A KINETIC MODEL FOR THE DELAYED FRACTURE OF LOW-ALLOY STEEL WELDMENTS

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The process of cold crack formation in welding of low-alloy steels exhibits the main features of delayed fracture. Experimental studies showed that the crack growth during delayed fracture was accompanied by the development of local yielding and defect cumulation (Fig. 1). So, for an analysis of stable crack extension kinetics it is reasonable to use a damage parameter . It is assumed that an elemantary event of the main crack is caused by the formation of a critical damage level in front of the crack tip. The residual elastic deformation energy accumulated in a weldment is spent on the local plastic strain and microcracking:

$$\Psi = \Psi_\alpha + \Psi_c$$

where $\Psi_\alpha = A_1 \cdot W\alpha$, Ψ_α : parameter showing the degree of structure distortion, related to the system of dislocations distributed in a material volume;

$W\alpha$: density of dislocations;
A_1 : constant; $\Psi_c = A_2 \cdot \alpha \cdot N_c$;
Ψ_c : parameter related to the microcrack distribution
α : casual microcrack length;
N_c : concentration of microcracks;
A_2 : constant.

These two processes predetermine the kinetics of crack growth. The damage cumulation ahead of the main crack tip depends on the grain boundary orientation with respect to the direction of maximum tangential stresses. Although the main crack direction is normal to that of effective static stresses, the microfracture occurs along individual surfaces depending upon the orientation of grain boundaries and local microstresses (Fig. 2). In this case, the polycristalline material may be considered as a kind of composite consisting of grain body material and that of interface zone. A period between separate main crack increments depends upon the damage cumulation rate and the critical level of cumulated

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damages Ψ_f :

$$\min_t \left[t : \Psi(t) = \Psi_f \right] = t_f \ , \quad \frac{\partial \Psi}{\partial t} = \Phi(\sigma_i \ , T \ , t) \ , \quad i = 1,2,3,$$

where t - time; t_f - time interval between elementary crack "pop-ins"; σ_i (i = 1,2,3) - principal components of the stress tensor; T - temperature.

At the initial stage of strain in the prefracture region the grain boundaries are the main sources and cumulators of dislocations. A further their saturation with hydrogen contributes to the predominance of micro-crack openings at these sites. It is precisely this fact that explains an extremely low energy absorption of delayed fracture when a crack propagates by a ductile micromechanism.

A distinguishing feature of the hydrogen assisted delayed fracture process lies in the fact that a change of physical-mechanical material properties in a local region due to hydrogen concentration contributes to a spontaneous release of cumulated energy and elastic strains thereout. As a result, a self-developing pre-fracture zone is formed whose rupture leads to the next fracture source occurence somewhere at this zone boundary.

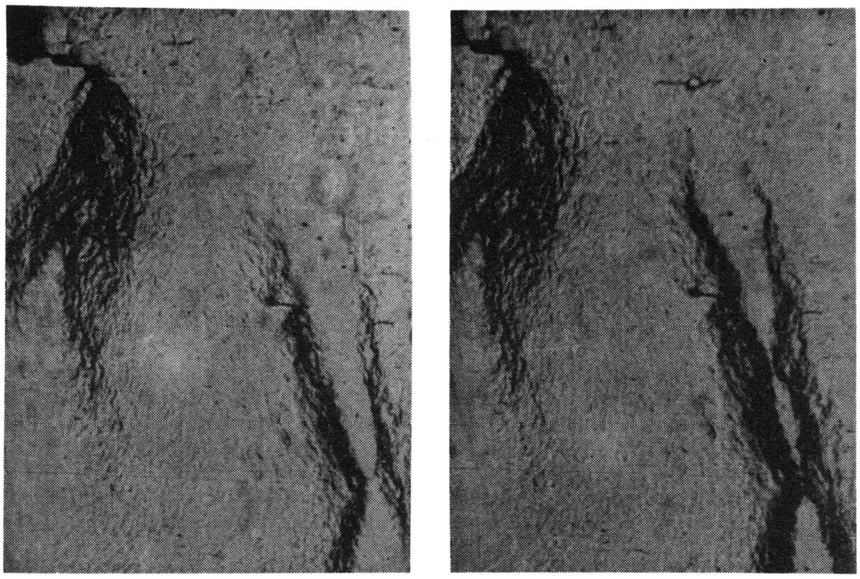

Figure 1 Kinetics of plastic strain development on the surface of a specimen: (a) t = 21 min, (b) t = 24 min, t - time from the loading onset.

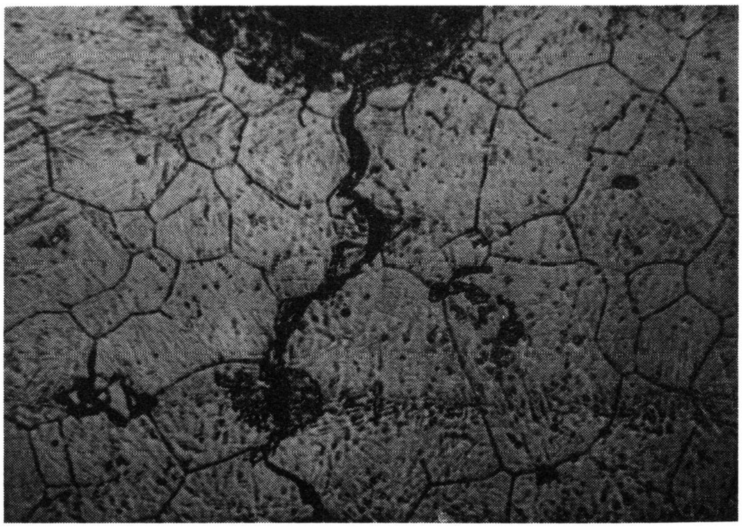

Figure 2 Delayed crack pattern in the regions of initiation and of stable growth