EFFECT OF LOCAL STRAIN IN STRESS CORROSION TESTING

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INTRODUCTION

In this work local strain -ε_L- in round notched bars of different geometries is numerically calculated in order to evaluate its effect in stress corrosion phenomena. To check these results, hydrogen embrittlement tests with notched samples of different notch acuity have been compared, showing that local strain is a relevant parameter for such processes.

LOCAL AND REMOTE STRAIN RATES

Four geometries of round notched samples were considered. In these specimens notch acuity, measured by notch radius R, as well as notch depth A, range from $0.03D$ to $0.40D$ and from $0.10D$ to $0.39D$, respectively, where D is the sample diameter. Results from computation confirm that a wide range of local strain-rate values were covered.

Material was modelled as strain hardening according to the Ramberg-Osgood expression, with E =199 GPa, σ_{02} = 600 MPa and u.t.s. 1151 MPa. Calculations were performed using the Finite Element Method and an elastoplastic code based on the Incremental Plasticity Theory. Tensile tests were simulated by displacement control at sample ends.

Strains are defined by dividing the displacements by a suitable length. For **local strain** at the notch tip, ε_L, a reference length $L_L = 0.01D$ was selected after checking that was small enough that numerical results were independent of that reference length and also much higher than relevant microstructural aspects -the size of pearlite colony for selected steel-. To be more precise, for D = 11 mm the local reference length is L_L = 110 μm and average colony size was 15 μm. This local strain is compared with a **remote strain**, ε_R obtained by dividing remote displacement -the displacement at sample end- by an arbitrary length D, the sample diameter. Strain rates $\dot{\varepsilon}_L$ and $\dot{\varepsilon}_R$ are defined, accordingly, as:

$$\dot{\varepsilon}_L = \frac{u_L^{i+1} - u_L^{i}}{0.01D\,\Delta t} \qquad \text{and} \qquad \dot{\varepsilon}_R = \frac{u_R^{i+1} - u_R^{i}}{D\,\Delta t} \qquad (1)$$

where indexes i and $i+1$ are used to designate values at instants t and $t + \Delta t$ respectively. Relative values of local and remote strain rates will depend on geometry, material properties and remote displacement if plasticity is present.

EXPERIMENTAL RESULTS

A commercial eutectoid pearlitic steel, supplied in bar form of 12 mm diameter, was used for the experimental programme. The test environment was the same used by Parkins et al (1). All tests were performed at -1200 mV (SCE).

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Test results are depicted in Figure 1, for geometries *A*, *B*, *C* and *D*, where rupture load in the aggressive enviornment, F_R, -normalized to rupture load in air, F_0- is plotted versus remote displacement rate $\dot{u}_R$. Such results show the well known trend of hydrogen embrittlment tests when plotted against remote strain-rate, if it is taken into account that t_R is proportional to $\dot{\varepsilon}_R^{-1}$.

Fractographic analysis of samples of type *A* and *C* always showed that crack initiates at a small region at the notch tip where fracture surface may be classified as TTS (tearing topography surface),according to Thompson and Chesnutt (2), and there is a strong suspiction that it is related to the hydrogen embrittlement phenomenon. Work on samples *B* and *D* is still in progress. Outside the small TTS region, fracture surfaces may be classified as quasi-cleavage.

ROLE OF LOCAL STRAIN IN FRACTURE

Hydrogen embrittlement results plotted in Figure 1 show quite clearly that although performed at the same remote displacement rate, $\dot{u}_R$ (or conventional remote strain rate $\dot{\varepsilon}_R = \dot{u}_R/D$), rupture load depends on notch geometry. If, as is suspected, local strain rate at the tip of the notch is a more relevant parameter, replotting rupture loads versus local strain rate, ε_L, should gather the results. Because rupture loads are also influenced by stress triaxiality -a function of notch geometry- it would be better to apply a more general fracture criterion embedding the stress tensor. A simple criterion is when the equivalent stress (in the Von Mises sense) reaches a critical value over a critical region as it has been pointed out by Toribio (3); i.e., when

$$<\bar{\sigma}> = \bar{\sigma}_c \qquad (2)$$

where < > means averaging over the TTS region, as it is verified in reference (3).$\bar{\sigma}_c$ is computed in two steps; first, from rupture load, stress distribution and equivalent stresses are computed; second, equivalent stress is averaged over TTS region, known from fractographic measurements. This procedure allows a change from F_R/F_0 to $\bar{\sigma}_c/\bar{\sigma}_0$, where $\bar{\sigma}_0$ is $\bar{\sigma}$ averaged over a characteristic microstructural region, in the average size of two pearlitic colonies, critical zone in an innert environment according to reference (3).Change from $\dot{\varepsilon}_R$ to $\dot{\varepsilon}_L$ is a bit more involved, by averaging $\dot{\varepsilon}_L$ over the TTS region and during test period (reference (3)). Such space-time average is represented by $<<\dot{\varepsilon}_L>>$. Finally, averaged local strain is included in a nondimensional parameter, $<<\dot{\varepsilon}_L>> \; x^2/D^*$ where D^* is hydrogen diffusion constant and x a characteristic length: the depth of the maximum hydrostatic stress ($\sigma_{ii}/3$). In figure 2, $\bar{\sigma}_c/\bar{\sigma}_0$ versus $<<\dot{\varepsilon}_L>> x^2/D^*$ is represented.

CONCLUSIONS

All the results fit in the same curve, showing the relevant role of local strain rate -$\dot{\varepsilon}_L$- in stress corrosion testing.

TTS region is the critic zone in hydrogen embrittlement phenomena.

A fracture criteria in aggresive environment, with a kinematic formulation, has been pointed out.

REFERENCES

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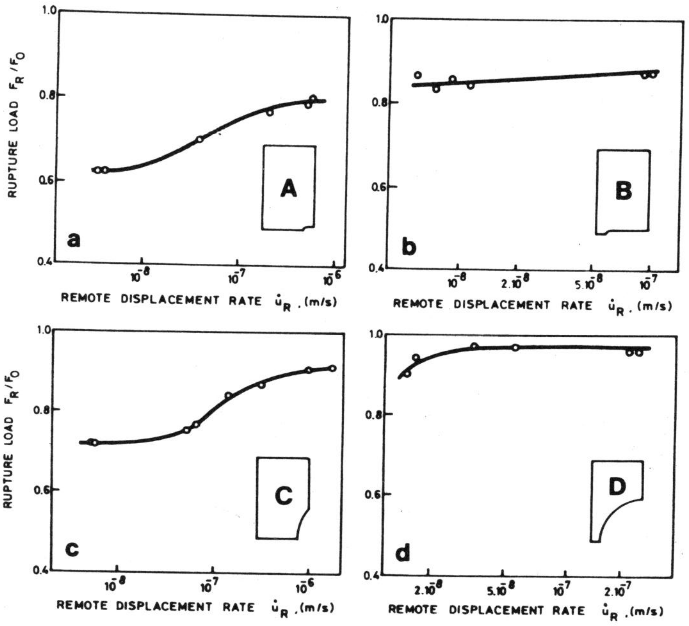

Figure 1 Hydrogen embrittlement test results versus remote displacement rate.

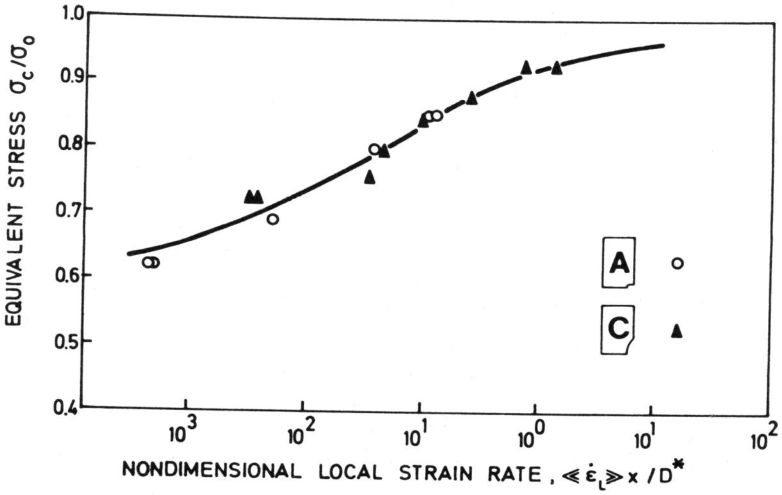

Figure 2 Hydrogen embrittlement test results versus local strain rate.