. Chumble, Prof.S.N. Shelke, ” Determination of effects of adhesive layer thickness on joint strength”
[27] M.Kemal Apalak, Recep ekici, and Mustafa Yildirim, “Free vibration analysis and optimal design of an adhesively bonded double containment cantilever joint” , Journal of Scientific and Industrial Research, Vol 67 octomber 2008 pp. 797-806 THESIS
[28] Todd R. Greene,“Analytical modeling of composite-tocomposite (scarf) joints in tension and compression”, Naval postgraduate school monterey, California.
[29] Ramesh Chandra Mohanty, “Damping of layered and jointed beams with riveted joints”, department of mechanical engineering national institute of technology rourkela - 769008, orissa, india august 2010.

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