International Journal of Mechanical and Industrial Engineering

Volume 3 | Issue 3 Article 6

January 2014

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Recommended Citation

SURESH, KALE; MURTY, K.L.N.; and KUMAR, T.JAYANANDA (2014) "ANALYSIS OF ADHESIVELY BONDED SINGLE LAP RIVETED JOINT USING ANSYS," *International Journal of Mechanical and Industrial Engineering*: Vol. 3 : Iss. 3 , Article 6.
DOI: 10.47893/IJMIE.2014.1150
Available at: https://www.interscience.in/ijmie/vol3/iss3/6

ANALYSIS OF ADHESIVELY BONDED SINGLE LAP RIVETED JOINT USING ANSYS

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Abstract— This project deals with the analysis of adhesively bonded single lap riveted joints. The present work involves the appropriate configuration and characterization of these joints for maximum utilization. The present study includes the effectiveness of bond line thickness, the bonded layer configuration. This is also applicable to dissimilar thickness joints, but in this project we have placed the adhesives at different places for riveted joints. The finite element technique was used throughout the analysis of present work. The present work showed that riveted bonded joints are superior in strengthening to the riveted joints. The riveted bonded joint seems to strengthen and balance the stress and distributed uniformly. This improves the efficiency and life time of the riveted joints; this is also applicable to dissimilar thickness and dissimilar metals joints for balancing, uniform distribution of stress and without any effect of corrosion on dissimilar metals. Modeling and analysis of adhesively bonded single riveted lap joint can be done by using ansys with a version of 13.0.

Keywords- *Adhesive, Finite element technique, PREP7, ANSYS,* etc.

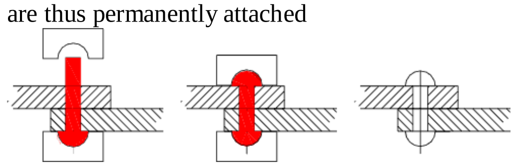
I. INTRODUCTION

Bonding of metals is becoming increasingly important, both in absolute terms and relative to mechanical fastening. Applications of adhesive bonding are found in the assembly of many products including aircraft, cars, trucks, and office furniture. This is because adhesive bonding offers more uniform distribution of stresses, increased fatigue life, weights savings, reduction of corrosion between dissimilar materials, added to the ability to join small and delicate parts.

Bonded structure can be of two types based on either purely adhesive or on adhesive/mechanical connection. The purely adhesive connections include shaft-pinion joints, laminated metal-metal joints The bonded mechanical types include bonded-riveted and bonded-screwed connections. The combined connections (bonded-welded, bonded-riveted and bonded-screwed) ensure high fatigue strength of the structures. The single lap riveted joint is an important part of an aircraft structure and rivets are used extensively for joining plates together.

2. INTRODUCTION TO RIVETS

Rivets are considered to be permanent fasteners Riveted joints are therefore similar to welded and adhesive joints. Rivets have been used in many large scale applications including shipbuilding, boilers, pressure vessels, bridges and buildings etc. A riveted joint, in larger quantities is sometimes cheaper than the other options but it requires higher skill levels and more access to both sides of the joint A rivet is a cylindrical body called a shank with a head. A hot rivet is inserted into a hole passing through two clamped plates to be attached and the heads supported whilst a head is formed on the other end of the shank using a hammer or a special shaped tool. The plates are thus permanently attached



Design of joints is as important as that of machine components because a weak joint may spoil the utility of a carefully designed machine part. Mechanical joints are broadly classified into two categories viz., non-permanent joints and permanent joints. Non-permanent joints can be assembled and dissembled without damaging the components. Examples of such joints are threaded fasteners (like screw-joints), keys and couplings etc.Permanent joints cannot be dissembled without damaging the components. These joints can be of two kinds depending upon the nature of force that holds the two parts.

The force can be of mechanical origin, for example, riveted joints, joints formed by press or interference fit etc, where two components are joined by applying mechanical force. The components can also be joined by molecular force, for example, welded joints, brazed joints, joints with adhesives etc.

2.1 Rivet

A Rivet is a short cylindrical rod having a head and a tapered tail. The main body of the rivet is called shank (see figure 1.1). According to Indian standard specifications rivet heads are of various types. Rivets heads for general purposes are specified by Indian standards IS: 2155-1982 (below 12 mm diameter) and IS: 1929-1982 (from 12 mm to 48 mm diameter).

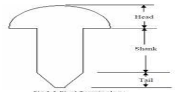


Fig 1.1 Rivet Terminology

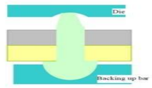


Figure 1.2: Riveting operation

Riveting is an operation whereby two plates are joined with the help of a rivet. Adequate mechanical force is applied to make the joint strong and leak proof. Smooth holes are drilled (or punched and reamed) in two plates to be joined and the rivet is inserted. Holding, then, the head by means of a backing up bar as shown in fig 1.2, necessary force is applied at the tail end with a die until the tail deforms plastically to the required shape.

2.2 Rivet testing

The BIS has also recommended standard test. According to IS: 1928-1961, the samples of manufactured rivets are subjected to bending and flattening test.

In bending test, arivet shank is bent old and hammered until the two ends of the shank are turned to each other with out cracking.

In flattering, the rivet head is flattened until its diameter is 2.5 times the diameter of shankand yet it doesn't crack

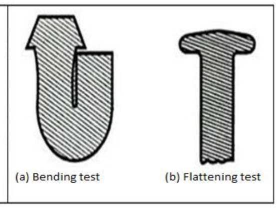


Fig 2: Types of rivet tests

2.2 In riveted joints following terminologies are most commonly used.

1. Gauge Line: - The line passing through the centerline of rivets and parallel to the edge of the plate is called gauge line or pitch line.
2. Pitch (p) :- The distance between the centers of the adjacent rivets measured on gauge line
3. Transverse Pitch (p_t):- Distance between the rivet centers in two adjacent gauge lines is called traverse pitch or back pitch.
4. Diagonal pitch (p_d):- It is the distance between the adjacent rivet centers on adjacent gauge line in zigzag or chain riveting.
5. Margin (m):- It is the distance between the outermost gauge line and the edge of the plate.

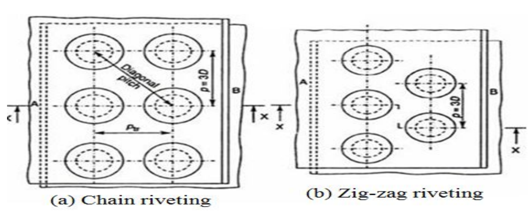


Fig 1:types of riveting.

2.4 Design stresses

2.4.1 The rivet joints are analyzed on the basis of following assumptions:

i. Rivets are loaded in shear the load is distributed in proportion to the shear area of the rivets

ii. There are no bending or direct stresses in rivets

iii. Rivet holes in plate do not weaken the plate in compression

iv. Rivets after assembly completely fills the hole

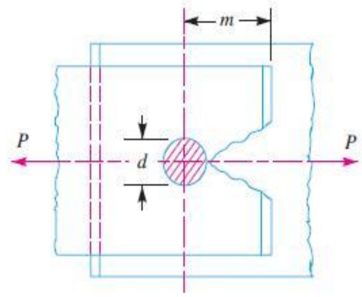
v. Friction between the adjacent surfaces does not affect the strength of the joints however the actual stress produced decreases

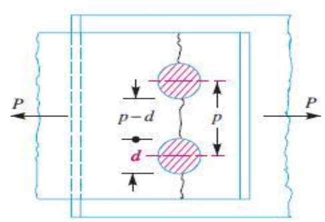
vi. When rivet is subjected to double shear, the shear force is equally distributed between the two areas of shear.

Thus according to the theory the failure of rivet may occur due to any one of the following modes.

2.4.2 Theories of Failures of Rivet Joints

1.Tearing of the plate at an edge:- A joint may fail due to tearing of the plate at an edge as shown in below figure. This can be avoided by keeping the margin, m=1.5d, where "d" is the diameter of the





2.Tearing of the plate across a row of rivet:-

Tearing resistance required to tear off the plate per pitch length, $P_t = A_t.\sigma_t$

$= (p-d)\ t.\sigma_t$

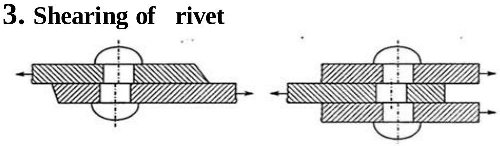
Where p = pitch of the rivets;

d = diameter of the rivet hole;

t = thickness of the plate:

σ_t = permissible tensile stress for the plate material

3. Shearing of rivet

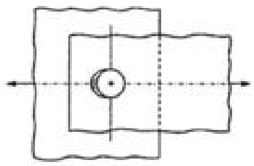


Thus shear strength is,

$P_s = n\,\pi/4\,d^2\,T_{max}$ - for single shear and
$P_s = 2 \times n\,\pi/4\,d^2\,T_{max}$ - theoritically in double shear and
$P_s = 1.875 \times n\,\pi/4\,d^2\,T$ - for double shear,according to Indian boiler regulations

Where, T_{max} = Shear strength of rivet;
n = number of rivets.

4. Crushing of the plate (or) rivets :-



The crushing strength is, $P_c = n\,d\,t\,\sigma_c$

Where, σ_c = Crushing strength of rivet;
n = no of rivets under crushing;
d = diameter of rivet = $6.1\sqrt{t}$;
t = thickness of plate

2.4.3. Efficiency of riveted joint

$$\eta = \frac{\text{Strength of the joint in the weakest mode}}{\text{Strength of the un punched plate}}$$

3. ADHESIVES

Adhesive is defined as a material that is capable of joining bodies together by surface adhesion and internal strength without the structures of the bodies undergoing any changes. The process of this adhesion is called bonding and the bodies are called adherents.

3.1 Bonding has several advantages

1. The common feature of all adhesive joints is the highly uniform distribution of forces over the entire joint area and free from any residual stresses which leads to optimal utilization of material strength compared to rivet and screw joints.
2. Adhesive bonding can be utilized to make the material leak-proof for liquids and gases.
3. The process of adhesion can be carried out very rationally, quickly and economically.
4. Many adhesives can be applied at room temperature hence the adherents are not exposed to high temperature as in the welding of plastics with metals.
5. The adhesive layer of an adhesive joint can have a vibration-dampening effect. Adhesives can introduce electrical and heat insulating layers between the adherents.

4. OVERVIEW OF ANSYS

The ANSYS computer program is a large scale multipurpose finite element program, which may be used for solving several classes of engineering analyses. As ANSYS has been developed, other special capabilities, such as sub structuring, sub modeling, random vibration, free convection fluid analysis, acoustics, magnetic, piezoelectric, couple field analysis and design optimization have been added to the program.

4.1 Program overview

Analysation of any problem in ANSYS has to go through three main steps. They are,

Pre-processor
Solution
Postprocessor

The input of the ANSYS is prepared using pre-processor. The general preprocessor contains powerful solid modeling and mesh generation capabilities, and is also used to define all the other analysis data such as geometric properties like real constants, material properties, constraints, loads, stiffness damping etc.,

4.2 General procedure to solve and problem in ansys

The ANSYS software has many finite element analysis capabilities ranging from simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis
Any problem in ANSYS has to go through the three main steps

Build the model
Apply loads and obtain solution
Review the results

4.2.1 Building the model

Before creating the finite element model, job name and job title has to be specified first. After that element type, real constants, material properties and geometry of the model are defined by using PREP7 command in the ANSYS input window or by using preprocessor from the ANSYS main menu.

4.2.1.1 Defining the job name

Utility menu=>file=>save as

(a) Defining the title

Utility menu=>file=>change title

(b) Defining element type

Main Menu=>preprocessor =>Element type=>Add/Edit/Delete

(c) Defining real constants

Main Menu=>preprocessor =>Real Constants

When creating the elements, the appropriate real constant set reference number for the portion for the element is specified by the following path.
Main Menu=>preprocessor=>Create=>Elements=> Element Attributes.

(d)Defining material properties

Main Menu=>preprocessor=>Material Properties

After defining the material properties, material properties sets are assigned to the particular element using the following path.

Main Menu=>preprocessor=>create=>Elements
=>Element Attributes

(e) Creating the finite element model

The finite element model is created by any of the three methods

Solid modeling
Surface modeling
Wire frame modeling

The following paths are used in creating the finite element model.

Main Menu=>preprocessor=>Create
Main Menu=>preprocessor=>Operate
Main Menu=>preprocessor=>Delete
Main Menu=>preprocessor=>Move/Modify

The mesh operation is performed by using the following path. Main Menu=>preprocessor=>Mesh

4.3 Apply loads and obtain the solution

a) Applying loads Different loads acting on the model and boundary conditions are applied either in the preprocessor or by using the solution Menu. The loads in the ANSYS program are

DOF Constraints
Forces
Surface loads
Body loads
Inertia loads
Coupled-field loads

(b) Defining the type of analysis and analysis options

Static Analysis: Used to determine displacements, stresses etc. under static loading conditions. Both linear and nonlinear static analysis. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. Our present analysis is "static Analysis".

(c) Specifying load step options The following path is used to specify load step options.

Main Menu=>Solution=>Load step options

(d) Initiating the solution The solution to the given problem is initiated by using the following path. Main Menu=>Solution=>Solve-Current LS
(load step)

5. DESCRIPTION OF THE PRESENT WORK

The present work deals with the Analysis of adhesively bonded single lap riveted joint. This is quite commonly used technique for finding the strength of different applications like pressure vessels, aerospace, marine and mostly for leak proof joints like oil tanks, boilers etc.. In this a lap joint of steel plate material having 100mm*1.5mm*20mm and a friction factor of 0.1 is over lapped with the other plate having same dimensions and material and are joined by means of a rivet having diameter 4mm, apply a load of 500N on one side and the other end is fixed in the ANSYS.

The normal riveted joint one is compared it with the other joints having an adhesive material at different places in the joints as described in the present work. By using the adhesives the stresses and deformation can be reduced. This will improve the strength of joints, rivets and uniform distribution of stresses will takes place in the joint. It has been found that the Analytical calculations were observed in the 'ANSYS' (3-dimensional finite element analysis) software by creating the model of the present one and apply the constant load conditions of 500N on different types as described in the present work, we can observe the reduced stress comparison from the figures.

5.1 Determination of Specifications:

The specifications of the present job has taken from the design considerations from the plate thickness as 1.5mm and that are specified in the following diagram. Figure shows the configuration, Dimensions, constraints and loading conditions. The following assumptions and boundary conditions were considered throughout the idealization process:

1. The problem is 3-D-FE model. A friction contact surfaces between rivet body and joint strips was specified having friction factor of 0.1.
2. The adhesive layer is isotropic, i.e. stresses on the micro-scale, such as those caused by flows in the adhesive, were neglected (in case of incorporating adhesive layer in the joint).

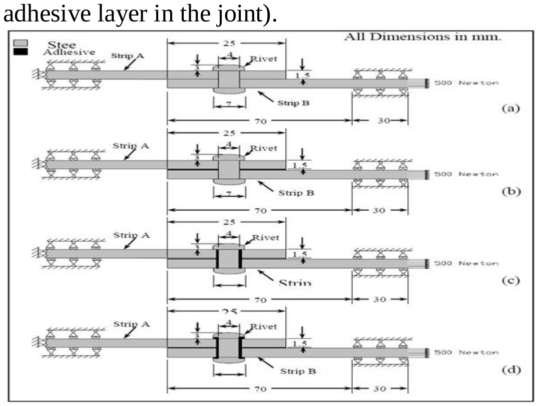


Fig.3 Assigned constraint and boundary conditions on FE models

5.1.1 Finite Element Modeling and Boundary Conditions

Four different bonded layer orientations in bonded-riveted joints were considered in the present work are listed as follows:

1. A single lap riveted model,
2. A single lap riveted-bonded model (bonded at overlap area only),

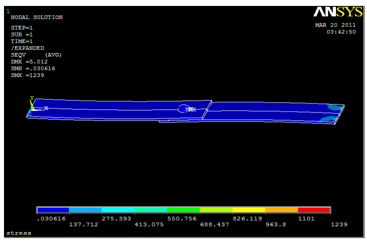
3. A single lap riveted-bonded model (bonded at overlap area and rivet-body),

4. A single lap riveted-bonded model (bonded at overlap area, rivet-body and rivet-cap-head).

5.2 Material properties:

Material properties of adherents and adhesive used			
Material	**Young's modulus (N/mm^2)**	**Poisson's ratio**	**Shear modulus (Gpa)**
Adhesive	**2.5□10^3**	**0.38**	**0.905**
Steel	**2.0□10^5**	**0.30**	**78.1**

Tables 1: material properties



of Fig1(a):The stress distribution a single lap riveted joint without adhesive

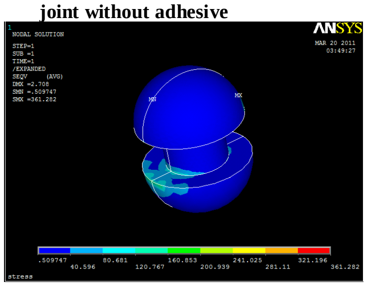


Fig1(b):The stress distribution of a rivet without Adhesive

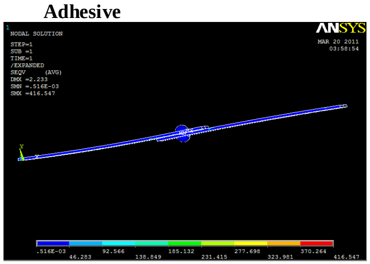


Fig2(a): The stress distribution of a single lap riveted joint with adhesive b/w the plates only.

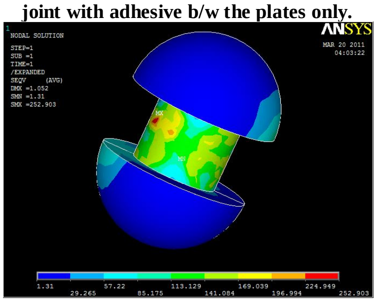


Fig2(b):The stress distribution at rivet of a single lap riveted joint with adhesive b/w the plates only

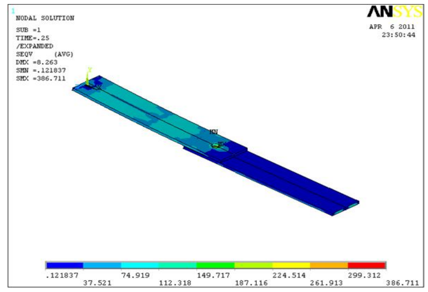


Fig3(a):The stress distribution of a single lap riveted joint with adhesive b/w the plates and rivet

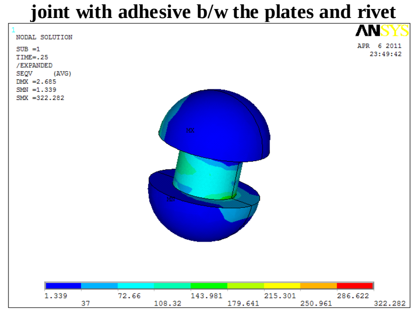


Fig3(b):The stress distribution at rivet of a single lap riveted joint with adhesive b/w the plates and rivet also.

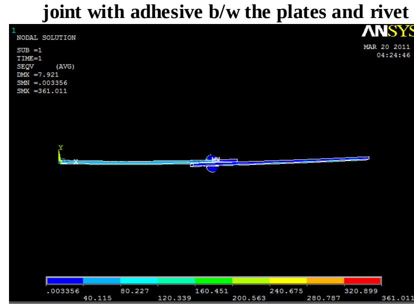


Fig4(a):The stress distribution of a single lap riveted joint with adhesive b/w the plates, rivet and head also.

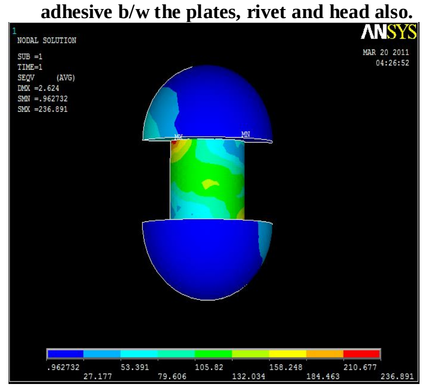


Fig4(b):The stress distribution at rivet of a single lap riveted joint with adhesive b/w the plates, rivet and head also.

6. CONCLUSION

- The results obtained from ANSYS software for the Adhesively Bonded Single lap riveted joints are compared with each other at different conditions of using adhesives at described locations leads to decreasing the stresses, uniform distribution of load gives more efficient and life to the joints.

- Finite Element Method is found to be most effective tool for designing mechanical components like single lap riveted joints.
- ANSYS can be used for analysis of complex and simple models of different type without any effect on practical and economical issues.

7. SCOPE FOR THE FUTURE WORK

There is a huge scope for the future work, on the present topic of Analysis of Adhesively Bonded Single Lap Riveted joint.

- By the consideration the design, and practical with these we can get some more accurate results.
- By considering a particular application and load leads to a scientific research.
- Analyzing the entire assembly of the joint by giving proper contact surface leads to complexity in the ANSYS.

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