Residual stress

Health & Medicine, Stress

INFLUENCE OF RESIDUAL STRESSES ON FATIGUEFAILUREOF BUTT WELDED STAINLESS STEEL PIPE Areef A Department of Mechanical Engineering Chendhuran college of Engineering andtechnologyPudhukkottai, Tamilnaducom Abstract— This project is aimed to understand the influence of residual stresses on the fatigue failure of butt welded stainless steel pipe joints. In order to carry out this study it requires an experimental fatigue failure data and a computer aided analysis of these results. A finite element scheme will be developed to simulate the residualstressin weld using the experimental data.

A Thermo-elasto-plastic analysis will be used to replicate the butt welded pipe joint and the residual stress will be determined. Residual stress that arises in welded joints by heating and cooling cycles during the welding process is another major factor in fatigue failure of welded structures. Welding residual stresses might lead to a drastic reduction in the fatigue strength of welded elements. In multi cycle fatigue (N > 106 cycles), the effect of residual stresses can be comparable to the effect of stress concentration.

The effect of residual stresses on the fatigue life of welded elements are significant as regards relieving harmful tensile residual stresses and introducing beneficial compressive residual stresses in the weld toe zones. The fatigue failure can be classified in to two categories based on the number of cycles taken to fail. A. High cycle fatigue High-cycle fatigue is when the number of cycles to failure is large, typically when the number of cycles to failure, Nf is greater than 103. B. Low cycle fatigue Low- cycle fatigue is when the number of cycles to failure is small, typically when the number of cycles to failure, Nf is less than 103.

III. RESIDUAL STRESS ON WELD Residual stresses can be defined as the stresses that remain within a material or body after manufacture and material processing in the absence of external forces or thermal gradients. They can also be produced by service loading, leading to inhomogeneous plastic deformation in the part or specimen. Residual stresses can be defined as either macro or micro stresses and both may be present in a component at any one time. They can be classified as: Macro residual stress that develop in the body of a component on a scale larger than the grain size of the material.

Micro residual stresses that vary on the scale of an individual grain. I. INTRODUCTION Welding has a number of detrimental effects on the structural integrity and in-service performance of the weldments. These detrimental effects are due to imperfections induced by the welding in the weldments, of which the structural shape change behavior, residual stresses and the weld solidification cracks are reported to have very severe degrading effects on the mechanical strengths and possibly can lead to catastrophic failure.

Fatigue is a type of fracture that occurs in welds that are subjected to changing or varying stresses over time. Fatigue is mainly caused by theenvironmentin which the welded joints are utilized. Fatigue fracture is a ductile fracture, and therefore occurs by non-uniform plastic deformation. Micro cracks and voids form after a certain number of cycles and grow proportional to the number of cycles eventually grow large enough to overcome recovery mechanisms and move quickly to fracture. The rate of this crack nucleation is proportional to the frequency of the applied stress.

II. FACTORS IN FATIGUE FAILURES Fatigue failures of welded joint are initiated by many factors, such as stress concentration, environment, loading and residual stresses. Stress concentration is mainly caused by the geometrical discontinuity and thus initiates fatigue crack at the locations of discontinuity. Stress concentration may also result from weld defects and metallurgical discontinuity. Fatigue strength of weld component may also be significantly affected by the environment, such as oxygen, sulfur, and temperature.

In addition to the axial stresses in the piping systems reduction in fatigue life also takes place by multiaxiality of loading or stresses. Micro residual stresses that exist within a grain, essentially as a result of the presence of dislocations and other crystalline defects. IV. CAUSES OF RESIDUAL STRESS Residual stresses are generated during most manufacturing processes involving material deformation, heat treatment, machining or processing operations such as welding, machining, grinding, and rod or wire drawing etc.

It is possible to classify the origin of residual stresses in the following way: 1. 2. 3. Differential plastic flow Differential cooling rates Phase transformations with volume changes are one of the main factors leading to the origination and propagation of fatigue cracks in welded elements. The residual stresses in the welded joints are formed as the result of differential contractions which occur as the weld metal solidifies and cools to ambient temperature. In fact, welding introduces high heat input to the material being welded.

As a result of this, non-uniform heat distributions, plastic deformations and phase transformations occur on the material. These changes generate different residual stresses patterns for weld region and in the heat affected zone (HAZ). Residual stresses induced by shrinkage of the molten region are usually tensile. Transformation induced residual stresses will cause more critical phase transformations. When the effect of phase transformations is dominant compressive residual stresses are formed in the transformed areas.

Tensile residual stresses are detrimental to the initiation and growth of fatigue cracks. Weld fatigue failure is often particularly sensitive to residual stress due to stress concentrations induced by the weld joint geometry and weld imperfections. Welding residual stress acts as a booster to the fatigue problem. Hence, crack growth rate becomes considerably higher in the weld vicinity compared to that far from weld. The fatigue failure mechanism in the presence of weld residual stress is not well understood and it is the intent of this project to explore this mechanism.

However, to quantify the effects of welding residual stresses in the design stage, one has to numerically simulate its distribution and redistribution and possible relaxation in a structure due to cyclic loading. This requires the need for a robust, reliable and numerically efficient method for modeling residual stresses. Previous studies reveals that depending upon mean stress, stress amplitude, and stress ratio of uni axial cycle stressing and two kinds of failures ratcheting failure and fatigue failure. Figure 3.

Explains the variation of ratcheting strain with stress amplitude. In which we shall see that stress increases apparently with the increase in nominal stress amplitude. It implies that the effect of nominal stress amplitude on ratcheting is more significant than mean nominal stress. The variation of mean stress with ratcheting strain is explained in figure 4. In which we shall see that ratcheting strain also has an increasing trend with the mean nominal stress up to a particular limit. V. EXPERIMENTAL TECHNIQUES

Welding residual stresses are generated in a structure as a consequence of local plastic deformations introduced by local temperature history consisting of a rapid heating and subsequent cooling phase. During the welding process, the weld area is heated up sharply compare to the surrounding area and fused locally. The material expands as a result of being heated. The heat expansion is restrained by the surrounding cooler area, which gives rise to thermal stresses. The thermal stresses partly exceed the yield limit, which is lowered at elevated temperatures.

Consequently, the weld area is plastically hot-compressed. After cooling down too short, too narrow or too small comparing to the surrounding area, it develops tensile residual stress, while the surrounding areas are subjected to compressive residual stresses to maintain the self-equilibrium The distribution of residual stresses in a welded pipe is more complex, Fig. 1 shows the possible expansion and shrinkage in a butt welded pipe. In this case, shrinkage of the weld in the circumferential direction induces circumferential force, F, shearing force, Q, and bending moments, M, to the pipe.

Figure. 2 shows a characteristic residual stress profile on a low carbon steel welded component. Also the distribution of residual stresses in a pipe is affected by many factors such as diameter, wall thickness of the pipe, weld geometry, and welding procedure. From the graphical plot we shall see that the maximum value of the harmful residual stress is about 360 N/mm2 (tensile stress) near the welding line and it decreases to be about 165 N/mm2 at the distance of 80 mm from the welding axis.

The minimum residual stress is about 90 N/mm2 near the welding line and it becomes about 60 N/mm2 in compression at the instance of about 60 mm, then it reduces to about 10 N/mm2 in tension at 80 mm distance from the axis. Such high tensile residual stresses are the result of thermoplastic deformations during the welding process and A. Sample Used The material used for the study is stainless steel material of grade SS304. The material is chosen because of its following properties. It has an excellent corrosion resistance in a wide range of atmospheric environments and many corrosive media.

Considering its heat resistant property it is not suitable to use in a range of 425-860°C if subsequent aqueous corrosion resistance is important. This material has excellent weld ability by all standard fusion methods, both with and without filler metals. Welding of 304 can be done with Grade 308 and 308L rods or electrodes (and with their high silicon equivalents). Heavy welded sections in Grade 304 may require post-weld annealing for maximum corrosion resistance. Tensile Strength (MPa) min 515 Yield Strength 0. 2% Proof (MPa) min 205 Elongation (% in 50mm) min 40 Rockwell B (HRB) max 92 Brinell (HB) max 201

D. Finite element analysis Most of the residual stress studies were conducted based on either axi symmetric or 2D plane assumptions due to the limitations of the finite element codes and computer resources available during the time of the study. Moreover, the thermo-mechanical problem was assumed to be uncoupled where the thermal and mechanical responses were treated separately. Furthermore fatigue failure usually initiate at the stress concentration area and fatigue loading is usually not axi symmetric, and hence a two dimensional model can not simulate the fatigue failure response of weld joints accurately.

In order to simulate the fatigue response of welded joints in the presence of residual stresses, it is essential to conduct a three-dimensional analysis. Figure 5. Illustrates the solid and FE model of the specimen RESULT AND DISCUSSION 3D finite element fatigue response analyses for a socketwelded joint were performed by using ANSYS. This is needed in order to include the calculated residual stress and strain fields as the initial stresses and strains in the fatigue analysis. A fixed boundary condition at the socket end is imposed.

Same finite element mesh and the material model used in the residual stress analysis, are restricted to be used in the fatigue analysis. The following are some of the discussions we found out after the comparative experiments on Fatigue machine and computer aided simulation. High tensile residual stresses, at or above the yield stress level, exist near the weld toe area, especially at the weld start/stop location. The magnitude of the residual stresses reduces quickly as the distance from the weld toe increases. The residual stress distribution does not change much when the slip-on gap in the socket weld joint is reduced to zero.

Hence, the increase in fatigue life of socket welds with no slip-on gap is unrelated to residual stress. The improvement in fatigue life may come from the change in failure mode, which in turn, may be influenced by the change of the external load stress or strain distribution. REFERENCES [1] Guozheng Kang, Yugie Liu, and Zhao Li “ Experimental study on ratchetting-fatigue interaction of SS304 stainless steel in uni-axial cyclic stressing” – International journal of MaterialsScienceand engineering, Volume 435, 2006, Pages 396-404. N. S. Rossini, M. Dassisti , K.

Y. Benyounis, A. G. Olabi “ Methods of measuring residual stresses in components” International journal of Materials and Design, Volume 35, 2012, Pages 572–588. Y. Kudryavtsev and J. Kleiman “ Fatigue of Welded Elements: Residual Stresses and Improvement Treatments” Integrity Testing Laboratory Inc. 80 Esna Park Drive, Units 7-9, Markham, Canada presented paper in the year 2005. Z. Barsoum “ Residual stress analysis and fatigue of multi-pass welded tubular structures” International journal of Engineering Failure Analysis, Volume 15, 2008, Pages 863–874. M.

Farajian-Sohi, Th Nitschke-Pagel, K “ Residual stress relaxation in welded joint under static and cyclic loading” Issued from International Centre for Diffraction Data 2009 ISSN 1097-0002. Grade 304 Table. 1 Mechanical property of SS grade 304 Elastic modulus (Gpa) 193 Thermal conductivity (W/m. K) 16. 2 Specific heat (J/kg. K) 500 Electrical resistivity (ohm) 720 Grade Density (kg/m3) 304 8000 Table. 2 Physical property of SS grade 304 B. Stainless steel welding Methods There are three methods of stainless steel welding which are preferred over the rest.

Metal Inert Gas (MIG) welding, Tungsten Inert Gas (TIG) welding, and Shielded Metal Arc Welding (SMAW). Stainless steel welding requires a bit more finesse than welding mild steel or aluminum, because heat is an enemy in this process. Also the fumes made from any of these processes are very harmful, and great care must be taken to avoid breathing them. TIG welding utilizes a tungsten welding electrode, a filler metal rod and an inert gas to shield the weld. This welding method requires little or no post-weld finishing. The tungsten tip in the welding torch is touched to the material to be welded.

This creates an arc that the welder dips the filler metal rod into and allows it to melt into the welding puddle. The shielding gas prevents contamination from entering the weld and allows the weld to flow out smoothly. Heat is controlled through a foot switch. So the suggested welding method is TIG welding. C. Fatigue test Butt welded piping joints were tested in a cantilever setup. In these test the welded joint to be tested is located near the heavy and stiff support column. The fatigue loading cycle is applied to the other end of the pipe using the actuator of a servo- hydraulic testing machine through a pin end fixture setup.

The pin end fixture consists of a self-aligning ball bearing and a pin, which is snugly fitted to the ball bearing and tightly attached to the end fixture. One of the pin end fixtures is tightly screwed to the actuator rod and the other welded to the specimen. [2] [3] [4] [5] [6] D. Akbari, I. Sattari-Far Faculty of Mechanical Engineering, Amirkabir University of Technology, Tehran, Iran " Effect of the welding heat input on residual stresses in butt-welds of dissimilar pipe joints" International Journal of Pressure Vessels and Piping, Volume 86, 2009, Pages 769–776. [7] B. Brickstad, B. L.

Josefson " A parametric study of residual stresses in multi-pass butt-welded stainless steel pipes" International Journal of Pressure Vessels and Piping, Volume 75, 1998, Pages 11-25. Figure 3. Relation between ratcheting strain with stress amplitude Figure 4. Relation between ratcheting strain with Mean stress Figure 1. Distribution of longitudinal fillet weld Residual stress on a butt welded pipe Figure 5. Solid model (a) and FE model (b) of welded pipe Figure 2. Distribution of longitudinal fillet weld on a carbon steel welded component Axial residual tress distribution in a buttwelded joint