DAMAGE CONCEPT IN WELDMENTS

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Two sciantific methods today, on the problems of deterioration and fracture of materials have been applied: linear elastic fracture mechanics wich starts by Griffiths /1/ considering brittle fracture, and continuous damage mechanics, originated from Kachanov's /2/ analysing creep fracture problem. High idealized assumptions both of menthioned approach tried to eliminate Janson and Hult /3/ and farther Janson /4/,/5/ by himself. They proposed a combined approach with intention to describe the interaction between a macroscopic crack and microscopic damage in the homogenous materials. In this paper a possibility of application of these procedure to the weldments problems has been analysed.

INTRODUCTION

A primary problem existing in the field of weldments is expressive inhomogenity in the material at the zone of welded joint. This inhomogenity has been expressed as in the structure of material as in important change of mechanical properties, often at the very small space. However, this inhomogenity has been mainly expressed to the change of the yield stres in each zone related to the base metal.

As analysis of single cracks, located in whichever zone of welded joint, understtands the appearance of the plastic zones at the crack tip, it will be a main difficulty to determine this zone.

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STATEMENT OF THE PROBLEM

A thin sheet with butt weldment, transversal to the strain direction, loaded in mode I, has been treated using the modified Dugdale /6/ crack model according to Jansons /5/ procedure for time-independent damage formation. Three independent and substantialy different cases are determined: /a/ the crack in the weld metal, /b/ crack in the heat-affected zone, and /c/ crack in base metal. However, in this worke, like most interesting, it will be considered a case when the crack just in the fusion line has been assumed /Fig. 1). To simplify the analysis, we assumed that there was no the residual stresses from welding. A plastic zone, wich is forming at the crack tip, will have in this case iregulare shape by reason of menthioned structural and mechanical anisotropy /before all by reason of differents yield strengths/.

We will assume the shape of plastic zone at the crack tip like in Figure 2.

Our further consideration has been conseieved on the possibility of determination a mechanical properties of materials at whichever point in welded joint /in accordance with Soet and Denys /7/ papers/. The following relations introduced in this case are:

Damage: $\omega = (A - A_{ef})/A$ (1)

Stress: $\sigma = P/A$ (2)

Net stress: $s = P/A_{ef}$ (3)

and consequently: $\sigma = s(1-\omega)$ (4)

Elasto-plastic relation, net stress-strain is assumed independently for weld metal and heat-affected zone /see Fig. 3/.

Relation damage-net stress, is assumed like in the paper /5/. However, by reason of menthioned inhomogenity, typical for welding procedure, a new greatness, caled initial or technological damage, has been introduced. This initial /technological/ damage exist independently from the external load, and is different for each of the three menthioned cases. It depends on the materials nature /basic or additional/, welding procedure, thermal treatement etc. That means that the initial /technological/ damage is the parameter of material. We can assume that it is constant for the assigned welding parameters.

If we denote new greatness with ω_i, we can expresse it like relation:

$$\omega_i = \varepsilon_m/\varepsilon_f \qquad (6)$$

where is: ε_m-max. strain, ε_f-strain at fracture in one plane parallel to the weld axis /in our case this is the fusion line/. It has to be mentioned here, that bouth value ε_m and ε_f are variable along the direction perpendicular to the weld axsis /y/, as is discribed in menthioned paper /7/, on the series of small specimens which have been cut out successively to the direction of weld axsis. In our case, for y=0, $\omega_i' = \omega_i$. In fact, this relation express a measure of ductility in the materials, whichis a very important property when the welded joints under fracture condition has been considered. Obviously, as a value ω_i is nearer to the unit a fracture conditions become more rigorous.

Now, we shell introduce a modified Jansons relation without a plastic zone:

$$\omega' = C_o'(s')^{\nu_o'} + \omega_i' \qquad (7.1)$$

$$\omega = C_o(s)^{\nu_o} + \omega_i \qquad (7.2)$$

At the zone boundary:

$$\omega' = C_o'(s_y') + \omega_i' = \omega_o' + \omega_i' \qquad (8.1)$$

$$\omega = C_o(s_y) + \omega_i = \omega_o + \omega_i \qquad (8.2)$$

Inside the zone damage is assumed to depend linearly on the crack opening whit a presence of the initial damage:

$$\omega'(x) = \omega_o' + \omega_i' + k'\eta'(x) \qquad (9.1)$$

$$\omega(x) = \omega_o + \omega_i + k\eta(x) \qquad (9.2)$$

where are ω_o', ω_o, k, k' and ω_i, ω_i' material parameters.

Introducing relations /9.1/ and /9.2/ in expression /4/ we have:

$$\sigma'(x) = s_y'[1 - \omega_o' - \omega_i' - k'\eta'(x)] \qquad (10.1)$$

$$\sigma(x) = s_y[1 - \omega_o - \omega_i - k\eta(x)] \qquad (10.2)$$

We shell concider now rezulting stress distribution in the sheet due to external load σ_∞ and the stress σ_x acting on the outer flanks of a crack /Fig. 4/ separeting our consideration on two parts: a<x<b and b<x<c.

Westergards /8/ complex stress functions are used here due to procedure indentical like in paper /5//which will not be represented by reason of shortness/. Using two independent integration procedure of stress function we get two relations /whit integration boundaries a-b and b-c/:

$$a/b = \cos[(\bar{u}/2)(\sigma_\infty/s_y')/\gamma'] \qquad (11.1)$$

$$b/c = \cos[(\bar{u}/2)(\sigma_\infty/s_y)/\gamma] \qquad (11.2)$$

From this two relations we can calculate the plastic zone length b and c, when we first calculate the crack half-opening $\eta'(x)$ and $\eta(x)$ by using Westergards solution for displacement at y-direction

$$\eta(z) = [2 \mathrm{Im} \bar{Z} - y(1+\nu) \mathrm{Re} Z]/E \qquad (12)$$

whit next conditions: z=x, y=0.

We shell concider now a possible crack instability criterion. Using equations /9.1/ and /9.2/ we get a values $\omega'(a)$ and $\omega(a)$.

As criterion for crack propagation Janson suggested the next condition: $\omega(a) = 1$.

In our case, this condition is transformed by two in the shape:

$$\omega'(a) = \omega'_o + k'\eta'(a) = 1 - \omega'_i \qquad (13.1)$$

$$\omega(a) = \omega_o + k\eta(a) = 1 - \omega_i \qquad (13.2)$$

where is $\omega'_i = \omega_i$. From two values got by this way, the smaller will be vaild. However, a particular situation will originate wher ω_i is very near /or equal/ to the unit, i.e. when a materials ductility is reduced at zero practicaly, and no damage in the material provoked by loading. It can be represented that the use of classical Dugdalss approach in this case is justified.

CONCLUSION

The method proposed here, presents one attempt that a combined approach of fracture mechanics and continuous damage mechanics can be applied on the weldments problems.

Introducting a new parametar of material / ω_i/ and separations of integration procedure on two independent parts, would make possible that the problems of local anisotropy and lamination in the welded joints be practicaly overrun.

SYMBOLS USED

ω = damage
A = surface
σ = stress
S = net stress
P = loading
ε = strain
C_0, ν_0, k = parameters of material
η = crack half-opening
z = complex variable
Z = Function of z, derived from stress function
$\bar{Z}$ = first integral of Z
I_m = imaginary part of complex function
R_e = real part of complex function
E = Young's moduls
ν = Poisson's ratio

REFERENCES

(1) Griffith, A.A., Phil. Trans. Roy. Soc., A221, 1920, pp.163-198

(2) Kachanov, L.M., Izv.Akad.Nauk SSSR, Otd.Tekh.Nauk., 8, 1958, pp. 26-31

(3) Janson, J., Hult J., J. de Mécan. Appl., 1, 1977, pp. 69-84

(4) Janson, J., Engng. Fracture Mech., 9, 1977. pp. 891-899

(5) Janson, J., Engng. Fracture Mech., 10, 1978, pp. 795-806

(6) Dugdale, D.S., J.Mech, Phys. Solids. 8, 1960, pp.100-104

(7) Soete, W., Denys, R., Revue de la Sounure, 4, 1975, pp. 165-176

(8) Westergard, H.M., J.Appl. Mech., 6.1939, pp. A49-A53.

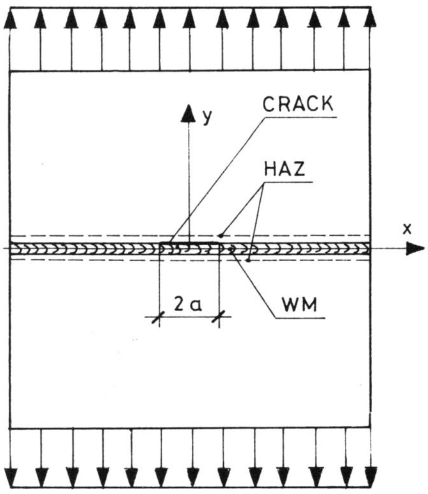
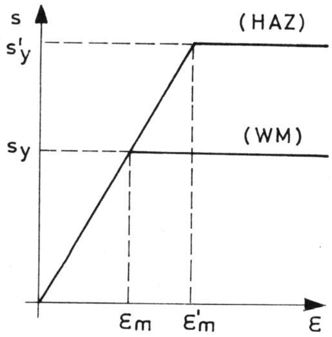


Figure 1



$s_y < s'_y$ (assumption)

$\varepsilon(\varepsilon') = s(s')/E, s(s') < s_y(s'_y)$

$\varepsilon(\varepsilon') = \text{indef.}, s(s') = s_y(s'_y)$

$\max\ \varepsilon(\varepsilon') = \varepsilon_m\ (\varepsilon'_m)$

Figure 2

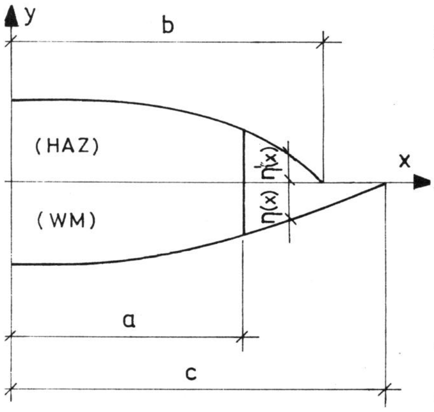


Figure 3

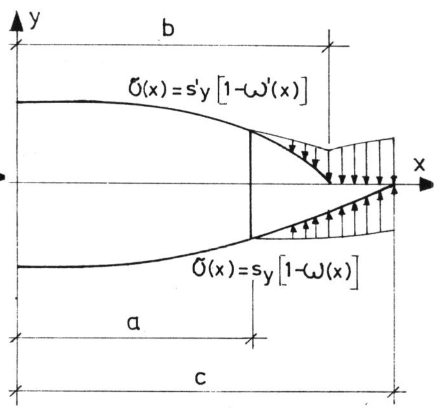


Figure 4