INFLUENCE OF THE STRESS STATE IN MISMATCHED WELD JOINTS ON FRACTURE RESINTANCE UNDER TENSION

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The results of this study concern the evaluation of stress state at interface of the under - and overmatched weld joints. After formulating a simplified model of mis matched weld joints an analysis of stress was made at interface. Conclusion from above analysis form a basis to an assessment of the stress state parameter S_p as a physical measure of effort of the mismatched weld joints and constraint parameter K_W which was used to an assessment of the fracture parameters such as ratio of driving forces δ_R^{un} and δ_R^{ov} .

INTRODUCTION

Fracture mechanics are widely applied in the design of engineering weld structures, but difficulties arise when fracture parameters used in characterizing toughness and yield significantly different results. A major factor responsible for variations in toughness in welds is likely to be the microstructural inhomogeneities. This can take place during the welding of toughened steel and strain or age hardened steel, etc. The heterogeneous nature of the weld joints are characterized by macroscopic dissimilarity in mechanical properties. This dissimilarity is caused by different mechanical and chemical properties of the weld and base materials as well as by the thermal and strain cycles during welding and my occur through the fusion line and heat affected zone (HAZ) of welds. Considering the above mentioned problem we will focus our attention on a simplified theoretical model in which the weld metal or part of HAZ is imitated by soft or hard layer (W) the yield strength of which R_e^W is smaller $\left(R_e^{W(un)}\right)$ or greater $\left(R_e^{W(ov)}\right)$ then that of the base material (B) R_e^B - figure 1a.

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THE STRESS STATE AT INTERFACE OF THE MISMATCHED WELD JOINTS

The essential physical phenomena affecting the mechanical properties of this model occur at the interface of zones (B) and (W). Determination of change in the state of stress occurring in that area is of primary importance for a correct interpretation and estimation of mechanical properties of this model. After setting the assumption according to rules determined in (2) a stress analysis was made in agreement with principles of the mechanics of solids (3). Components of the state stress in mis - matched weld joints for inclined layer under static tension are determined by the equilibrium equations and the equation of the plasticity condition which fulfilling the boundary condition on the interface of zones (B) and (W) by used the models presented on figure 1 b, c.
The components σ_x , σ_y and σ_{xy} for the undermatched and overmatched weld joints to be determined as follows (1, 2):

- undermatched weld joints:

$$\sigma^{un}_{x(rel)} = \frac{\sigma^{un}_x}{k} = \frac{1}{1-\gamma}\left(\frac{\pi}{2} - \gamma\sqrt{1-\gamma^2} - \arcsin\gamma\right) + \frac{1-\gamma}{2}\frac{\xi}{\kappa} - $$
$$-2\sqrt{1-\left(\frac{1-\gamma}{2}+\frac{1-\gamma}{2}\frac{\eta}{\gamma}\right)^2} \qquad (1)$$

$$\sigma^{un}_{y(rel)} = \frac{\sigma^{un}_y}{k} = \frac{1}{1-\gamma}\left(\frac{\pi}{2} - \gamma\sqrt{1-\gamma^2} - \arcsin\gamma\right) + \frac{1-\gamma}{2}\frac{\xi}{\kappa} \qquad (2)$$

$$\sigma^{un}_{xy(rel)} = \frac{\sigma^{un}_{xy}}{k} = \frac{1+\gamma}{2} + \frac{1-\gamma}{2}\frac{\eta}{\kappa} \qquad (3)$$

- overmatched weld joints:

$$\sigma^{ov}_{x(rel)} = \frac{\sigma^{ov}_x}{k} = -\left[\frac{1}{1-\gamma}\left(-\frac{\pi}{2} + \gamma\sqrt{1-\lambda^2} + \arcsin\gamma\right) + \frac{1-\gamma}{2}\frac{\xi}{\kappa} + \right.$$
$$\left. +2\sqrt{1-\left(\frac{1+\gamma}{2}+\frac{1-\gamma}{2}\frac{\eta}{\kappa}\right)^2}\right] \qquad (4)$$

$$\sigma^{ov}_{y(rel)} = \frac{\sigma^{ov}_y}{k} = \left(-\frac{\pi}{2} + \gamma\sqrt{1-\gamma^2} + \arcsin\gamma\right) + \frac{1-\gamma}{2}\frac{\xi}{\kappa} \qquad (5)$$

$$\sigma^{ov}_{xy(rel)} = \frac{\sigma^{ov}_{xy}}{k} = \frac{1+\gamma}{2} + \frac{1-\gamma}{2}\frac{\eta}{\kappa} \tag{6}$$

where:

- physical parameters:

$$\gamma = \frac{k_1}{k} \;;\; |\gamma| \le 1 \;;\; k = \frac{R_e^{W(un)}}{\sqrt{3}} \quad \text{or} \quad k = \frac{R_e^{W(ov)}}{\sqrt{3}} \;;$$

$$-k \le k_1 \le k \;;\; R_e^{W(un)} \le R_e^B \quad \text{or} \quad R_e^{W(ov)} \ge R_e^B$$

and geometric parameters:

$$\kappa = \frac{h}{l} \;;\; \eta = \frac{y}{l} \;;\; \xi = \frac{x}{l}$$

From the practical point of view the effect of the change in the state of stress on the mechanical properties is very interesting. We are introducing to the further consideration the stress state parameter S_p as follows:

$$Sp = \frac{\sigma}{\sigma_H} = \frac{\frac{\sigma_x + \sigma_y}{2}}{\frac{\sqrt{2}}{2}\sqrt{2(\sigma_x - \sigma_y)^2 + 2\sigma_x\sigma_y + 6\tau_{xy}^2}} \tag{7}$$

In this situation the relation between σ and σ_H, is a physical measure of the influence of the stress state at interface on the deformation and effort of the mismatched weld joints. After inserting σ_x , σ_y , τ_{xy} in accordance with equations (1) ÷ (3) and (4) ÷ (6) we are obtain the stress state parameter Sp.
Figure 2 a, b presents the characteristic of Sp for under- and overmatched weld joints. Some examples were presented in reference (2) reveal the difference tendency and upward tendency for undermatched and downward tendency for overmatched weld joints at the same geometric characteristic as above.

FRACTURE RESISTANCE OF MISMATCHED WELD JOINTS UNDER TENSION.

The stress analysis to enables establish the average value of stress of the layer (W), σ_{ever} , at static tension as follows (3):

- undermatched joints at $R_e^{W(un)} < R_e^B$

$$\sigma^{un}_{ever} = K^{un}_W \cdot R_e^{W(un)} \tag{8}$$

- overmatched joints at $R_e^{W(ov)} > R_e^B$

$$\sigma_{ever}^{ov} = K_W^{ov} \cdot R_e^{W(ov)} \tag{9}$$

Analytical assessment of the constraint factor of the under - and overmatched weld joints in accordance to references (1) , (3) yields:

$$K_W^{un} = \frac{2}{\sqrt{3}}\left(\frac{1}{4(1-q)}\left[\frac{\pi}{2} + 2(1-2q)\sqrt{q(1-q)} - \arcsin(2q-1)\right] + (1-q)\frac{1}{4\kappa}\right) \tag{10}$$

$$K_W^{ov} = \frac{2}{\sqrt{3}}\left(\frac{1}{4(1-q)}\left[-\frac{\pi}{2} - 2(1-2q)\sqrt{q(1-q)} - \arcsin(2q-1)\right] + (1-q)\frac{1}{4\kappa}\right) \tag{11}$$

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

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

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. It will be able to determine the fracture parameters $\delta_R = \delta_W / \delta_R$ at regions (W) and (B) fully plastic as follows:

- undermatched joints at matching ratio $K_S = R_e^B \big/ R_e^{W(un)} > 1$

$$\delta_R^{un} = \left(\frac{1}{K_S}\right)^{(1-1/n_W)} \left(\frac{K_W^{un}}{K_S}\right)^{\left(\frac{1}{n_W} - \frac{1}{n_B}\right)} \tag{12}$$

- overmatched joints at matching ratio $K_S = R_e^B \big/ R_e^{W(ov)} < 1$

$$\delta_R^{ov} = \left(\frac{1}{K_S}\right)^{(1-1/n_W)} \left(\frac{K_W^{ov}}{K_S}\right)^{\left(\frac{1}{n_W} - \frac{1}{n_B}\right)} \tag{13}$$

The results of this study of mismatched weld joint reveals high dependence of the fracture parameter δ_R according to equation (10) , (11) on the constraint factors K_W^{un} , K_W^{ov} and matching ratio K_S and strain hardening exponents n_W , n_B as presented on figure 2 a, b.

CONCLUSION

The theoretical analysis form a basis to an assessment measure of the stress state parameter S_p as a physical measure of the deformation and effort of the thin layer - soft or hard - in mismatched metal joints. Furthermore, the determined parameters $K_W^{un/ov}$ and δ_R gives the basic information about change of the mechanical properties and fracture resistance of mismatched metal joints.

SYMBOLS USED

$R_e^{W(un)}$	-	yield point of the soft layer,
$R_e^{W(ov)}$	-	yield point of the hard layer,
R_e^B	-	yield point of the joining metals (base material),
κ	-	relative thickness of the soft layer,
h	-	half of the thickness of the soft layer,
l	-	half of the thickness of the joining metals,
η , ξ	-	relative geometric parameters of the analysed points,
σ	-	mean stress,
σ_H	-	equivalent of stress according to Huber - Mises,
$\delta_R^{un/ov}$	-	ratio of driving forces.

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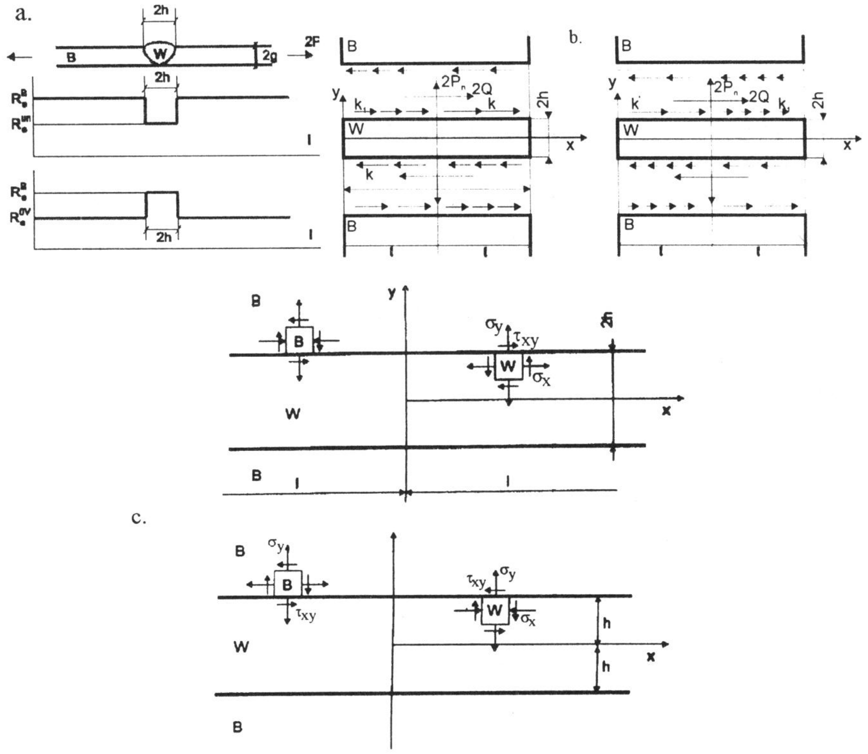

Figure 1 General characteristic of the situation: a. mismatched weld model, b. analytical models and c. stress state at interface in under- and overmatched weld models.

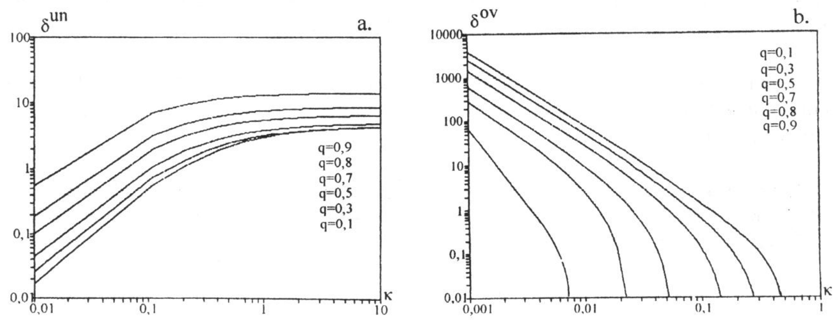

Figure 2. Characteristic of: a. $\delta_R^{un} = f(\kappa)$, at q = 0,1 ÷ 0,9; b. $\delta_R^{ov} = f(\kappa)$ at q = 0,1 ÷ 0,9.