Influence of Rivet Association on Strength of Riveted Joint

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Abstract—the technology development in steel constitution has comprehensive in every discipline corresponding to theory, material, and process. The metal structure is constructed from the junction of exclusive metal member field by means of rivets, high-tensile bolt, welding, and so forth. The paper deals with stress analysis of riveted lap joint subjected to eccentric load intensity. It is trial to prepare the rivet in such manner that riveted joint withstand for highest loading situation by way of altering the association of rivets for the equal no of rivets. For that made some specimen of lap joint of moderate steel plate dimension of 150 × 80 × 5 mm thick joint with 4 rivets in distinct method of arrangement and proven on numerical basis situation to find out maximum load bearing capacity of riveted joint.

Keywords— Eccentric Load, Load Bearing Capacity, Metal Structure, Rivets, Stress Calculation.

I. INTRODUCTION

In engineering observe it is usually required that two sheets or plates are joined collectively and elevate the weight in such ways that the joint is loaded. Normally such joints are required to be leak proof so that gas contained inside of just isn’t allowed to escape. A riveted joint is with ease conceived between two plates overlapping at edges, making holes by means of thickness of each, passing the stem of rivet by means of holes and creating the top at the end of the stem on the other facet. A quantity of rivets may pass through the row of holes, which are uniformly distributed along the perimeters of the plate. With this kind of joint having been created between two plates, they can’t be pulled aside. If force at each and every of the free edges is applied for pulling the plate apart the tensile stress within the plate alongside the row of rivet gap and shearing stress in rivets will create resisting drive. Such joints had been utilized in buildings, boilers and ships. \cite{1}

A rivet is a permanent mechanical fastener. Earlier than being hooked up, a rivet includes a gentle cylindrical shaft with a head on one end. The top reverse the top is referred to as the tail. On set up the rivet is positioned in a punched or drilled hole, and the tail is upset, or bucked (i.e. deformed), in order that it expands to about 1.5 times the original shaft diameter, conserving the rivet in place.

In different phrases, pounding creates a brand new head on the opposite end through smashing the tail fabric flatter, leading to a rivet that's roughly a dumbbell shape. To distinguish between the two ends of the rivet, the usual head is called the factory head and the deformed end is called the store head or bucktail. A variety of solid rivet is shown in figure 1. \cite{2}

\begin{figure}[h]
  \centering
  \includegraphics[width=0.5\textwidth]{SimpleButtonHeadSolidRivet.png}
  \caption{Simple Button Head Solid Rivet}
\end{figure}

\textbf{A. Nomenclature of Riveted Joint}

Several dimensions become obviously important in a riveted joint and a design will consist in calculating many of them. These dimensions and their notations as to be used in this text are described below.

\textit{Pitch (P):} As seen from Figure 2 pitch, denoted by P, is the center distance between two adjacent rivet holes in a row.

\textit{Back Pitch (Pb):} The center distance between two adjacent rows of rivets is defined as back pitch. It is denoted by Pb and is shown in Figure 2.

\textit{Diagonal Pitch (Pd):} The smallest distance between centers of two rivet holes in adjacent rows of a zigzag riveted joint is called diagonal pitch. Denoted by Pd, the diagonal pitch is shown in Figure 2.

\textit{Margin (m):} It is the distance between centre of a rivet hole and nearest edge of the plate. It is denoted by m as shown in Figure 2.
Figure 2 Nomenclature of Riveted Joint

A) Design considerations for riveted joint

1. A joint may just fail as a result of tearing of the plate at a facet. This can be refrained from via maintaining the margin, \( m = 1.5d \), where \( d \) is the diameter of the rivet hole.

2. Considering that the compressive and bending load for the failure. Traditionally while designing beforehand handiest tensile and compressive load is also viewed handiest.

3. Due to the stresses in the major plates, the most important plate or cover plates may just tear off across a row of rivets. In such instances, it's regarded only one pitch size of the plate, on account that every rivet is responsible for that a lot size of the plate simplest.

4. The influence of bending moment and shear force on the riveted joint is regarded for stress calculation when designing the rivet joint.

II. LITERATURE SURVEY

Takao Yokota, Takeaki Taguchi, Mitsuo Gena formulated an top of the line riveted joints design quandary of a by means of gusset plate on a body constitution for a restricted allowable stress as an inflexible structural calculation quandary and clear up it straight with the aid of retaining the constraints based on an multiplied genetic algorithm (GA). They talk about the effectivity between the proposed procedure and the natural approach. [1]

K. S. Bodadkar, Prof. S. D. Khambarkar discovered that Riveted joints are used in many structural works like ship buildings, in bridge structure and in manufacturing of boiler shells etc. The disasters of riveted joint takes place through tearing of the plate, shearing of rivet and crushing of rivet and plate underneath the action of overloading.

Therefore the stress pattern in riveted butt joint by various parameters like thickness of plate, linear pitch, transverse pitch and procedure of riveting is studied. In this research, analytical, numerical and experimental stress analyses are applied. [2]

Jacek Mucha and Waldemar Witkowski presents the branches of enterprise which generate new product options very fast are construction, aerospace and automobile industry. Metal factors are increasingly substituted with the aid of fiber-bolstered plastic components or by means of light metallic alloys part such as aluminum or magnesium alloys. New material generates the necessity of developing the brand new joining applied sciences or modifying commonplace technologies. The use of new fabric in the construction techniques resulted in the use of the alternative becoming a member of technologies at the rate of the normal applied sciences. Because of this the experimental studies involving the formation and force of new joining techniques are required. The brand new becoming a member of options now not consistently can make sure an enough strength of a joint. In some circumstances the joint formation for the new substances is very complicated. As a consequence, the riveted joint applied sciences with blind rivets or with blind rivets for closing up are still used and will undoubtedly proceed to be used sooner or later. [3]

Suyogkumar W. Balbudhe, S. R. Zaveri deals with the stress evaluation of riveted lap joints. The reward work includes the appropriate configuration and characterization of these joints for highest utilization. With the aid of using finite detail procedure, stress and fracture analyses are carried out under both the residual stress discipline and outside tensile loading. Utilizing a two-step simulation, riveting system and subsequent tensile loading of the lap joint are simulated to verify the residual and total stress state. [4]

Arumulla Suresh, Tippa Bhimasankara Rao concludes that Finite detail process is located to be most robust instrument for designing mechanical add-ons like single lap riveted joints. ANSYS can be used for evaluation of complicated and simple units of one of a kind kind without any influence on practical and fiscal issues. [5]

III. DESIGN METHODOLOGY

There are five types of failure occurs in riveted joint. The failure due to tearing of plate at an edge and across row of rivets are of plates. The third failure of riveted joint takes place through tearing of the plate, shearing of rivet and crushing of rivet and plate underneath the action of overloading. The theory of failure have been discussed below.
A] Tearing of plate at an edge

A joint may fail due to tearing of the plate at an edge as shown in Figure 3. This can be avoided by keeping the margin, \( m = 1.5d \), where \( d \) is the diameter of the rivet hole.

![Figure 3 Tearing of Plate at an Edge](image)

\[ \text{Figure 3 Tearing of Plate at an Edge} \]

B] Tearing of the plate across a row of rivets

Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets as shown in Figure 4. In such cases, it is consider only one pitch length of the plate, since every rivet is responsible for that much length of the plate only. The resistance offered by the plate against tearing is known as tearing resistance or tearing strength or tearing value of the plate.

![Figure 4 Tearing of the Plate across a Row of Rivets](image)

\[ \text{Figure 4 Tearing of the Plate across a Row of Rivets} \]

\( \begin{align*}
\text{Let,} \\
p &= \text{Pitch of the rivets}, \\
d &= \text{Diameter of the rivet hole}, \\
t &= \text{Thickness of the plate}, \text{ and} \\
\sigma_t &= \text{Permissible tensile stress for the plate material} \\
l &= \text{length across row of rivets} \\
A_t &= (l-n d) t
\end{align*} \]

\[ \therefore \text{Tearing resistance or pull required to tear off the plate}, \\
Pt = A_t \cdot \sigma_t = (l-n d) t \cdot \sigma_t \]  
(Equation 1)

C] Shearing of the rivets

The plates which are connected by the rivets exert tensile stress on the rivets, and if the rivets are unable to resist the stress, they are sheared off as shown in Figure 5.

![Figure 5 Shearing of Rivets](image)

\[ \text{Figure 5 Shearing of Rivets} \]

\( \begin{align*}
\text{Let } d &= \text{Diameter of the rivet hole}, \\
\tau &= \text{Safe permissible shear stress for the rivet material, and} \\
n &= \text{Number of rivets per pitch length}. \\
\text{We know that shearing area}, \\
As &= \pi/4 \times d^2 \\
\therefore \text{Shearing resistance or pull required to shear off the rivet per pitch length}, \\
Ps &= n \times \pi/4 \times d^2 \times \tau \\
\]  
(Equation 2)

D] Crushing of the plate or rivets

Sometimes, the rivets do not actually shear off under the tensile stress, but are crushed as shown in Figure 6. Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The failure of rivets in such a manner is also known as bearing failure. The area which resists this action is the projected area of the hole or rivet on diametral plane.

![Figure 6 Crushing of the plate or rivets](image)

\[ \text{Figure 6 Crushing of the plate or rivets} \]

\( \begin{align*}
\text{Let,} \\
d &= \text{Diameter of the rivet hole}, \\
p &= \text{Pitch of the rivets}, \\
\sigma_p &= \text{Permissible press stress for the rivet material} \\
\]
t = Thickness of the plate, 
\( \sigma_c \) = Safe permissible crushing stress for the rivet or plate material, and 
n = Number of rivets per pitch length under crushing. 

We know that crushing area per rivet (i.e. projected area per rivet), 
\( A_c = d.t \) 
∴ Total crushing area = n.d.t 

And crushing resistance or pull required to crush the rivet per pitch length, 
\( P_c = n.d.t.\sigma_c \) ............... (Equation 3) 

### Eccentrically Loaded Riveted Joint 

Usually rivets are connected by using utilizing gusset plate connection process. The connection is viable when you consider that its close the inflexible joint. The rivet of this juncture is transmits the stress of the one plate to yet another plate. The moment BM and shearing Force \( P_s (=Q) \) influence this rivet group. It is count on that the shearing force is uniformly disbursed in the whole rivet crew. The stress per 1 rivet can also be proven by using the next. 

\[ R_Q = \frac{Q}{n} \] (n is number of rivets)................. (Equation 4) 

The stress in each rivet are proportional to the distance from the center of gravity of the rivet group and, the rivet and the line which connects G are affected from the right-angled as the moment affected the rivet group. The maximum stress occurs in the rivet which is the farthest from G, and it is shown in the following. 

\[ R_M = \frac{M}{Z_R} \] ...................................... (Equation 5) 

Where, 
\[ Z_R = \frac{\sum x_i^2 \Sigma y_i^2 + \Sigma x_i y_i^2}{r_{max}} \] .................................. (Equation 6) 

\( x_i, y_i \) : the coordinate of each rivet \( ri \) in making the origin to be G. 
\( r_{max} \) : the distance from G to the farthest rivet. 
\( Z_R \) : the section modulus of the rivet group. 

Therefore, resultant stress \( R \) between \( R_Q \) and \( R_M \) is calculated, because the moment BM and shearing force \( P_s \) affect the rivet, and \( R \) may not exceed the permissible proof stress of the rivet. Thus, we obtain \( R \) in the following. 

\[ R = \sqrt{\left( (R_Q + R_M \cdot \frac{xi}{r_{max}})^2 + (R_Q + R_M \cdot \frac{yi}{r_{max}})^2 \right)} \] ..(Equation 7) 
\[ R = \sqrt{\left( R_Q^2+R_M^2+R^2+R^2 \right)} \] ........................................ (Equation 8) 
\[ \tau_{max}=R/A \] ..................................................... (Equation 9) 

figure 7 Eccentrically Loaded Rivets with Rectangular Arrangement 

The design have made based on eccentric load of 5000 N with rectangular plate of size 150×80×5 mm and having four number of rivets of rivet diameter 4 mm. the overlapping area is 80×80 mm. The optimum design is selected out of five different models. Each model has different position of rivets like rectangular, diamond, horizontal, vertical and diagonal. The models have checked for tearing, shearing, crushing and resultant shear stress based on the theories present in this paper. The permissible stresses for rivet and plates are Permissible Tensile Stress = 120 MPa, Permissible Shear Stress = 100 MPa, Permissible Crushing Stress = 160 MPa. The results are tabulated in Table I.
### Table I

<table>
<thead>
<tr>
<th>Rivet Arrangement</th>
<th>Tear Force (N)</th>
<th>Shear Force (N)</th>
<th>Crushing Force (N)</th>
<th>Resulting Force (N)</th>
<th>Max. Shear stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Arrangement</td>
<td>43200</td>
<td>5027</td>
<td>12800</td>
<td>3481.0</td>
<td>277.15</td>
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<tr>
<td>Diamond Arrangement</td>
<td>43200</td>
<td>5027</td>
<td>12800</td>
<td>3930.2</td>
<td>312.92</td>
</tr>
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<td>Horizontal Arrangement</td>
<td>43200</td>
<td>5027</td>
<td>12800</td>
<td>4999.5</td>
<td>398.05</td>
</tr>
<tr>
<td>Vertical Arrangement</td>
<td>43200</td>
<td>5027</td>
<td>12800</td>
<td>4999.5</td>
<td>398.05</td>
</tr>
<tr>
<td>Diagonal Arrangement</td>
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<td>5027</td>
<td>12800</td>
<td>5223.9</td>
<td>415.92</td>
</tr>
</tbody>
</table>

### IV. RESULT AND CONCLUSION

The present study includes the various failure criteria for riveted joint. It is concluded that the arrangement of rivets does not change the strength of rivets when considering tearing of plates, shearing of rivets and crushing of rivets. But when the eccentric load is in action, the combined effect of shearing and bending acts on the rivets. Thus, it is required to design the rivets under resultant force due to shear force and bending moment. The maximum shear stress is calculated by resultant force per area of rivets.

Figure 8 shows the graph of resultant force vs rivet arrangement. It is concluded that the resultant force for rectangular arrangement is less as compare to other arrangement so the rectangular arrangement is more optimum for the eccentric loading. Thus, stress due to resultant force in case of rectangular arrangement is optimum in compare with other sets. The plot between maximum shear stress vs rivet arrangement is shown in figure 9.

### REFERENCES


