STRESS CORROSION TESTS IN WATER AT 288°C, USING THE UNLOADING COMPLIANCE TECHNIQUE.

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The environmentally assisted cracking of pressure vessel steel in water environment causes very high crack velocity (10^{-4}mm/s). Tests were performed on notched compact tension specimens of A533B cl1 steel, in pressurized (8Mpa) water environment, at 288°C, using a technique similar to the Unloading Compliance, with different loading rates. The results were compared with those of similar tests in air.

The strain rate dependence of the environmental effect was clearly confirmed; a first indication of the criteria to get reliable K_{ISCC} values from J_{ISCC} data was obtained.

INTRODUCTION

Precracked specimens were firstly used by F. Brown (1), to evaluate Stess Corrosion Cracking (SCC) materials properties, such as K_{Iscc} and the SCC crack growth rate. The test technique was either constant deflection or constant load; only recently monotonically increasing load has been used (2), leading to the application of fracture mechanics testing procedures in agressive environments. Although these techniques are well esperienced in laboratory air, they can present some problems in environments, particularly when high temperature and high pressure (autoclaves) are involved. Moreover it is not yet clear which testing conditions must be actually used to obtain reliable SCC data.

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EXPERIMENTAL

The tested material was A533B cl.1 pressure vessel steel, with the composition given in Tab.1.

TABLE 1 Chemical composition of A533B-Cl1 (wt %)

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al
0.18	1.41	0.008	0.009	0.23	0.13	0.48	0.11	0.48	0.045

1TCT specimens were precracked to a/w in the interval 0.4-0.6. Tests were performed in demineralized water at a temperature of 288 °C; the nominal dissolved oxygen was about 200 ppb and the pressure was 8 MPa. Constant opening rate values ranging from $1.5*10^{-6}$ mm/s and $2.5*10^{-4}$ mm/s were used. Experimental conditions are summarized in Tab.2. Unloadings were performed at time intervals to obtain some information about mean crack lengths. (An approximation of a linear crack growth behaviour was adopted when unloadings did not gave good enough results).
Fracture surface morphologies were observed in a Scanning Electron Microscope (SEM).

TABLE 2 PRECRACKED CT 1" SPECIMENS

SAMPLE N°	DISPLACEMENT RATE (mm/s)	STARTING CRACK LENGTH (mm)	FINAL CRACK LENGTH (mm)	da/dt (mm/s)	SCC
SSR1	$7.5*10^{-6}$	23.92	29.44	$3.2*10^{-5}$	yes
SSR2	$1.5*10^{-6}$	27.54	29.19	$3.3*10^{-6}$	no
SSR3	$2.5*10^{-4}$	31.92	39.91	$3.2*10^{-4}$	50%
SSR4	$1.5*10^{-6}$	30.86	33.97	$3*10^{-6}$	no

RESULTS

In fig.1 and 2 load (P) vs displacement (δ) and J vs crack increment (da) curves for the four specimens tested in water are shown, compared with the results of air tests previously performed on the same steel at $1.7*10^{-3}$mm/s displacement rate.

In the elastic part, the P vs δ curves of water tested specimens have a higher slope, indicating an increase in elastic modulus of the material due to the presence of water, as previously observed in corrosion fatigue (3). The J vs da curves of the water tests are lower than for the one in air, indicating that less mechanical work is necessary for crack growth in environment. The $J_{0.2}$ values obtained are shown in Fig.3 versus displacement rates, to notify their strain rate dependence.

The enviromental effects are present at the highest level in the specimen SSR1, which sustained the lowest load level and had the lowest $J_{0.2}$ and tearing slope values. The fracture surface morfology of this specimen is completely brittle, with fan shaped features, typical of SCC of pressure vessel steel in water at 288°C (see fig.4). Fracture surface morfology is generally ductile in the two specimens tested at the lowest displacement rate (see fig. 5). Brittle regions are present mainly around the sites of elongated MnS inclusions and in the lateral regions of the SSR3 specimen, tested at an opening rate higher than that of SSR1 (see fig.6,7).

Crack growth rates were calculated from fracture surface markings (mainly those obtained on lateral brittle regions of SSR3 sample, by 100% unloading); distances were measured in the local effective direction of crack propagation (arrows in fig.7). The measured 10^{-4}mm/s value is quite similar to the $(da/dt)_{SCC}$ values obtained both from traditional static SCC tests (4) and from corrosion fatigue tests (plateu values) (5).

DISCUSSION

The occurrence of the SCC process has been found to be generally dependent on the displacement rate used in the tests (2,3). The results shown in fig.3

confirm that the $J_{0.2}$ values obtained in water exhibit a minimum at displacement rate values around 10^{-5}mm/s, in the region where SCC is dominant. If the opening rate is higher or lower of about one order of magnitude the environmental effect is no more dominant and $J_{0.2}$ values are higher. Only for the minimum J_{Iscc} value, K_{Iscc} values calculated using the well known relationship ($J=K^2/E'$) give results comparable to those obtained from SCC classical tests; the $J_{0.2}$ value of the test showing completely brittle fracture surface (SSR1) is comparable with J_{ISCC} while the other $J_{0.2}$ values are higher. This result indicates a very important point: fracture mechanics tests at constant opening rates on precracked specimens can determine K_{ISCC} only if SCC is dominant.

From a pratical point of view, it can be proposed a test technique using different displacement rates, until the lowest $J_{0.2}$ is obtained. That will permit a the correct estimate of K_{ISCC} value. The described testing procedure can however be time consuming and expensive; some more considerations about the crack growth rate (da/dt) results can be useful.

In both Slow Strain Rate and Corrosion Fatigue testing, it has been evidenced that the onset of SCC is related to a competition process between passivation rate and bare surface creation rate (6), this last parameter being proportional to crack growth rate.

In tab.2 mean crack growth rate values are compared with the nominal opening rate for all the tests. Only when the nominal opening rate is about one order of magnitude lower of the crack growth rate of the SCC process, this is dominant (brittle morfology present all over the crack front as in SSR1 specimen) and a correct J_{ISCC} o K_{ISCC} is obtained. In the specimens tested at too low opening rates, SCC can't ever become the dominant process and ductile tearing occurs. If the opening rate is too high, environmentally assisted cracking does not have enough time to be operating. Moreover, at intermediate values of displacement rates both SCC and ductile tearing can be observed; this was actually the case of the specimen SSR3, on the sides (see Fig.7) and locally around inclusions. A better insight of the influence of loading rate on the onset of SCC can be obtained by using the superposition model (7); it is also important to take into account the influence of local effective (da/dt) values, since they can be different at different positions on the crack front.

CONCLUSION

As a conclusion these results seem to give a first indication of the criteria to obtain K_{ISCC} from fracture mechanics tests in environment. More precisely: SCC is the dominant crack growth process if the local effective (da/dt) value induced from the mechanical loading is about one order of magnitude lower than the $(da/dt)_{SCC}$ of the couple material-environment under study. This seems to be the indication requested by Dietzel (2) in his work on Al alloy with different experimental conditions.

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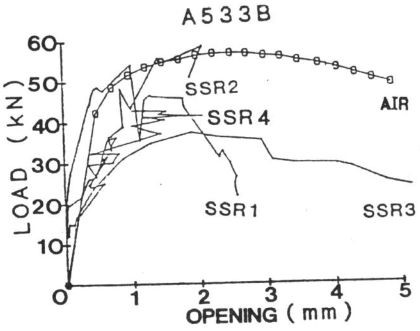

Figure 1 Load-Displacement

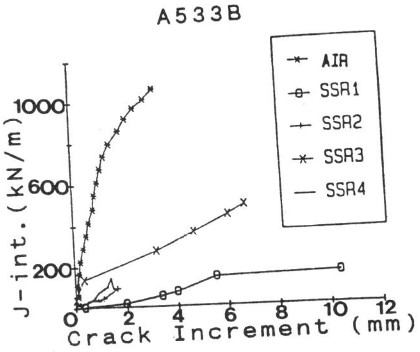

Figure 2 Jintegral-δa curves

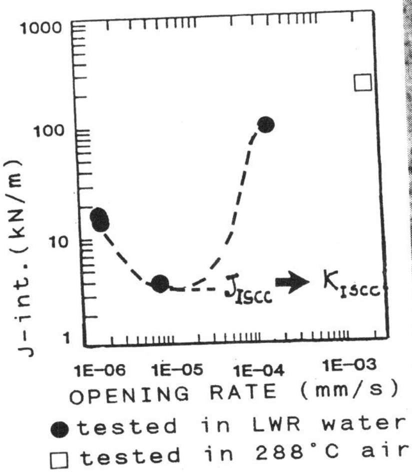

Figure 3 J_{ISCC} values as function of opening rate

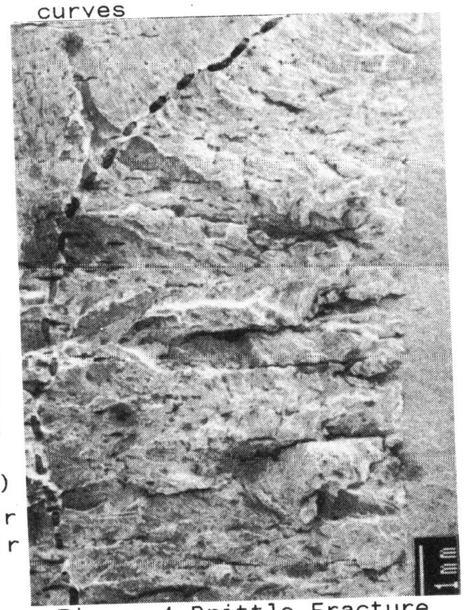

Figure 4 Brittle Fracture Surface of Speciment SSR1

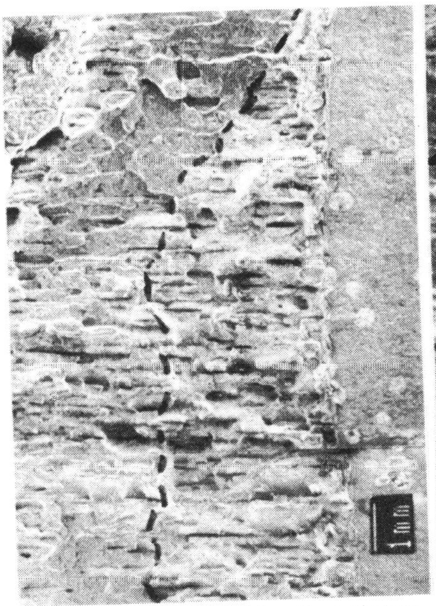

Figure 5 Ductile Fracture Surface of Specimen SSR2

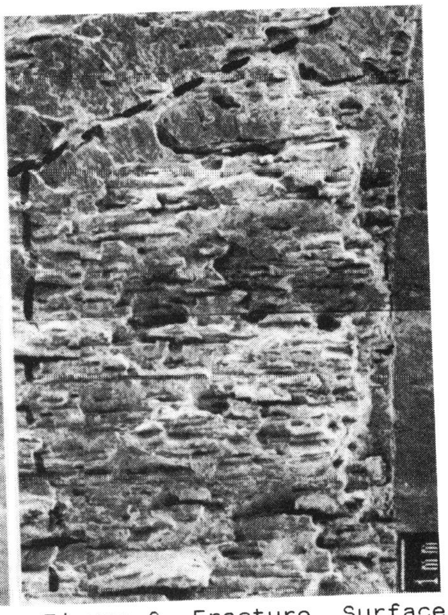

Figure 6 Fracture Surface of Specimen SSR3

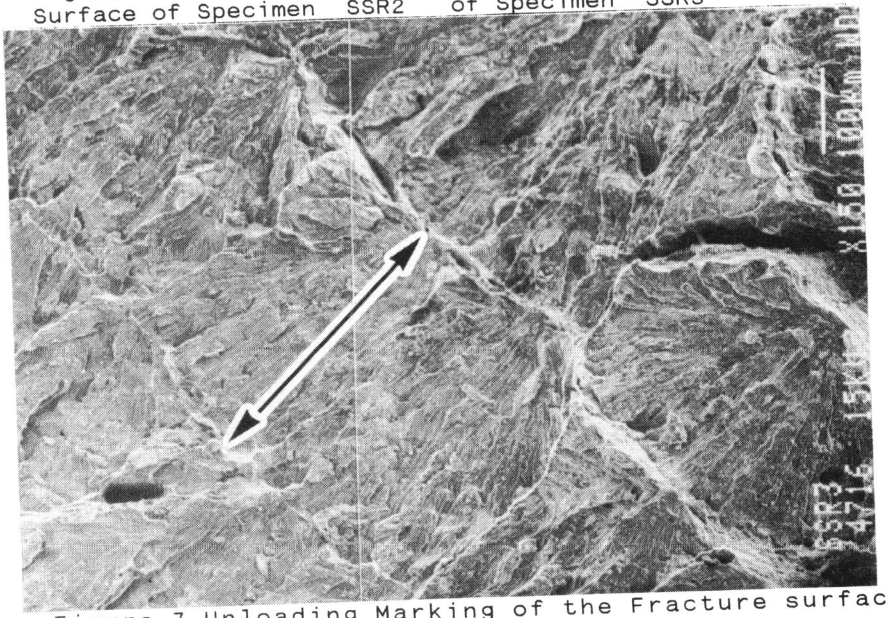

Figure 7 Unloading Marking of the Fracture surface of Specimen SSR3