

Stress Analysis of Single Lap Riveted Joint for Leak Proof Applications by Adhesive Bonding Using Finite Element Method

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Abstract

A Rivet is a short cylindrical rod having a head and a tapered tail. The present work deals with the analysis of single lap riveted joints for leak proof applications using adhesives. The work involves in the appropriate configuration and characterization of these joints for maximum utilization and also includes the effectiveness of bond line thickness, the bonded layer configuration. In this work we placed the adhesives at different position of the plate for riveted joints. The finite element method was used throughout the analysis of work. The 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. The modelling of the rivet was done by CATIA V16.0 and analysis of riveted lap joint was done by using ANSYS-14.

Keywords: Adhesive; Bond Line Thickness; Rivet; Finite Element Method; Stress Distribution.

1. Introduction

Rivets are considered to be permanent fasteners. Riveted joints are therefore similar to welded and adhesive joints. When considering the strength of riveted joints similar calculations are used as for bolted joints. Rivets have been used in many large scale applications including shipbuilding, boilers, pressure vessels, bridges and buildings etc. In recent years there has been a progressive move from riveted joints to welded, bonded and even bolted joints. 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. There are strict standards and codes for riveted joints used for structural/pressure vessels engineering but the standards are less rigorous for using riveted joints in general mechanical engineering. Mechanical joints are broadly classified into two categories viz., non-permanent joints and permanent joints. Non-permanent joints can be assembled and disassembled without damaging the components. EG of such joints are threaded fasteners (like screw-joints), keys and couplings etc.

Permanent joints cannot be disassembled 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.

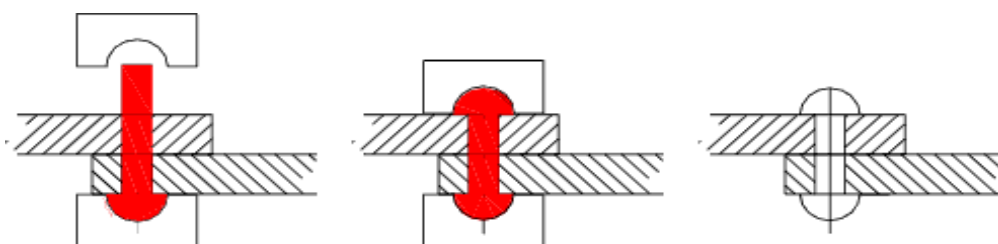


Fig. 1: Rivets.

2. 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). Rivet heads used for boiler works are specified by IS: 1928-1978.

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.



Fig. 1.1 & 1.2: Rivet Terminology and Riveting Operation.

3. Manufacturing of Rivet

Solid rivets which is of commonly used in mechanical system are generally manufactured in large numbers starting with a wire, rod or bar of material of substantially the same diameter as the desired shank of the finished rivet. In fabrication, the rod is cut off; the end of the rod is inserted into the die defining the rivet, and then typically given an initial upset followed by a final blow to form the head and tapered region between the head and shank of the rivet.

1. Selecting of rod of same diameter as of rivet
2. Cutting of rod
3. Cold heading of rivet into dies

3.1 Terminology of Riveted Joint

3.1.1 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.

3.1.2 Pitch (p): - The distance between the centers of the adjacent rivets measured on gauge line

3.1.3 Transverse Pitch (pt): - Distance between the rivet centers in two adjacent gauge lines is called traverse pitch or back pitch.

3.1.4 Diagonal Pitch (Pd): - It is the distance between the adjacent rivet centers on adjacent gauge line in zigzag or chain riveting.

3.1.5 Margin (m): - It is the distance between the outermost gauge line and the edge of the plate.

4. Rivet Material

Rivets are manufactured for the materials conforming to IS:1148-1982 and IS:1149-1982 for structural work and to IS: 1990-1973 for pressure vessels. Rivets are usually made from the tough and ductile material namely low carbon steel (C15), nickel alloy steel, and wrought iron. Rivets are also made from non - ferrous material such as copper, aluminum alloys and brass for anti corrosive properties where strength is not major requirement. According to BIS, the rivet material should have tensile strength more than 350 N/mm^2 and elongations not more than 20%.

4.1 Design Stresses

The rivet joints are analyzed on the basis of following assumptions

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

4.1.2 There are no bending or direct stresses in rivets.

4.1.3 Rivet holes in plate do not weaken the plate in compression

4.1.4 Rivets after assembly completely fills the hole

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

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

4.2 Theories of Failures

According to the theory the failure of rivet may fail due to any one of the following modes.

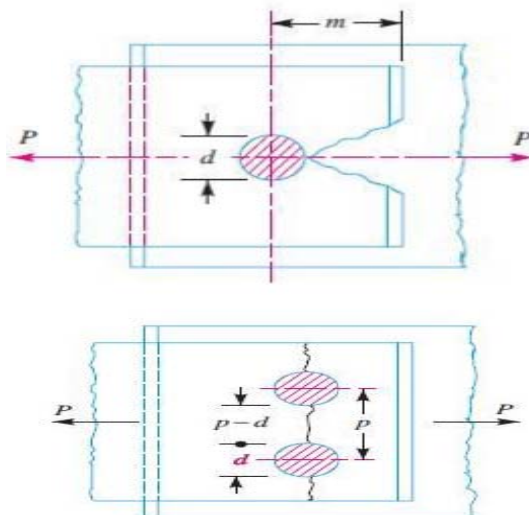


Fig 2: a & b

4.2.1 Tearing of the Plate at an Edge(Fig 2 a). 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 hole or diameter of the shank of rivet.

4.2.2 Tearing of the Plate Across a Row of Rivet(Fig 2 b).

Tearing resistance required to tear off the plate per pitch length, $P_t = A_t \cdot \sigma_t = (p-d) t \cdot \sigma_t$

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.

4.2.3 Shearing of Rivet

Thus shear strength is,

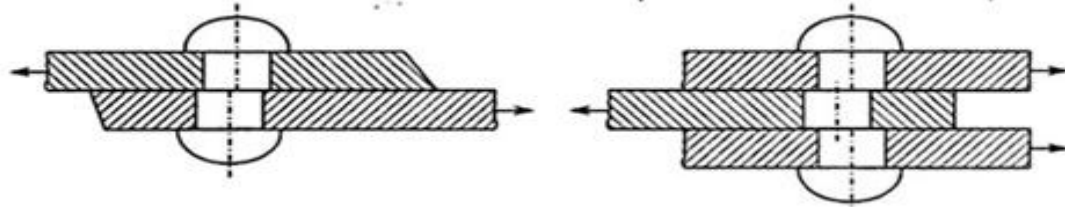


Fig. 3

$P_s = n \pi / 4 d^2 T_{max}$ for single shear,

$P_s = 2 \times n \pi / 4 d^2 T_{max}$ - theoretically 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.

4.2.4 Crushing of the Plate (or) Rivets Fig. 4

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

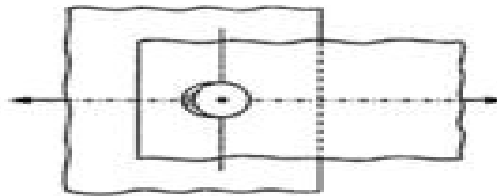


Fig. 4: Crushing of Plate.

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.

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.

Building the model

In this project model is designed with the help of CATIA V.16.0 and also given the material property in this software by providing the proper constraining. This model developed with three stages first upon developing all the object as a part file single pieces with separate file and then assemble with constrained in assembly i.e. product environment. Then converted this model into **.stp** format to importing the ANSYS (workbench).

Apply loads and obtain the solution

a) Applying loads Boundary conditions and Different loads acting on the model are applied either in the preprocessor as well as contact surface between the object also given. The loads in the ANSYS program are DOF Constraints Forces Surface loads Body 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=>Insert option

(d) Initiating the solution The solution to the given problem is initiated by using the following path.

Main nu=>Solution=>Solve

(e) Initiating the results After the solution any type of result can be seen by following path.

Main Menu=>Solution=>Insert Results.

5. Analysis of Rivet

The material properties which are used for analysis of rivet

Table1: Properties of the Material and the Adhesive.

Properties of Adherents and Adhesive Used			
Material	Young's Modulus (N/mm²)	Poisson's Ratio	Shear Modulus (GPa)
Steel	2.0 x 10 ⁵	0.38	78.1
Adhesive	2.5 x 10 ³	0.30	0.905

6. Results and Discussions

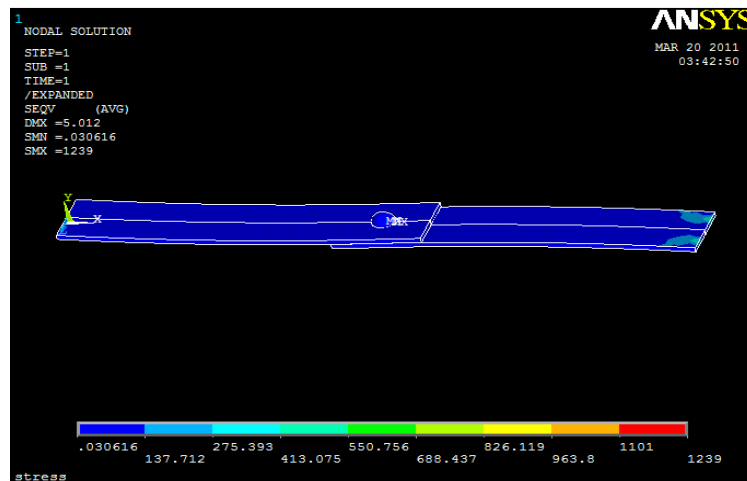


Fig. 5: The stress distribution of a single lap riveted joint without adhesive.

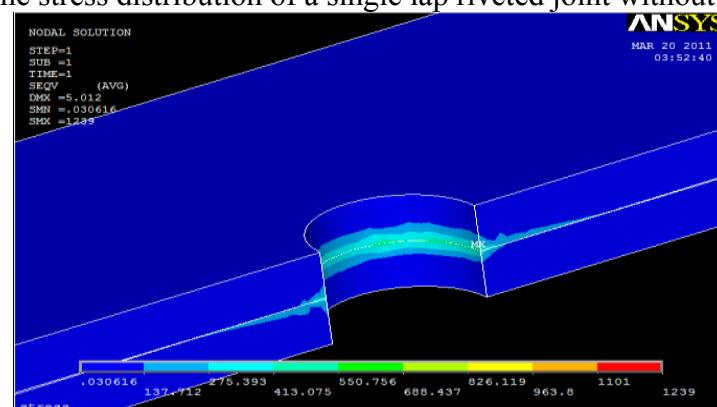


Fig. 6: The stress distribution of a single lap riveted joint without adhesive and shows at the contact of plates and rivet.

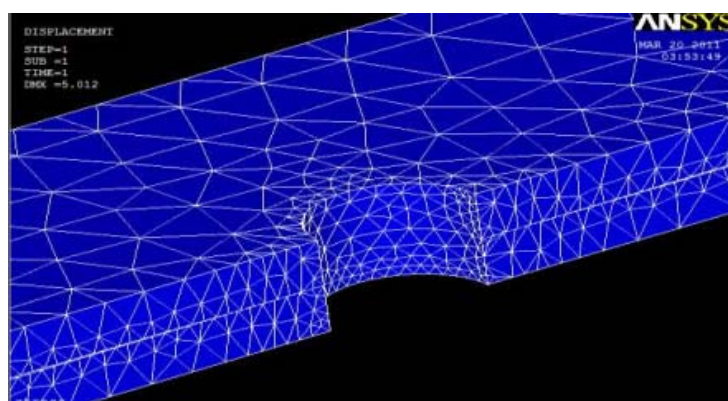


Fig. 7: The stress distribution of a single lap riveted joint without adhesive and shows at the contact of plates and rivet with meshing elements.

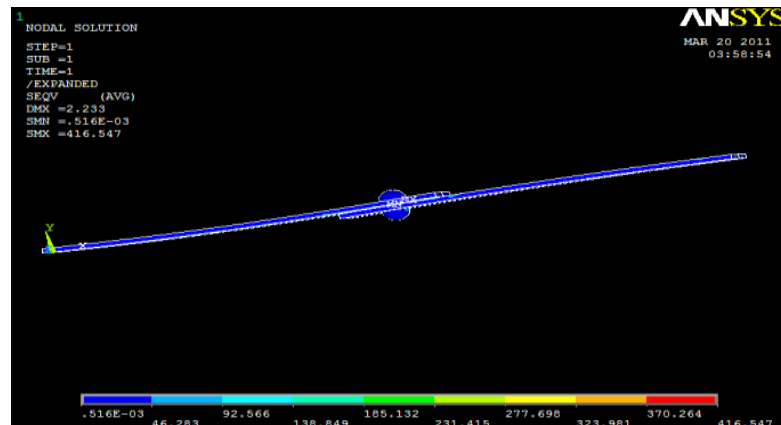


Fig. 8: The stress distribution of a single lap riveted joint with adhesive b/w the plates only.

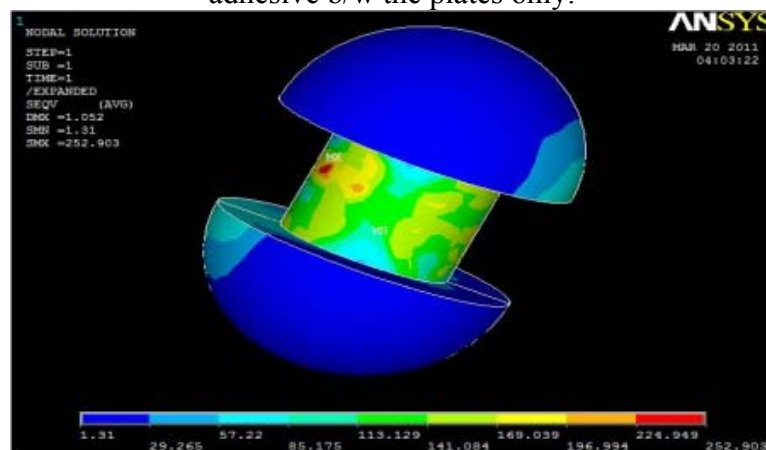


Fig. 9(a): The stress distribution at rivet of a single lap riveted joint with adhesive b/w the plates only.

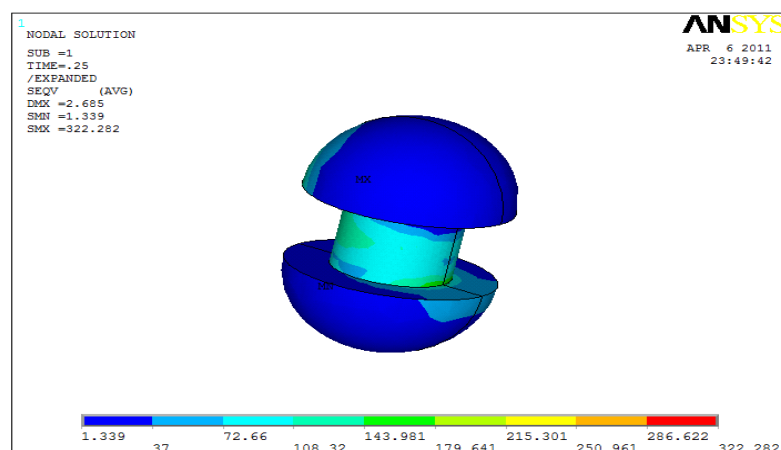


Fig. 9(b): The stress distribution at rivet of a single lap riveted joint with adhesive b/w the plates and rivet also.

7. Conclusions

The results obtained from ANSYS for the Single lap riveted joint using with and without Adhesive Bonding are compared with each other at different conditions of using adhesives at described locations leads to decreasing in the different stresses, uniform application of the Force on the sepecimen gives more effective and efficient durability of 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.

8. Scope for the Future Work

There is a huge scope for the future work, on the present topic of stress Analysis of single riveted joint for the leak proof applications by using adhesives.

- 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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