INFLUENCE OF THE CONSTRAINT EFFECT OF FRACTURE RESISTANCE OF MISMATCHED WELD JOINTS

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The paper deals with some aspects of the theory of constraint factor K_W and its application to an assessment of the fracture resistance of the under - and overmatched weld joints. Conclusions from the theoretical analysis form some basis for the application of parameter K_W to an assessment of the fracture parameters. For example, there was made an assessment of the ratio of driving forces δ_R. Furthermore the ratio of $r_p^{(un/ov)} / r_p$ has been presented as a function of K_W^{un} and K_W^{ov} respectively.

INTRODUCTION

Welding is probably the most popular manufacturing process for joining metals used in structural applications. Some groups of weld joints are often highly inhomogeneous. This can take place during the welding of toughened steel and strain or age hardened steel, etc. Changes in the material structure are directly related to the mechanical properties in that area, e.g., tensile yield point Re and tensile strength Rm.

Considering the above - mentioned problem of a mis - match welded joints, it is essential that a model which shows the real condition of the joint is presented - figure 1.. In this situation we will focus our attention on a model in which the weld metal or part of the heat affected zone (HAZ) is imitated by layer - fig.1a. Strength mismatching occurs as an undermatching - fig. 1b or as an overmatching - fig. 1c. Moreover, the model was based on the assumption that the materials used are ideal plasticity.

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CHARACTERIZATION OF THE CONSTRAINT FACTORS K_W^{un}, K_W^{ov}

The essential physical phenomena affecting the mechanical properties of this model occur at the interface of zones (B) and (W). This mis - match causes constrains and stress concentrations which are enhanced by geometric parameters of the mismatched weld joints and state of loading - under tension or bending loading. With reference to above - mentioned statement on figure 2 presents the characteristic of stresses in undermatched and overmatched weld joints according to rules determined in (1). The stress analysis to enables establish the average value of stresses of the layer (W), σ_{ever}, at static tension :

- undermatched weld joints at $R_e^W < R_e^B$

$$\sigma_{ever}^{un} = K_W^{un} \cdot R_e^W \tag{1}$$

- overmatched weld joints at $R_e^W > R_e^B$

$$\sigma_{ever}^{ov} = K_W^{ov} \cdot R_e^W \tag{2}$$

Analytical assessment of the constraint factor of the under - and overmatched weld joints in accordance to references (1) , (2) yields:

$$K_W^{un} = \frac{2}{\sqrt{3}}\left(\frac{1}{4(1-q)}\left[\frac{\pi}{2}+2(1-2q)\sqrt{q(1-q)}-\arcsin(2q-1)\right]+(1-q)\frac{1}{4\kappa}\right) \tag{3}$$

$$K_W^{ov} = \frac{2}{\sqrt{3}}\left(\frac{1}{4(1-q)}\left[-\frac{\pi}{2}-2(1-2q)\sqrt{q(1-q)}-\arcsin(2q-1)\right]+(1-q)\frac{1}{4\kappa}\right) \tag{4}$$

$\chi = 2h/2l$; $0 \le q < 1$

Figure 3a, b presents the dependence of the constraint factors K_W^{un}, K_W^{ov} on the parameters κ and q.

INFLUENCE OF K_W^{un}, K_W^{ov} ON THE FRACTURE RESISTANCE

Regarding the previously accepted assumption concerning materials which create the mismatched weld joints model the value of σ_{ever} is also equal new value of yield point of the layer :

$$\sigma_{ever}^{un} = R_e^{Wun} \quad \text{or} \quad \sigma_{ever}^{ov} = R_e^{Wov} \tag{5a, b}$$

It is clear that a change in the state of stress in the layer (W) also causes change in the mechanical action of stress and the mechanical properties of the material in the area of the mismatched weld model. The layer causes a change in the state of stress which also leads to a change in crack resistance in these zones, the procedure of destruction and the kind of fracture.
For example consider the above - mentioned problem of the crack is located in the middle part of the layer parallel to the interface and in the homogenous material. We can assessment the change of the size r_p of the plastic zones at the crack tip for layer R_e^W and homogenous materials R_e^H at $R_e^W = R_e^H$ and at the same thickness $g_W = g$ as :

$$\frac{r_p^{un}}{r_p} = \frac{1}{K_W^{un2}} \quad or \quad \frac{r_p^{ov}}{r_p} = \frac{1}{K_W^{ov2}} \tag{6a,b}$$

Figure 4a, b presents the characteristic of the relative size of the plastic zone at crack tip of the under - and overmatched weld joints. It should be noted that in the layer (W) favorable conditions for passing from plane stress to plane strain occur when the value of K_W is increased (1). Furthermore, according to the previously determined equations by Schwalbe (3) for assessing the ratio of the driving forces in weld metal and base metal and after taking the constraint factor K_W, it will be able to determine the parameter $\delta_R = \delta_W / \delta_R$ at regions (W) and (B) fully plastic as follows:

- undermatched weld joints at matching ratio $K_S = R_e^B / R_e^W > 1$

$$\delta_R^{un} = \left(\frac{1}{K_S}\right)^{(1-1/n_W)} \left(\frac{K_W^{un}}{K_S}\right)^{\left(\frac{1}{n_W}-\frac{1}{n_B}\right)} \tag{7}$$

- overmatched weld joints at matching ratio $K_S = R_e^B / R_e^W < 1$

$$\delta_R^{ov} = \left(\frac{1}{K_S}\right)^{(1-1/n_W)} \left(\frac{K_W^{ov}}{K_S}\right)^{\left(\frac{1}{n_W}-\frac{1}{n_B}\right)} \tag{8}$$

The results of this study of mismatched weld joint reveals high dependence of the fracture parameter δ_R according to equation (7) , (8) on the constraint factors K_W^{un} , K_W^{ov} , matching ratio K_S and strain hardening exponents n_W, n_B.

CONCLUSIONS

The fracture resistance of an under - and overmatched of weld joints reveals high dependence the fracture parameters δ_R according to equations (7), (8) on the parameters: K_W^{un}, K_W^{ov}, K_S and n_W, n_B. The thus determined parameters δ_R gives the basic information about how to choose the critical parameter CTOD in under - and overmatched weld joints for having strength equal to base material.

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(3) Schwalbe K.-H.: Effect of weld metal mis - match on toughness requirement; Some simple analytical considerations using the Engineering Treatment Model (ETM). International Journal of Fracture, 56, pp.257 - 277, 1992

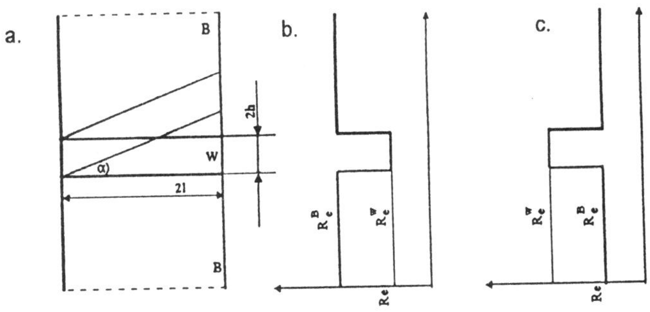

Figure 1. General characteristic of the model of the mismatched weld joints

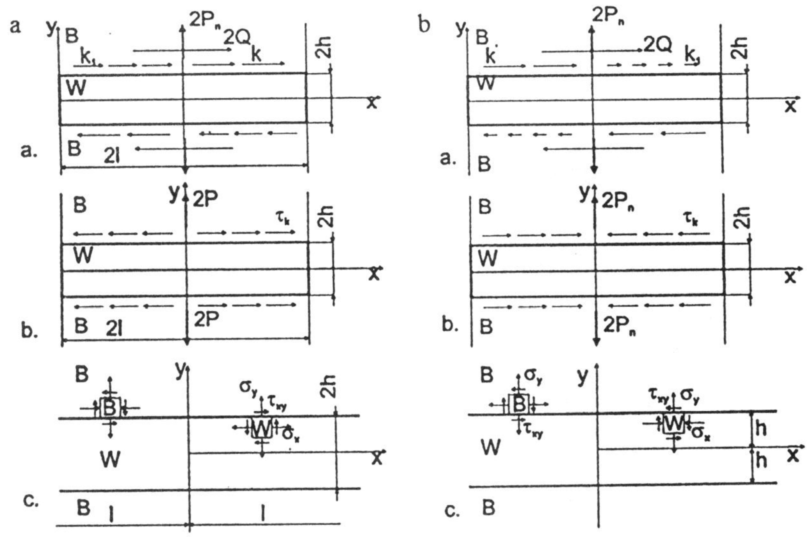

Figure 2. Stress distribution of the a. undermatched b. overmatched weld joints

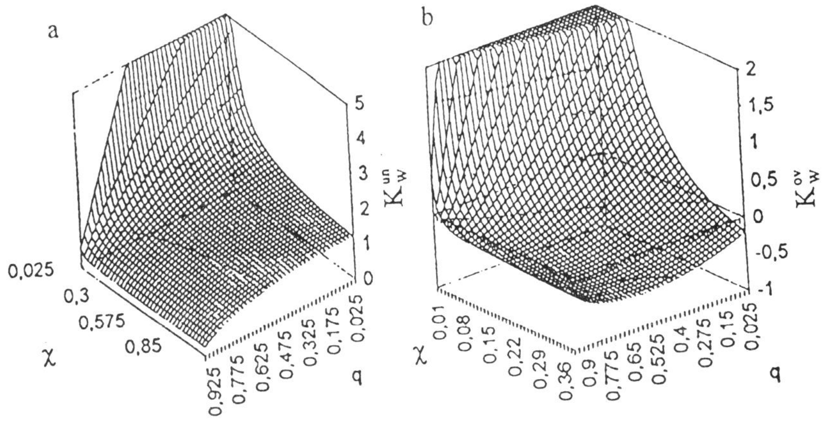

Figure 3. Diagrams of K_w^{un}, K_w^{ov} for a. undermatched b. overmatched weld joints.

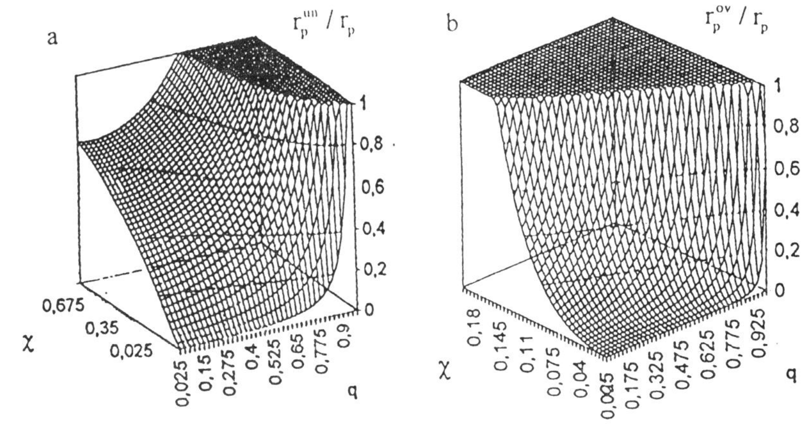

Figure 4. Relative size of r_p^{un} / r_p, r_p^{ov} / r_p for a. undermatched, b. overmatched weld joints.