Analysis of Fillet Welded Joint for Supporting Structure in Pipe Industries

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Abstract- *In the recent years, the welded joints becomes 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. Linear finite element analysis has been carried out to determine the peak stresses which is followed by the modal analysis to decide the mode of vibration. The results of FEM analysis have been validated experimentally using strain gauge technique.*

Keywords- Experimental analysis, FEA analysis, Model analysis, Fillet welded joints, pipe supports in offshore industries.

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 depends on various applications and where the permanent joints 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.

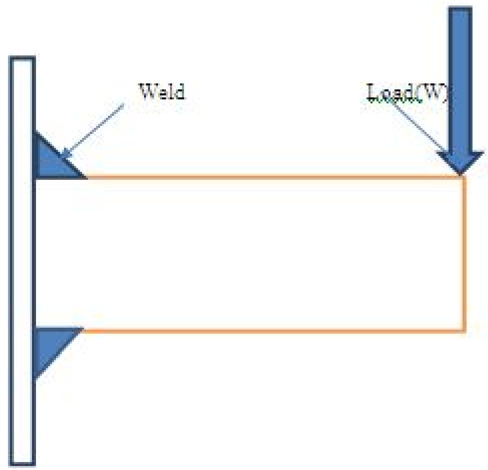
Welded joints used in the industries are subjected to various types of loading such as axial, bending or torsional. Sometimes these loads are dynamic in nature. Most of the time these loads act together. Hence the rigorous analysis of welded joint is very complicated in such cases involving a detailed study of both the rigidity of the parts being joined and the geometry of the weld. 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. 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

II. WELDED JOINTS SUBJECTED TO BENDING MOMENT

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, along with a couple as shown in figure.



Since there are two such symmetrical welds,

⟦I=⟧_2^(bd^2)

III. MODEL ANALYSIS OF WELDED JOINT

Modal analysis is used to determine the natural frequencies and the mode shapes of the components/systems. The natural frequencies and the mode shapes are important parameters in the design of a structure for dynamic loading conditions and is a starting for more detailed analysis such as harmonic response analysis, transient analysis etc.

The modal analysis of a welded joint was carried out to find its fundamental frequency. Modal analysis is carried out at free-free condition. To perform modal analysis the same ANSYS software was used with some modifications in the material properties. In this case, it is necessary to define only young's modulus of elasticity and the density of the material. The density of the material steel material and weld fill material has been assigned to the model. The mapped meshing is considered for modal analysis in order to reduce the number of elements. SOLID1855 is the element used for mapped meshing. The mode extraction can be done by different methods in ANSYS 13.0 software such as Block Lanczos, Subspace, and Power Dynamics etc. The Block Lanczos method is the default method and recommended for most of the applications. This method can extract more than forty mode shapes. It is typically used in complex models as it handles the different types of elements at a time and also the rigid body models. The modes are normalized to mass matrix option in ANSYS 13.0 by default which allows using the modes in further mode superposition analysis such as transient analysis or spectrum analysis. Such normalized modes can be used in FEM based fatigue analysis also.

Natural Frequencies of Welded Joint Using FEM

Mode Number (n)	Natural Frequency (Hz)
1	426.19
2	1550.0
3	1823.3
4	2415.5
5	3611.7

In the free-free condition modal analysis first five natural frequencies are observed significantly in FEM analysis. Hence, the first natural frequency is considered as the fundamental frequency. It is 426.19 Hz by FEM which is quite higher.

IV. SOFTWARE BASED FINITE ELEMENT METHOD

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.

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.

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

V. STRESS ANALYSIS BY USING ANSYS SOFTWARE

CAD MODEL OF SUPPORT JOINT

Material Properties of Structural Steel	Value (SI Units)
Modulus of Elasticity	2.07E5
Poisson's Ratio	0.34
Density	7.139E-9
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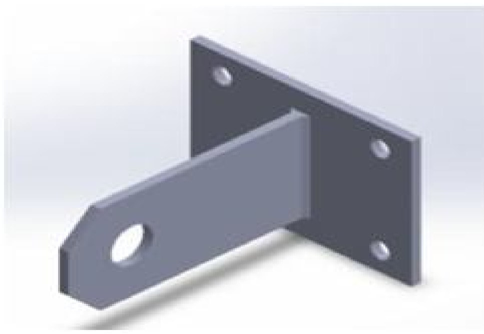
Shear stress comparison (N/mm2)

Load (N)	Theoretical	FEA
343.35	15	17.2
686.7	32.64	36.4
1030	50.97	60
1373.7	70.64	78.8



CAD Model

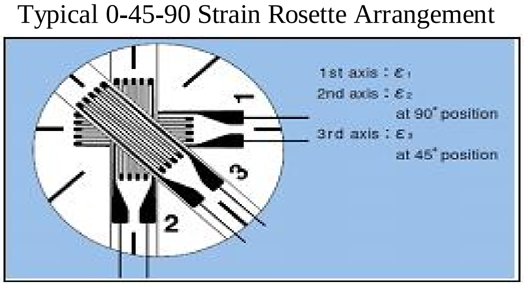
VI. EXPERIMENTAL STRESS ANALYSIS

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.

Typical 0-45-90 Strain Rosette Arrangement



Steps Used for Strain Gauge Mounting

Initially surface of the helical spring where strain gauge was decided to mount made ready for pasting. It includes removal of grease or dirt by any mechanical agent. Then complete removal of mechanical rust, corrosion if any. This is followed by leveling the surface by filing and sanding; cleaning with acetone and iso- propanol and marking the position of strain gauge.

Then Pasting of the strain gauge at the marked position using selected bonding material cyanoacrylate was done as per the instructions provided in manufacturer's catalogue. Some stable pressure was kept on the installation area for some time. Use of Teflon foil was done to prevent thumb impressions on strain gauge. The strain gauge was kept as it is for some time to cure the bonding material. Afterwards the gauge was inspected visually for inclusions of the air, or dust particles, poor soldering quality. It was seen that the strain gauge was fixed properly.

Finally the nitride rubber as a protective coating is applied directly by brush in order to prevent mechanical damage and to get stability. Again strain gauge was kept as it is for some time to cure the protective coating.

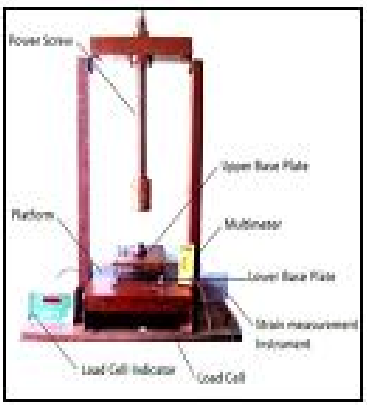
This technique is used in the strain gauge measurement. Depending upon the configuration and accuracy required, either one gauge called a quarter bridge, two gauges called a half bridge or four gauges called a full bridge configurations are used. In a quarter bridge, one of the resistors is replaces with a strain gauge; whereas the other three arms are employed with high precision resistors with nominal value same as that of gauge. If a half bridge is used, the two resistors are replaced by the two strain gauges and are positioned in the bridge such that the greatest unbalance of the bridge is achieved when the gauges are exposed to the strain of the component. Remaining two arms receive precision resistors. If full bridge is used , all four resistors are replaced by active strain gauges. With the strain gauge installed in the bridge arms, the bridge output is easily determined. For quarter bridge configuration, the strain gauge replacing one of the bridge resistors (either). This bridge is referred as quarter bridge arrangement. For a balanced bridge if, and is the strain gauge resistance, after the load applied on the test specimen, the will change which result in unbalancing the bridge. This unbalanced differential voltage is measured in terms of the strain produced in the component. This strain can be measured by the expression

System calibration is very important part of any measuring system. The strain gauge calibration can be done by shunt resistance of by series resistance calibration method. In shunt resistance calibration method, a high calibration resistor is placed across the one of the arm of the active gauge. With the calibration resistor in position, the bridge is unbalanced and known output is produced.

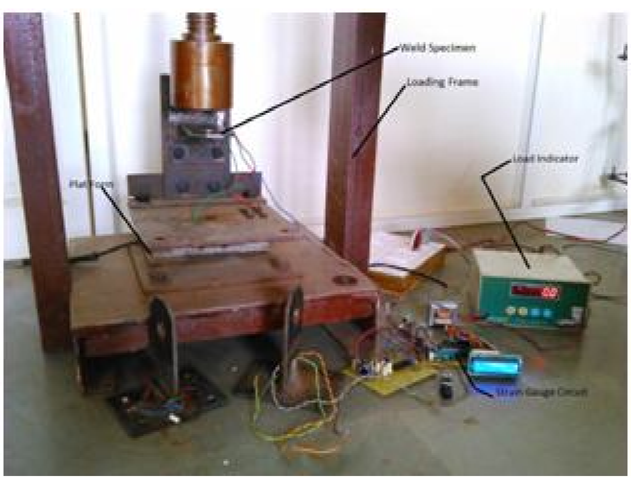
VII. EXPERIMENTAL SETUP AND STRAIN MEASUREMENT

In this experimentation, the directions of principal stresses were unknown but the location has been found by earlier FEM analysis results. The gauge location was then fixed. Therefore linear strain gauge rosette is found suitable and hence was selected for the purpose. Finally the gauge continuity and installation resistance were checked by the multi-meter. The quarter bridge configuration was used in Wheatstone bridge along with dummy gauge arrangement for temperature compensation.

The experimental setup was used as shown in Figure for applying the static load with the help of power screw arrangement.



Experimental Setup for Static Stress Analysis

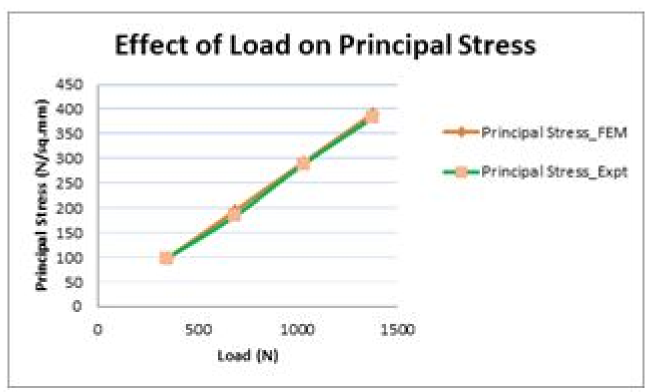


Welded Joint Specimen Mounted on Experimental Setup

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 ware 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 micro strain for different loads.

Strain Readings for Loading and Unloading

Max. Principal Stress N/m^2		Error
Experimental	FEM	%
98.02033376	97.56	0.4
184.3102039	195.129	5.54
288.7581561	292.636	1.32
381.6360961	390.257	2.20



VIII. CONCLUSION

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.

As for the given welded joints the fundamental natural frequency is very high, this structure can be used in the pipe supports where dynamic loads are coming. There are very less possibilities where resonance can occur.

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.

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