A Theoretical and Experimental Analysis of Fillet Weld

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Abstract

Welding is defined by the American Welding Society (AWS) as a localized coalescence of metals or non-metals produced by either heating of the materials to a suitable temperature with or without the application of pressure, or by the application of pressure alone, with or without the use of filler metal. Welding techniques are one of the most important and most often used methods for joining pieces in industry. Any information about the shape, size and residual stress of a welded piece is of particular interest to improve quality. In the recent years, the welded joints become the integral part of assemblies used in the industries. In fact in piping industries welded joints are crucial and prone to different types of loadings. Hence in such applications most of the failures are due to the failing of the welded joints. Hence a modern computational approach based on finite element analysis for strength assessment has been used in this dissertation work.

Keywords: Finite Element Analysis, Fillet Welded, Microstrain, Rectangular Strain Rosette

I. INTRODUCTION

Welding is defined by the American Welding Society (AWS) as a localized union of metals or non-metals produced by either heating of the materials to a suitable temperature with or without the application of pressure, or by the application of pressure alone, with or without the use of filler metal. Welding techniques are one of the most important and most often used methods for joining pieces in industry. Welded joints are used in almost every industries depend on various applications and where the permanent joint with high strength is necessary. Some of the applications are where welded joints used are the structural supports, automotive joints, piping industries, pressure vessels etc. The latest trends in the industries are focusing on the high strength, high rigidity welded joints for different metals with the advancement in the welding technology. Any information about the shape, size and residual stress of a welded piece is of particular interest to improve quality now a days.. The various incremental segments of the weld serve as a multiplicity of redundant attachments, each carrying a portion of the load dependent on its stiffness. The well-known procedures of welded joint analysis are based on simplifying assumptions commonly used to obtain results sufficiently accurate for engineering use in most applications. Hence it is necessary to carry out accurate stress analysis of welded joints to overcome the errors occurred in the strength estimation using conventional methods. Therefore in this dissertation work the structural analysis of fillet type welded joint used in structural supports for pipes in offshore industries has been carried out using finite element method (FEM). From the review of the literature on welded joints it is seen that there is some scope for research work in the area of structural analysis of welded joints. As such, it is proposed to carry out some theoretical and experimental studies on structural analysis of fillet type welded joint used in structural supports for pipes in offshore industries using finite element method (FEM). For this purpose following work will be carried out.

A. Objectives of Project

- To identify important design parameter affecting the weld performance in case of fillet weld.
- To design the fillet weld by considering important design parameters.
- To carry out Numerical Analysis of designed fillet weld.
- To carry out Experimental analysis of fillet weld.
- To validate Numerical result with Experimental result

II. THEORETICAL ANALYSIS

A cantilever beam of rectangular cross-section is welded to a support by means of two welds W1 and W2 as shown in fig. According to the principle of Applied Mechanics, the eccentric force P can be replaced by an equal and similarly directed force P acting through the plane of welds.
III. STRESS ANALYSIS BY USING FINITE ELEMENT METHOD

1) Pre-Processing-This is the vital step in the FEM analysis. It includes the CAD modeling, Meshing (Discretization of the total model into finite number of elements) and applying the boundary conditions. This also involves the element selection, assigning material properties and real constants.

2) Solution-It involves the actual solving of the differential equations for each element and finding out the unknowns. This job is done by the software itself in the computer. However, the user has to select the method of the solution based on the type of the problem.

3) Post-Processing-This step includes the viewing of the results, interpretation of results and verification of the data obtained and conclusions.

The results of analysis is tabulated and compared in the table below.

<table>
<thead>
<tr>
<th>Welded Joint Specimen</th>
<th>Shear Stress</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>Theoretical</td>
<td>FEA</td>
</tr>
<tr>
<td>N</td>
<td>N/mm²</td>
<td></td>
</tr>
<tr>
<td>343.35</td>
<td>14.45</td>
<td>16.21</td>
</tr>
<tr>
<td>686.7</td>
<td>30.64</td>
<td>33.41</td>
</tr>
<tr>
<td>1030.05</td>
<td>49.97</td>
<td>59.04</td>
</tr>
<tr>
<td>1373.4</td>
<td>69.64</td>
<td>75.87</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL STRESS ANALYSIS

The method for the experimental stress analysis of the welded joint based on the electric resistance strain gauge technique has been presented. This involves the selection of strain gauge or rosette, bonding material, strain gauge circuits, and use of dummy gauge and the experimental methodology. The experimental setup was developed to carry out the stress analysis. Strain Rosette-When a state of strain at a point and the direction of the principal stress or strain is known, then the single strain gauge can be oriented along this direction and strain measurement is carried out. However when the state of strain is not known, then three or more strain gauges may be used at the point under consideration to determine the strain at that point. The resulting configuration is termed as strain rosette. Figure shows the typical three gauges rectangular strain rosette having orientation 0-45-90 degrees with each other. It means that gauge 1 is horizontal and other two gauges at 45 degree and 90 degree with gauge 1 respectively. In this way strain in three different directions is measured.

The welded joint is held between the upper base plate and power screw cup. There was a thrust bearing provided between the power screw and cup to provide free rotational movement of the cup while screw is gradually moving up and down. Below the upper base plate the load cell was mounted in order to measure the load coming on the welded joint in Newton. The lower base plate is rested and fastened to platform. In order to guide the power screw movement two vertical beams were provided and one horizontal beam which guide the power screw arrangement and resting on these vertical beams. The setup is easy to disassemble.
The load was gradually applied on the spring and the output voltage difference of the quarter bridge Wheatstone circuit was measured on multi-meter in terms of microvolts. Readings have been taken for different loads and necessary calculations were done in Microsoft Excel to get the required strain readings. To avoid strain hardening effect the strain measurements were done at loading as well as unloading. Table shows the values of strain in microstrain for different loads.

Table - 2

<table>
<thead>
<tr>
<th>Load</th>
<th>Epsilon A (Microstrain)</th>
<th>Epsilon B (Microstrain)</th>
<th>Epsilon C (Microstrain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>343.35</td>
<td>0.00040</td>
<td>0.00030</td>
<td></td>
</tr>
<tr>
<td>686.7</td>
<td>0.00080</td>
<td>0.00070</td>
<td></td>
</tr>
<tr>
<td>1030.05</td>
<td>0.00135</td>
<td>0.00110</td>
<td></td>
</tr>
<tr>
<td>1373.4</td>
<td>0.001796</td>
<td>0.00130</td>
<td></td>
</tr>
</tbody>
</table>

By using above readings calculate maximum principle stress induced in to the specimen. The readings are tabulated in the following table.

Table - 3

<table>
<thead>
<tr>
<th>Max. Principal Stress(N/mm²)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>FEM</td>
</tr>
<tr>
<td>98.0203376</td>
<td>96.56</td>
</tr>
<tr>
<td>184.3102039</td>
<td>190.129</td>
</tr>
<tr>
<td>288.7581561</td>
<td>290.636</td>
</tr>
<tr>
<td>381.6360961</td>
<td>385.257</td>
</tr>
</tbody>
</table>

By using above reading plot the graph showing comparison between FEA and experimental values of principle stress.

V. CONCLUSION

The welded joints have the effect of residual stress on its strength. So there may be the variations in the theoretical stress values and the experimental stress values. Strain gauge rosette technique can be used for the stress analysis of welded joints and gives results in good agreement.

The peak stress value of welded joints obtained by finite element analysis is in good agreement with that obtained using experimental stress analysis. This suggests that FEM can be used at the design stage of the welded joints.

As the load increases the stress and deflection values increases. This follows the good linear relationship. But the stress distribution pattern for the welded joints was similar in all loading cases.

REFERENCES