A Review on Design and Analysis of Adhesive Bonded Joint by Finite Element Analysis

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Abstract

The need to design light weight structures and the increased use of light weight materials in industrial fields, have led to wide use of adhesive bonding. Recent work relating to finite element analysis of adhesively bonded joints is reviewed in this paper, in terms of static loading analysis, fatigue loading analysis and dynamic characteristics of the adhesively bonded joints.
In this work fabrication of joint using Ms flat plate will be done. The joint will be made by welding, riveting and adhesive bonding process. Adhesive bond will be created by using epoxy as an adhesive material. The numerical calculation will be done for the experimental analysis. Computational analysis will be comprises of stress, buckling and vibrational analysis. Result of experimental analysis will be validating with computational analysis.

Keywords – *Adhesive bonded joint, buckling analysis, finite element analysis, stress and vibrational analysis.*

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. 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.

Adhesive 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 detailed explanation on the steps followed to get an adhesive joint is given below. Three essential steps are required to follow to make an adhesive joint including (a) preparation of the surfaces, (b) application of the adhesive on to the mating surfaces, and (c) assembly of workpieces / parts and curing the joint.

The more important features of a good adhesive for metal bonding can be presented synthetically as follows:

- Strength when cured meeting the requirements.
- Possibly low viscosity, facilitating wetting.
- Relatively low free surface energy.
- Presence of various functional groups in the chemical structure of the adhesive, expanding the applicability of the adhesive and permitting the formation of chemical bonds.
- Low chemical curing shrinkage rate, in the case of thermal-setting adhesives also low thermal cure shrinkage rate; this permits bonding under contact pressure.
- Possibility of curing at ambient temperature.
- Short curing time.
- Resistance to cracking of brittle character.

A. *Types of Adhesives*

Heat-Cured Adhesives	Any adhesives which must be heated to promote curing.
Holding Adhesives	Holding adhesives are used to hold surfaces together, but not permanently. They do not have to withstand a great deal of force. Adhesive tape is a good example of a holding adhesive.
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 the parts are joined. Once the adhesive cools and solidifies, the joint is complete.
Instant Adhesives	Any adhesive which cures within seconds to minutes
Locking Adhesives	Locking adhesives or

	sealants are used to prevent the loosening of threaded parts. Locking adhesives are placed on the threads of a bolt to prevent it from becoming loose from vibration.
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.
Retaining Adhesives	Retaining adhesives are used to prevent the twisting or sliding of non threaded parts. Retaining adhesives are very similar to locking adhesives except they are used on non-threaded parts.
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.
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.
Ultraviolet adhesives	Any adhesives which cure when exposed to UV light

B. Structural Adhesives

Structural or performance adhesives are load-bearing 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
- Cyanoacrylate
- Epoxy
- Hot Melt
- Methacrylate
- Polyurethane

Acrylic Adhesives have formulations that tolerate dirtier and less prepared surfaces generally associated with metals. They challenge epoxies in shear strength, and offer flexible bonds with good peel and impact resistance. Acrylics are two-part adhesives, the resin is applied to one surface and an accelerator or primer to the other. The two parts can be pre-applied and later mated. Once mated, handling strength is typically achieved in a few minutes. Curing can be completed at room temperature. Newer versions of acrylics are now available in two component formulations than are mixed together prior to application.

Anaerobic adhesives are one of the most easily applied structural adhesives. Because the curing mechanism is trigged by deprivation of oxygen (hence the name 'anaerobic' or 'without air'), anaerobic adhesives will not cure prematurely. 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 and are not suited to permeable materials. Anaerobics do not fill gaps well and may require primers. They are generally used as thread fasteners.

Cyanoacrylate Adhesives Cyanoacrylate Adhesives (superglues) are also easily applied and offer extremely fast cure rates. Cyanoacrylates are relatively low viscosity fluids based on acrylic monomers and, when placed between closely fitting surfaces, some will cure to a strong joint in two to three seconds. Cyanoacrylates' ability to bond plastics and rubbers to themselves or to other substrates is their biggest advantage. On the other hand, cyanoacrylate adhesives exhibit poor impact resistance, are vulnerable to moisture and solvents, and are suitable only for bonding small areas. In addition, they do not fill gaps well, require precise mating of bonded surfaces, and are relatively expensive. They also have poor solvent and water resistance.

Epoxy Adhesives have been available longer than any engineering adhesive and are the most widely used structural adhesive. Epoxy adhesives are thermosetting resins which solidify by polymerisation 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.

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. Methacrylates can generally be used without surface preparation when joining plastics, metals and composites. They are two component reactive materials based on methyl methacrylate monomer that, when mixed together, have a controlled cure speed based on the appropriate application process. Methacrylates are tolerant to off ratio mixing and remain strong and durable under severe environmental conditions. They resist water and solvents to form an impenetrable bond.

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.

C. Advantages and Disadvantages of the Adhesive Bonded Joints

Advantages	Disadvantages
• Fast and cheap joining technique • The adherents are not affected by heat • Uniform stress distribution • Possibility to join large structures • Ability to join different materials • Possibility to join very thin adherents • Gas proof and liquid tight joints • No crevice corrosion • No contact corrosion • Good damping properties • High dynamic strength	• Limited stability to heat • High strength adhesives are often brittle • Long term use may alter the properties • Cleaning and surface preparation of the adherents is necessary in many cases • Specific clamping devices are often required to fix the joint • Difficult disassembly of joined parts

II. PROBLEM FORMULATION

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 labour 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 Aluminium alloys, steel, or CRES and other special metals like titanium, nickel, etc.

There are some braw backs: Skilled workers required. Leakage may be a problem for this type of 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.

The subject of Structural analysis primarily concerns determination of static and dynamic behavior of joints. Once they are determined, they can be used in understanding the dynamic and static nature of the systems, and also in design and control. Therefore structural analysis is extremely important in engineering.

Structural analysis is useful in a variety of stages in the development and utilization of a product. In the design and development stage, structural analysis 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.

III. METHODOLOGY

Experimental Analysis consists of fabrication of welded, Riveted and Adhesive bonded joint of MS flat plate. The Adhesive material use will be epoxy. Stress and strength of various joints will be find out by using universal testing machine. Computational analysis will comprise of stresses, buckling and vibrational analysis. Comparison of welded, riveted and adhesive joint will be done on the basis of both experimental and computational analysis.

In this analysis single lap Adhesive joint, single lap rivet joint, welded T joint and Adhesive T joint are investigate. The specimen is used which is Ms-Ms plates and Adhesive is Epoxy. The two set of adherents use are mild steel plates of dimension for single lap joint are 140 mm long , 38 mm wide , 5 mm thickness. And dimensions for T joint are 100 mm long, 38 mm wide and 5 mm thickness.

In analysis of single lap joint for first case adhesive thickness 3 mm is kept constant and vary the bonding length of 50 mm to 90 mm. And in second case bonding length 70 mm kept constant and vary the Adhesive thickness between 1 mm to 5 mm.

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

- To collect all data related with Adhesive Bonded Joints.
- Procurement of material
- Fabrication of joints.
- Testing and Finding of readings.
- Numerical calculation for experimental analysis.
- CAD molding of joint.
- Computational analysis of joints.
- Validation of experimental Analysis with computational Analysis
- Conclusion

IV. 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. In addition, some joint redesign and production processing adjustments may greatly affect ultimate project success. 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.

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