Analysis of Dynamic Response of Adhesively Bonded Joints of Different Materials: A Review

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Abstract-*The aim of this study is to investigate effects on stresses of using different adherent material in single lap joint.This paper deals with study of Dynamic response of adhesive bonded joints of different type materials. It is important to design lightweight structures and the increased use of lightweight materials in industrial fields, have led to wide use of adhesive bonding. The effects of surface preparation, joint configuration, adhesive properties, and environmental factors on the joint behavior are described briefly for adhesively bonded composite structures. The environmental factors such as pre-bond moisture, moisture and temperature are also discussed in detail and how they affect the durability of adhesive joints. Majority of automobile and aerospace parts, mainly their body components are joined together by different types of adhesives. So these growing needs demand the detailed study on stress concentration and strength analysis of adhesive joints. The environmental factors such as pre-bond moisture, moisture and temperature are also discussed in detail and how they affect the durability of adhesive joints with different adherents.*

Keywords-Adhesively bonding, Stress concentration, Strength analysis, Single lap adhesive joints and Adhesive thickness.

I. INTRODUCTION

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. There are many industrial applications of structural adhesive joints. These incompass the automotive, aerospace, marine, appliance industriesAdhesive bonding is a process of joining materials in which an adhesive (liquid or a semi solid state material) is placed between the faying surfaces of the workpiece / parts (adherents) to be joined. Either heat or pressure or both are applied to get bonding. The aim of the paper is to study the dynamic characteristics of rectangular cross sectioned cantilever plate with different material and compare it with different adhesive material.

The important features of a good adhesive for different metal bonding can be presented syntheticaly as followes.

- The adhesive materials may penetrate into the adherend material and locks the two bodies.
- The mechanism of adhesion helps to reduce stress concentration found in bolted, riveted and welded joints.
- Dissimilar materials, such as metals, plastics, wood, ceramics can be joined.
- Adhesive joining techniques do not require holes, as riveted or bolted joints do, which can lead to stress concentration.
- Adhesives can be contoured and formed in various fabrication processes.
- Possibility of curing at ambient temperature.

II. ADHESIVE BOND

Adhesive bonding is a material joining process in which an adhesive, placed between the adherent surfaces, solidifies to produce an adhesive bond. 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.

A. TYPES OF ADHESIVE JOINTS

Common types of adhesive joints are shown in figure 1

1. Single lap joint.

2. Balanced double lap adhesive joint

3. Unbalanced double lap joint

4. Scarf Joint

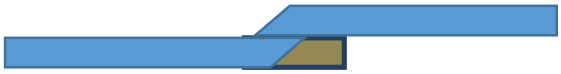

Fig 1 Adhesive Joints

B.TYPES OF ADHESIVES

Table 1 Types of Adhesives

Hot Melt Adhesives	Hot melt adhesives are applied in the molten state and then harden. The adhesive substance is melted, applied to the surface and then two adherents to be joint.
Holding Adhesives	Holding adhesives are used to hold surfaces together, but not permanently. They do not have to withstand a great deal of force. Example – Adhesive tape
Instant Adhesives	Any adhesive which cures within seconds to minutes.
Pressure Sensitive Adhesives	Pressure sensitive adhesives form bonds easily when pressure is applied. Pressure sensitive adhesives are used on self-sealing envelopes and double sided tape. The joint is made with very little pressure.
Sealing Adhesives	Sealing adhesives are used to prevent the passage of air, water, oil, etc. between two surfaces. The caulking around windows is an example of a sealing adhesive.
Ultravioletadhesives	Any adhesives which cure when exposed to UV light
Retaining Adhesives	Retaining adhesives are used to prevent the twisting or sliding of non-threaded parts.
Structural Adhesives	Structural adhesives are capable of withstanding a significant load. The term ‘significant load’ has never been defined, but the implication is that the adhesive must be able to withstand a great deal of stress. In fact, it could be said that in the absence of unnaturally high forces, the substrates could be considered to be permanently joined.

C.STRUCTURAL ADHESIVES

Structural or performance adhesives are loadbearing adhesives. That is they add strength to the products being bonded. Structural adhesives are used to build products as varied as office furniture, boats, trains, cars to name a few. There are approximately ten adhesive families commonly referred to as structural adhesives: Acrylic, Anaerobic, Cyanoacrylate, Epoxy, Hot Melt, Methacrylate, Phenolic, Polyurethane, Solvent cement and Tapes.

The seven most commonly used are:

- Acrylic
- Anaerobic
- Epoxy
- Hot Melt
- Methacrylate
- Polyurethane

Acrylic Adhesives have formulations that tolerate dirtier and less prepared surfaces generallyassociated with metals. They challenge epoxies inshear strength, and offer flexible bonds with goodpeel and impact resistance. Acrylics are two-part adhesives, the resin is applied to one surface and anaccelerator or primer to the other. The two partscan be pre-applied and later mated. Once mated,handling strength is typically achieved in a fewminutes. Curing can be completed at roomtemperature. Newer versions of acrylics are nowavailable in two component formulations than aremixed together prior to application.

Anaerobic adhesives are one of the most easilyapplied structural adhesives.These adhesives are based on acrylic polyester resins and are produced in viscosities ranging from thin liquids to viscous thixotropic pastes. Although they have high cohesive strength, they have low adhesive strength.

Epoxy Adhesives have been available longer than any engineering adhesive and are the most widely used structural adhesive. Epoxy adhesives consist of an epoxy resin plus a hardener. Epoxy adhesives are thermosetting resins which solidify by polymerization and, once set, will soften but not melt on heating. Two part resin/hardener systems will solidify on mixing (sometimes accelerated by heat), while one part materials require heat to initiate the reaction of a latent catalyst. Epoxies offer very high shear strengths, and can be modified to meet a variety of bonding needs. Generally epoxy bonds are rigid: they fill small gaps well with little shrinkage.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.

Hot Melt Adhesives have moved out of their traditional applications into areas of low-stress product assemblies. They form flexible and rigid bonds, achieve 80% of their bond strength within seconds, bond permeable and impermeable materials, and usually require no elaborate surface preparation. Hot melts are insensitive to moisture and many solvents, but they soften at high temperatures.

Methacrylate Adhesives provide a unique balance of high tensile, shear and peel strengths with the maximum resistance to shock, stress and impact across a wide temperature range. Methacrylate can generally be used without surface preparation when joining plastics, metals and composites.

Polyurethane Adhesives are named after the polymer type formed on completion of the reaction. The adhesives are usually two component, one side is always isocyanate based, the other formulated from one of several core reactants often amines or glycols. They are known for toughness and flexibility even at low temperatures. They have fairly good shear strength and excellent water and humidity resistance, although uncured urethanes are sensitive to moisture and temperature.

III. ADHEREND

In adhesive bonding joint, the load is transmitted from one adherend to another adherend through the adhesive layer in the overlap region.The structural materials most frequently used in design can be categorized in fourprimary groups: metals, polymers, composites, and ceramics. Composite materials have been in existence for many centuries. No record exists as to when people first started using composites. In the most general of terms, a composite is a material that consists of two or more constituent materials or phases. The fact that there has been a major effort to develop composite material systems, and analyze and design structural components made from composite materials. In the meantime, adhesive bonding technology is frequently used in almost all the industries fields of the world and this is mainlydue to its high strength-weight ratio, low cost and high efficiency nowadays. The various types of adherend are used in industry applianceslike metal, ceramic, composite, fabric etc. adhesive bonding gaining moreimportance in joining process where you have toavoid stress concentration and avoid localizedheating. 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.

Table 2: Mechanical properties data of the materials

Material Properties	Copper	Aluminum	Steel	Titanium
Modulus of elasticity (E)	110	66	207	116
Density (ρ)	8940	2707	7780	4570
Poisson's ratio (v)	0.34	0.33	0.29	0.34
Bulk modulus (k)	398	204	80.3	20.4
Heat capacity (C_p)	386	896	460	523

Table 3: Mechanical properties data of the epoxy material

Material Properties	Epoxy	Unit
Modulus of elasticity (E)	3.3	GPa
Density (ρ)	1264	Kg/m^3
Poisson's ratio (v)	0.30	-
Bulk modulus (k)	0.179	W/mk
Heat capacity (C_p)	1046	J/kgK

IV. PROBLEM DEFINATION

A mechanical joint is a part of a machine which is used to connect another mechanical part or mechanism. Mechanical joints may be temporary or permanent.

A. Welded joint:

Metals can be generally joined using the welding technique – although there are some exceptions, but almost any metal material (aluminum, carbon steel, stainless steel, tungsten) has a variation that is suitable for welding. Welding is a type of permanent joint. There are some drawbacks: uneven heating and cooling during fabrication so members get distorted or additional stress may develop. The inspection of welding is more difficult. It required highly skilled labor and supervision.

B. Rivet joint:

A riveted joint is a permanent joint which uses rivets to fasten two materials. A rivet is a structure that has a hemispherical head on one side and a cylindrical shaft on the other. Made from Aluminum alloys, steel, or CRES and other special metals like titanium, nickel, etc.There are some draw backs: Skilled workers required. Leakage may be a problem for this typeof joints, but this is overcome by special techniques.

C. Adhesive joint:

It is a permanent joint which used adhesive material for joining two parts. 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.

V. 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 aluminum plates of dimension 500 mm long, 50 mm wide, 5mm thickness; copper plates of dimension 500 mm long, 50 mm wide, 5mm thickness, mild steel plates of dimension 500 mm long, 50 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.

The following methodology will be implanted for achieve the aim and objective of research work:

- To collect all data related with Adhesive bonded joint.
- Finding of material related to type of adhesive.
- Fabrication of joints.
- Experimental and finding the result by FFT.
- Modal analysis.
- Validation of experimental analysis with modal analysis.
- Conclusion.

VI. CONCLUSION

Various driving forces are leading numerous companies that have relied upon standard joining methods such as welding, brazing, rivets and bolts in the past; to consider the use of high performing toughened structural adhesives. Such adhesives can provide significant advantages in terms of overall cost and weight reduction, as well as the ability to join dissimilar substrates and the ability to create joints with good stress distribution and concomitantly good fatigue and force resistance. Toughened adhesives can also improve aesthetics and eliminate labor-intensive finishing costs such as sanding off slag from spot welding. Choosing the right adhesive is paramount and engineers should work closely with their material supplier to select the right product. 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. However, as can be demonstrated empirically, when used properly structural adhesives can meet or exceed the performance of traditional joining methods such as welding, rivets and bolts.

REFERENCES

[1] Y.B. Patil, R.B. Barjibhe, Modal analysis of adhesively bonded Joints of different Materials, International Journal of Modern Engineering Research, Vol.3, Issue.2, March-April (2013) pp-633-636.

[2] Yu Du*, Lu Shi, Effect of vibration fatigue on modal properties of single lap adhesive joints, International Journal of adhesion and adhesives 53 (2014) 72-79.

[3] Xiaocong He, A review of finite element analysis of adhesively bonded joints, International journal of adhesion and adhesives 31 (2011) 248-264.

[4] X.He, S.O. Oyadiji, Influence of adhesive characteristics on the transverse free vibration of single lap-jointed cantilevered beams, Journal of material processing technology 119 (2001) 366-373.

[5] Xiaocong He, A review of finite element analysis of adhesively bonded joints, International journal of adhesion and adhesives 31 (2011) 248-264.

[6] NehaB.Thakare, A.B.Dhumne, A review on design and analysis of adhesive bonded joint by finite element analysis, International Journal of mechanical engineering, vol 2 (2015).

[7] Faruk Sen,and Kemal Alda, Effects of Using Different Metal Materials on Stresses in Metal-Composite Hybrid Joints University Journal of Science and Engineering Volume 8 (2011), No . 1.

[8] Aruleswaran, Dr. J. Balkwill and Dr. D. Morrey dynamic behaviour of a structure featuring adhesive bonded joint.