OPTIMIZATION OF WELD PENETRATION PROBLEM IN BUTT WELDED JOINTS USING STRESS CONCENTRATION FACTORS AND STRESS INTENSITY FACTORS

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ABSTRACT

One of the imperfections in butt welds is referred as the lack of penetration (LOP). Lack of penetration occurs due to weld metal fails to reach the root of the joint which is inevitable considering both the cost of the edge preparation and machining time into account. The LOP may act as a crack when it is subjected to loading. States of stress at these highly stress concentration regions are evaluated by two important fracture parameters namely stress concentration factor (SCF) and stress intensity factor (SIF) using FEA.

The SIF & SCF are evaluated at lack of penetration defects for double-V, single-V, double-J, and single-J butt welded joints subjected to axial loading with varying defect length (LOP) to plate thickness ratios to find an acceptable defect length. Few comparisons are made with the previous existing experimental results. Hence Present work becomes the first approach for approximation of typical weld penetration defects.

Keywords: Butt weld, lack of penetration(LOP), stress concentration factor(SCF), stress intensity factor(SIF).

Introduction

Butt welded joints have wide variety of applications in the industries and engineering constructions such as bridges, boilers, pressure vessels, automobile industries, offshore structures etc., due to higher strength of these joints. The inherent presence of discontinuity like lack of penetration (LOP) is quite common in butt-welded joints due to weld metal fails to reach root of the joint which is inevitable considering both the cost of edge preparation and machining time into account which is considered as a crack from facture mechanics point of view.

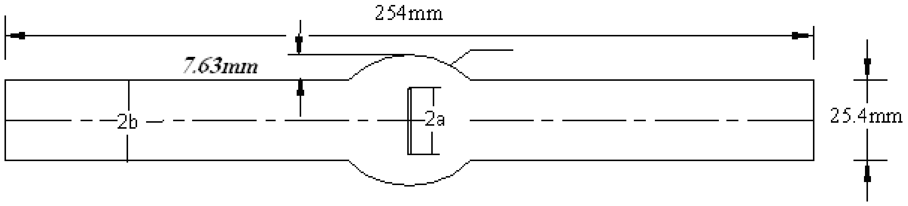
The LOP and other weld defects constitute a group of stress raisers. Fracture mechanics provides basis for quantifying the behavior of cracks or crack like defects during both the initiation and propagation phase. The important parameters in fracture mechanics are the stress concentration factor and stress intensity factor, which are the measure of the magnitude of stress occurring in the highly stressed region like LOP.The ratio of the maximum stress and the nominal applied tensile stress is denoted as the Stress concentration factor, K_t. The fundamental principle of fracture mechanics is that the stress field ahead of a sharp crack can be characterized in terms of a parameter K, the Stress intensity factor.Accurate analysis in presence of cracks is required to determine the stress state at these highly stress concentration regions. Numbers of analytical procedures as well as experimental procedures are available to evaluate stress parameters like Stress concentration factors (SCF) and Stress intensity factors (SIF). However Finite element methods are readily accessible for analyzing defects involving weld penetration problems even with complicated geometry and loading conditions when compared with other methods.

In the present analysis, stress concentration factor and stress intensity factor for weld penetration problems in single-V, double-V, single-J, double-J butt welded joints are determined using F.E.A with varying defect length to plate thickness ratios. There exists proportionality between SCF and defect length i.e. larger the defect lengths higher the stress concentration factor. Hence it is important to find out the optimal defect length considering the cost of edge preparation (Machining cost), expensiveness of the joining process. Based on the nature of the graphs the optimum defect lengths are determined. Present work becomes the first approach for approximation of typical penetration defects .It shows that, for typical defect profiles, an "acceptable" defect length exists beyond which stress concentration increases rapidly.

Literature Review

If a component or a structure is subjected to fluctuating loading in service, avoidance of fatigue failure is likely to be a factor which limits the design stresses. This is particularly true of welded components because their fatigue strength can be much lower than those of welded components.

Maddox [1], *Gurney* [2] and *Radaj* [3] classified the butt welded joints on the basis of loading as transverse and longitudinal. Butt welds are also classified on the basis of being welded on single side or double side and on the basis of shape of edge preparation as V and J butt joints. *C.P.Burger*, *L.W.Zachary* and *W.F.Riley* [4] conducted a series of photo elasticity tests on two-dimensional plane-stress models of double-V butt-welded joints with typical penetration defects subjected to axial loading as shown in Fig. 1. The experimental results obtained by them reveals that, if the defect length-to-plate thickness ratio is below 0.2 then the stress-concentration factor changes very little and for ratio larger than 0.2 the stress concentration factor increases rapidly. It constitutes the specification of an "acceptable" level of penetration defects for production processes. The present work deals the determination of SIF and SCF at lack of penetration defects for double-V, single-V, double-J, and single-J butt welded joints subjected to axial loading with varying defect length (LOP) to plate thickness ratios to find an acceptable defect length.



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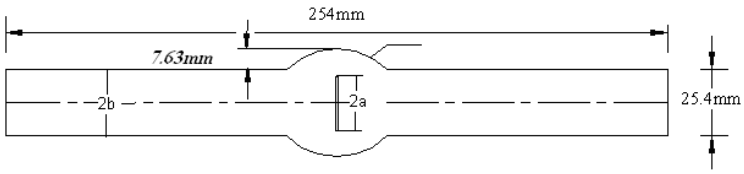

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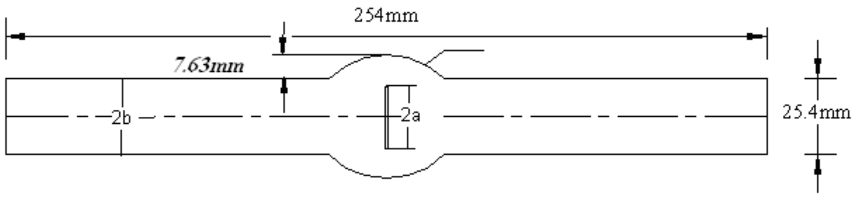

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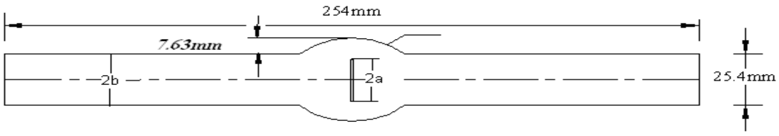

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Finite Element Analysis

FEA has many advantages when compared to other techniques as there are no shape or intricacy limitations. Every nook and corner can be analysed for great variety of parameters simultaneously. Accuracy of analysis is very much closure to the experimental analysis by taking large number of elements. Hence FEA (ANSYS Package) is adopted to determine SCF and SIF.

As the stress analysis is of primary concern, plane stress models are modeled and analysed as shown in the Fig.2. In the present study double-V, single-V, double-J and single-J butt welded joints are simulated using FEA. Modulus of elasticity and Poisson's ratio are assumed as $2x10^5$ N/mm^2 and 0.3 respectively.

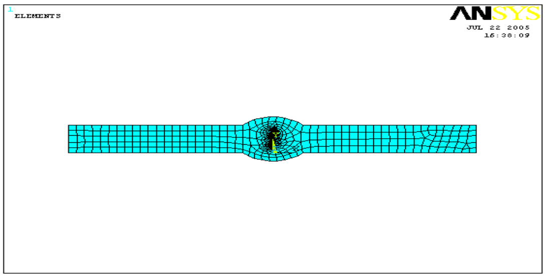

Fig. 2 Meshed model of a Double-V butt-welded joint

Results and Discussions

The inherent presence of defects like LOP in a butt-welded joint leads to the presence of the high stress concentration at that region. Static analysis of two-dimensional plane-stress models of typical penetration defects has been carried out using FEA for different butt-welded joints to know the state of stress. Fracture parameters like Stress Concentration Factor and opening mode Stress Intensity Factor are computed for different lack of penetration defect to plate thickness ratios (a/b).

Stress analysis of double-v butt welded joints

Double V butt-welded joints have been analyzed by varying defect length to plate thickness ratio i.e. varying a/b ratios to find out an acceptable level penetration defect lengths.

The values obtained are plotted in the Fig. 3. It is observed that the graph has a "knee" at defect length-to-plate thickness ratio around 0.2. Below the "knee", the Stress-Concentration factor changes very little with change in defect length but for lengths beyond the knee, i.e. ratios larger than 0.2, the stress concentrations increase rapidly with defect length. It may constitute to the acceptable level of penetration defects. These observations are conformity with Photo elastic tests conducted by *C.P.Burger*, *L.W.Zachary* and *W.F.Riley* [4]. Stress intensity factors are also computed for double-V butt-welded joint at the same defect length to plate thickness ratios. The values obtained are represented in Fig. 4 and have the similar trend as that of the Stress concentration factor.

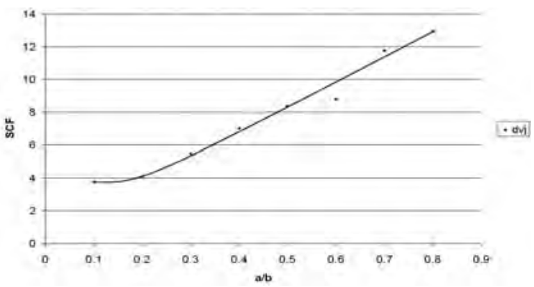

Fig. 3 SCF Vs a/b ratios of double V butt-welded joint

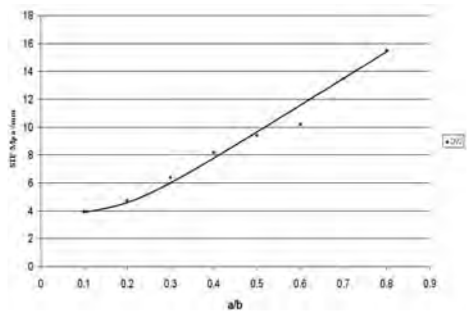

Fig.4 SIF Vs a/b ratios of double v butt-welded joint

Stress analysis of single-v butt welded joints

Geometrical models of single-V butt-welded joints are modeled and analyzed at different defect length to plate thickness ratios. Both SCF and SIF are computed for single-V butt-welded joint.

From the Fig. 5, it is observed that the graph has a “knee” at defect length-to-plate thickness ratios about 0.1 to 0.2. Below the “knee”, the stress-concentration factor changes very little with changes in defect length but for lengths beyond the knee, i.e., ratios larger than 0.2, the stress concentrations increase rapidly with defect length. It may constitute to the acceptable level of penetration defects. Stress intensity factor values in Fig. 6 have the same trend as that of the Stress concentration factor.

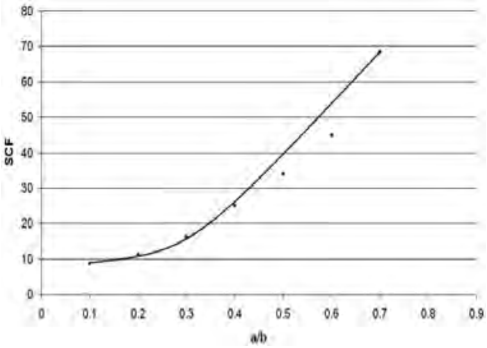

Fig. 5 SCF Vs a/b ratios of single-V butt-welded joint

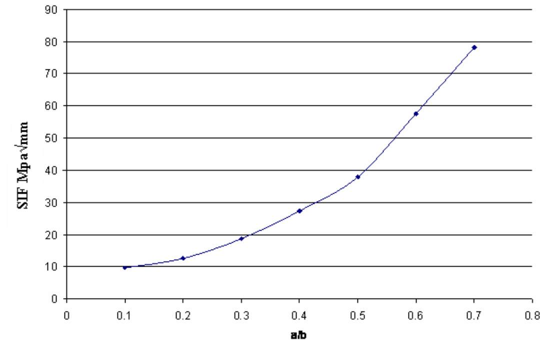

Fig. 6 SIF Vs a/b ratios of single-V butt-welded joint.

Stress analysis of double-j butt welded joints

Geometrical models of Double J butt-welded joints are modeled and analyzed at varying defect length to plate thickness ratios. Both SCF and SIF are computed for Double J butt-welded joint.

From the Fig. 7 it is observed a “knee” exists at defect length-to-plate thickness ratios around 0.4. Below the “knee”, the stress-concentration factor changes very little with changes in defect length but, for lengths beyond the knee, i.e., ratios larger than 0.4, the stress concentrations increase rapidly with defect length. It may constitute to the acceptable level of penetration defects. Stress intensity factor values in Fig. 8 have the same trend as that of the Stress concentration factor. It is observed that both SCF and SIF for double J butt-welded joint have higher values than that of the double V butt welded joint.

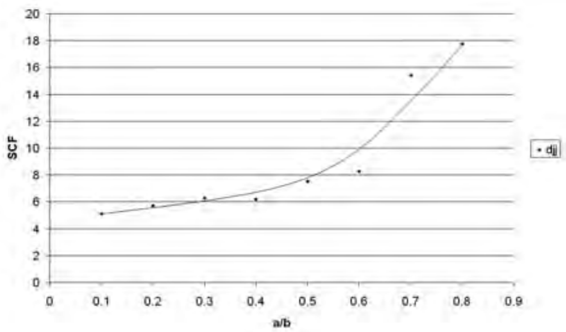

Fig. 7SCF Vs a/b ratios of double J butt-welded joints

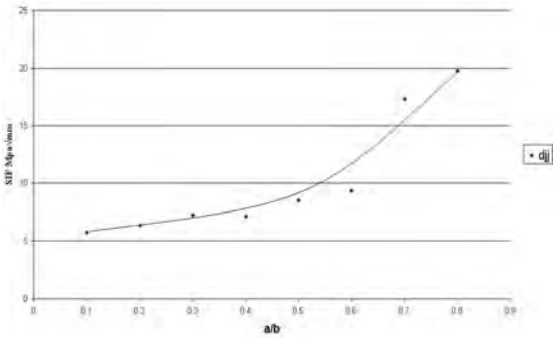

Fig.8 SIF Vs a/b ratios of double J butt-welded joint

Stress analysis of single-j butt welded joints

Geometrical models of single-J butt welded joints are modeled and stress analysis at varying defect length to plate thickness ratios is carried out. Both SCF and SIF are computed for single-J butt-welded joint.

From the Fig. 9, it is observed that the graph has a “knee” at defect length-to-plate thickness ratios around 0.3. Below the “knee”, the stress-concentration factor changes very little with changes in defect length but, for lengths beyond the knee i.e., ratios larger than 0.3, the stress concentrations increase rapidly with defect length. It may constitute to the acceptable level of penetration defects. Similarly SIF is computed with varying a/b ratios as shown in Fig. 10 and has the same trend as that of the Stress concentration factor.

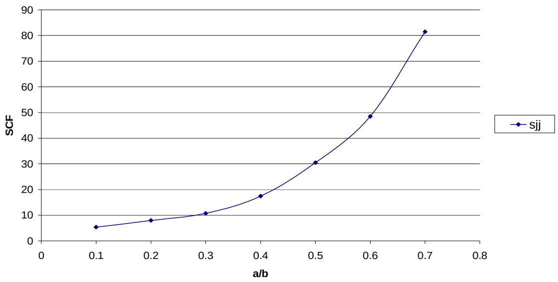

Fig. 9 SCF Vs a/b ratios of single-J butt welded joint

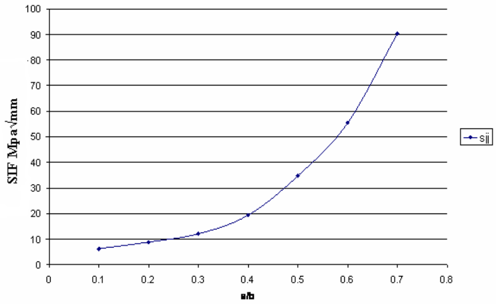

Fig. 10 SIF Vs a/b ratios of single J butt-welded joint

Conclusions

The largest acceptable length of weld penetration defect in Double-V butt-welded joint based on SCF values is about 0.2 times the plate thickness.

- For Single-V, Double-J and Single-J butt-welded joints the acceptable level of weld penetration defect is around 0.2, 0.4 and 0.3 times the plate thickness respectively.
- Acceptable level of weld penetration defect is same for SIF values as that of SCF values for Single-V, double-V, Single-J and Double-J butt-welded joints.
- Both the SCF and SIF values of double-J butt welded joint are higher than that of double-V butt welded joint.

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