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Review on Structural Analysis of Weld Joints

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Abstract— Analysis of welded structures is still remains a challenge for the designer to produce desired output results. In welding process rapid heating and cooling introduced residual stress and geometrical deformations. Heat effected zone play pivotal role in determining the strength of a welded joint which changes the properties of parent material and reduce the strength after welding operation. There are many cases which structures are continuously under cyclic loading when the fatigue life of the welded joints are a major design consideration The paper studies the previous researches conducted to diagnose welding defects and reduce it.

Keywords: Weld Joints, Quality Improvement, Weld Analysis

I. INTRODUCTION

Welding is a process of permanent joining of two materials through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon combination of temperature and pressure from high temperature with no pressure to high pressure with low temperature, a wide range of welding processes has been developed. Welding enables direct transfer of stress between members eliminating gusset and splice plates necessary for bolted structures. Hence, the weight of the joint is minimum. In the case of tension members, the absence of holes improves the efficiency of the section. Welding is used as a fabrication process in every industry, large or small.

Fig. 1: Welding operation

It is a principal means of fabrication and repairing metal products. The process is efficient, economical and dependable as means of joining metals. This is the only process which has been tried in the space. The process finds its applications in air, underwater and in space. Fillet welds are widely used because of their economy, ease of fabrication and adaptability. The weld of concave shape has free surface which provides a smoother transition between the connected parts and hence causes less stress concentration than a convex surface. But it is more vulnerable to shrinkage and cracking than the convex surface and has a much-reduced throat area to transfer stresses. Fillet welds are broadly classified into side fillets and end fillets. When a connection with end fillet is loaded in tension, the weld develops high strength and the stress developed in the weld is equal to the value of the weld metal, but the ductility is minimal. On the other hand, when a specimen with side weld is loaded, the load axis is parallel to the weld axis. The weld is subjected to shear and the weld shear strength is limited to just about half the weld metal tensile strength. But ductility is considerably improved.

II. LITERATURE REVIEW

T. Ninh Nguyen and M. A. Wahab[1] suggested that the misalignments in weld joints are of two types: eccentricity and angular distortion. Due to this misalignment in weld joint the force transmitted by the misalignment weld joint in axial loading can be split into an axial and bending component.

KyungwooLee[2] investigated that the large deflection of a cantilever beam made of Ludwick type material under a combined loading . The problem involves both material and geometrical non-linearity and a closed-form solution to such problem cannot be obtained. He stated that, numerical solution was obtained by using Butcher’s 1fifth order Runge-Kutta method. Equation can be used for not only the combined load consisting of a uniformly distributed load and one vertical concentrated load at the free end but also the general loading condition.

According to Robb C Wilcox[3] there are several different theoretical approaches available for the design of fillet weld. Conventional design treats all fillet welds as if load was oriented in the weakest direction (longitudinally). The result obtained by his method was an over sizing of fillet welds loaded transversely since transverse loaded welds are stronger than welds loaded longitudinally

Mahapatra et al. [4] investigated the use of constraint in one-side fillet welding to see its effect on angular distortion. Strategically placed tack welds were used to counter the effect of the welding process. Results of the experiment showed that applying constraints at the proper position could indeed counter the distortion from welding. However, no study of residual stress was included in this investigation.

Kumose et al. [5] looked into prediction of angular distortion in one-pass fillet welding. Pre-straining to eliminate distortion in welding was researched. Pre-straining involves either plastic or elastic straining in the direction opposite to distortion before welding is done. Kumose found that the magnitude of plastic pre-strain to avoid distortion was comparatively smaller than that of free angular distortion when the flange thickness is comparatively greater than the weld leg length. Free angular distortion in this research is referring to angular distortion that is free from external forces and only affected by the experimental parameters. When applying elastic pre-strain to a welded component, Kumose found that it was only necessary to consider applied skin stress and nothing else to find suitable values to avoid distortion, meaning that skin stress is directly related to amount of distortion.

Michaleris[6] investigated the use of the thermal tensioning technique to reduce residual stress and distortion in welding . Thermal tensioning is pre-heating of the weldment before the welding takes place. He proposes the use of heating bands which move along with the torch on either side of the weld. Thermal tensioning works to control residual stress and distortion by generating a tensile strain and the weld zone prior to and during welding by imposing a temperature differential. The width and length of the band are obtained by optimization of the parameters that would lead to minimal stress and distortion.

Okerblom[7] laid the groundwork for simplified analytical models of the welding process . He proposed a model that predicted the curvature and contraction (shrinkage) of longitudinal bending distortion in t joint fillet welds. Figure 4 shows examples of longitudinal bending and longitudinal contraction. Using simple elasticity and plasticity theory, he determined magnitude of curvature and contraction based on heat input from the welding process, the center of gravity of the weldment, and the basic material properties of carbon steel such as thermal expansion and yield stress. He also identified that the major permanent deformations are driven by the cooling phase of the welding process. That fact is what allowed him to use a simple treatment for the longitudinal contraction previously discuss. An analytical method that came about from Okerblom's simplifications was the mismatched thermal strain method (MTS).

Teng et al.[8] investigated the effect of weld conditions on residual stresses in butt welds . He predicted residual stresses in one pass arc welding using the finite element package ANSYS. As stated before, Teng was using butt welded steel plates, and was predicting both the longitudinal and transverse residual stresses. He used spacing between stress points of roughly 10 millimeters for the longitudinal stress (parallel to weld line) and a spacing of roughly 15 millimeters for the transverse stress (perpendicular to weld line). Teng did not specify where these points occur, but it is assumed that they are on the surface of the steel plate.

Teng et al. [9] was an analysis into residual stresses specifically in t-joint fillet welds. Residual stresses were again predicted with a finite element method, and it was assumed that both sides of the t-joint were welded simultaneously. Spacing between stress points of roughly 3 millimeters was used for both the longitudinal stress and for the transverse stress. The stress points are located on the surface of the base plates of the t joint. Teng briefly investigates the effect of restraint on angular distortion and residual stresses near the toe of the weld. He found that the peak residual stress was decreased with restraint and he showed that the technique used to prevent angular distortion also reduced stress near the toe of the weld. Figure 2 shows the transverse stress perpendicular to the weld line.

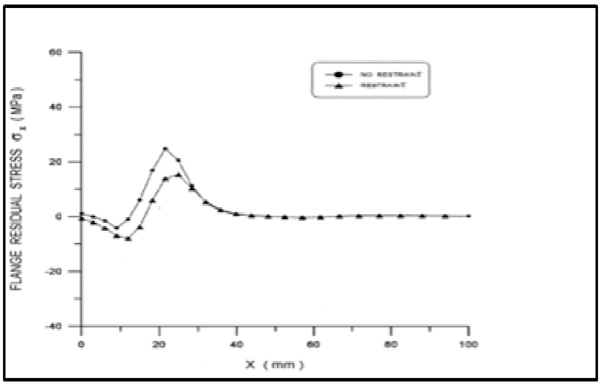

Fig. 2: Transverse residual stresses

Tekriwalet al.[10] used ABAQUS finite element software to predict residual stress distributions in vgroove butt welded plates. Tekriwal found that the maximum transverse stress is produced near the heat-affected zone (HAZ) boundary. Andersson looked at the transverse stress in butt welded joints done by submerged arc welding. The stress points are located on both the top and bottom surfaces of the plates. Andersson used strain gages to capture the stress data from the welding process.

T. Lassen et al, 2005[11] an alternative statistical model based on a joint random fatigue life and a random fatigue limit has been applied. Constant amplitude fatigue life data near the "knee point" of the rule-based bilinear S-N curves are assembled to study and corroborate the model. The model has been fitted to experimental fatigue lives and the obtained S-N curve is compared with the traditional bilinear S-N curves given in rules and regulations. The rule-based S-N curves and the RFLM based curve coincide for stress ranges above 110 MPa. For stress ranges below 100 MPa, the RFLM curve will predict fatigue lives that are from 2 to 10times longer than the predictions made by the F-class S-N curve. It appears that the nonlinear curve obtained from the RFLM has a much better ability to model fatigue life behavior in this stress region. The abrupt knee point of rule-based bilinear curves does not fit the experimental facts for the assembled data. The fatigue life behavior in this stress regime is obviously more complex than the conventional bilinear S-N curve can describe.

Teppei Okawa et al,2013 [12] A fatigue life prediction system for welded structures has been developed, wherein small initial cracks are assumed to form along the toe of a weld bead, and their growth and coalescence behavior is simulated up to the time when a crack breaks through the plate thickness, which represents the fatigue life. The simulation of crack opening/closing behavior by applying a strip yield model makes it possible to adequately analyze the propagation of fatigue cracks considering the effects of the residual stress and loading sequence. The developed system proved capable of analyzing the effects of overloads on the fatigue life of welded joints and the fatigue strength improvement effects of UIT, and the prediction results agreed well with those obtained with actual fatigue tests. The system is expected to find wide application in the fields of fatigue design and maintenance for ships, bridges, plants, construction machinery, and other welded structures as a means for improving their reliability, extending their service life, and reducing environmental loads.

Wolfgang Fricke [13] reviewed fatigue analysis of welded joints, for the past 10–15 years. After a short introduction, the different approaches for fatigue analyses are covered, i.e. the nominal stress approach, the structural or hot-spot stress approach, the notch stress and notch intensity approach, the notch strain approach and finally the crack propagation approach. Only seam-welded joints are considered, and not the behaviour of spot-welds, which is a very special field. Due to the vast amount of relevant literature, some specific areas are left for other reviews or only touched, i.e. fatigue testing and evaluation, fatigue loading and variable amplitude effects, environmental effects and fatigue reliability.

L.F. Jaureguizahar and M.D. Chapetti [14] studied crack like defect. Crack-like defect lengths of about 0.1 mm is obtained. However, much effort should be done in order to analyses the influence of short crack effect in the definition of fatigue strength. The influence of short crack effect depends on the applied stress ratio and only can be neglected when the transition from short to long crack regime become similar to the initial crack length. It is necessary to keep in mind when estimating fatigue strength that the smaller the initial crack length is, the greater the over-prediction of fatigue strength will be if the short crack effect is not taken into account. Besides, even though more detailed experimental results should be obtained and extensive parametric studies should be carried out in order to reach important conclusions about the influence of the geometrical, micro structural and mechanical parameters involved in the definition of the fatigue behavior of welded joint, the analysis showed that the present model could be able to describe most of their interactions and to provide a powerful tool to estimate the fatigue strength of different weld configurations.

A.Chattopadhyay et al [15] studied an efficient shell finite element technique for obtaining stress data in welded structures relevant for fatigue analyses has been proposed. According to the proposed method the entire welded structure can be modeled using a relatively small number of large shell finite elements. The modeling technique captures both the magnitude and the gradient of the hot spot stress near the weld toe which are necessary for calculating the stress concentration and the peak stress at critical crosssections, e.g. at the weld toe. A procedure for the determination of the magnitude of the peak stress at the weld toe using the classical stress concentration factors (one for axial load and one for bending) has been laid proposed. The approach is based on the decomposition of the hot spot stress into the membrane and bending contribution. The method can be successfully applied to any combination of loading and weldment geometry. The stress concentration factors are used together with the hot spot membrane and bending stress σ Mhs and σ bhs at the location of interest in order to determine the peak stress at the weld toe and the through-thickness on-linear stress distribution.

C. Acevedo, A. Nussbaumer[16] has been shown that the drilling system developed for tubes has given suitable results with an accuracy of 10% in residual stresses assessment. In this measurement campaign, the effective hole-diameter was greater than the theoretical hole-diameter, this difference was taken into account. The first residual stress evaluations on bridge tubular joints, presented in this paper, have led to drastically different residual stress field than found in the literature on pipe and pressure vessels tubes. In future work, influence of tube curvatures on the accuracy of the hole-drilling method, will be studied. Moreover, in order to evaluate both intensity as well as variability of the residual stresses at surface and in the depth, measurements by means of the non-destructive neutron diffraction technique, will be performed. It will give us a complete map of the triaxial stresses.

J. Cotrell [17] presented the design, analysis, and testing of a two-bladed hub. This section discusses report conclusions and recommendations on design methodology, and testing techniques, as well as work on the hub that remains to be completed. In thesis, author focus on the analysis and testing of the hub body. Work performed solid-mechanics calculations, ran a finite-element analysis simulation, and experimentally investigated the structural integrity of the hub body. Both the predicted and experimental results indicate that the hub body is structurally adequate.

Mustafa Aygul [18] performed conclusions based on the work performed in this study are divided into two parts. In the first part, the conclusions and recommendations for the fatigue assessment of orthotropic bridge deck details are given. In the second part, the conclusions for the studied welded details for the three fatigue assessment methods are presented.

Donders S. et al [19] studied the effect of spot weld failure on dynamic vehicle performance. The impact of spot weld quality and design for vehicle functional performance also an industrial robustness study is presented that assess the effect of spot weld failure on dynamic vehicle characteristics. The FEA body in white (BIW) structure of vehicle is introduced in the study.

III. CONCLUSION

Various researches are conducted to analyze weld defects like angular misalignment, welding distortion, fatigue life of weld joint, residual stresses of weld joint, spot weld failure and crack formation. The numerical method (Finite Element Analysis) is used by various scholars and results of FEA simulations are validated with experimental results.It has been found that when toe radius increases, tensile strength and compressive strength of fillet weld joint decreases.

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