THE USE OF SLOW STRAIN RATE TESTS FOR MEASURING THE VELOCITY OF ENVIRONMENTALLY ASSISTED CRACKING

K. Strieder, K.-H. Daum, W. Dietzel and J. Müller-Roos*

Slow Strain Rate Tests (SSRT) on smooth cylindrical tensile specimens were carried out in corrosive environments for three material/environment systems. The fracture modes were investigated by scanning electron microscopy and found to be identical to earlier experiments on pre-cracked specimens under equivalent environmental conditions. The crack growth velocities for environmentally assisted cracking (EAC) were determined. A comparison of the data obtained with the two different test techniques led to the conclusion that crack growth velocities from SSRT on smooth cylindrical tensile specimens may serve as suitable input data for dynamic EAC tests following the test procedure in ESIS P4-92 D.

INTRODUCTION

Slow strain rate testing has been used for more than 25 years as a method for characterizing the propensity of metallic materials to environmentally assisted cracking (1). In its original form, in which the specimens are continuously strained to total failure, the test was developed as a rapid sorting approach to the effects of metallurgical or environmental changes in material/environment systems. However, in recent years it has increasingly been employed for quantitative testing, e.g. to determine threshold stresses for environmentally assisted cracking. Another parameter often deduced from slow strain rate tests is the velocity at which the EAC takes place.

According to the ISO Standard 7539 - Part 7 (2) an average stress corrosion crack growth velocity may be determined from a slow strain rate test by measuring the depth of the longest environment induced crack on the fracture surface of a

* GKSS-Forschungszentrum Geesthacht GmbH, Geesthacht, Germany

specimen that has failed, and then dividing this value by the time of testing. Here it is assumed that EAC initiates at the start of the test which, for obvious reasons, in most cases is not a valid assumption. In the work reported here, an attempt was made to identify the exact onset of EAC in a slow strain rate test, and to thus achieve more precise information about the time elapsed during crack growth.

One goal of this work was to determine the amount of error that is associated with computing average crack velocities following ISO 7539-7 instead of using the correctly measured values. The second goal was to assess the usefulness of crack growth velocities measured in slow strain rate tests on smooth specimens serving as input parameters for the determination of the displacement rates at which dynamic EAC tests on pre-cracked fracture mechanics specimens should be carried out following the ESIS document P4-92 D (3).

EXPERIMENTAL PROCEDURE

In the experiments three different material/environment systems were investigated: The high strength aluminium-copper-magnesium alloy Al 2024 (T351 temper, short transverse) tested in a chromate inhibited aqueous 3.5% sodium chloride solution, a higher strength low alloy steel with the European designation FeE 690 T, again tested in 3.5% sodium chloride but under cathodic protection (- 1 V vs. Ag/AgCl), and a duplex stainless steel. This latter material with the German designation G-X3CrNiMoCuN 26 6 3 3 was tested in a 20% calcium chloride solution at 75°C.

The tests were performed at strain rates ranging from 3×10^{-8} to 3×10^{-5} s^{-1}; reference tests were done at similar strain rates in air. A direct current potential drop technique (DCPD) was used as a means for monitoring the behaviour of environmentally induced cracks (Fig. 1). The crack velocities obtained were compared with values measured for the identical material/environment combinations in fracture mechanics tests. In these latter tests pre-cracked compact tension (CT) specimens were subjected to constantly rising load line displacements. The displacement rates at which these experiments were carried out were chosen on the order of 1 µm/h. Here too, the crack growth was monitored using the DCPD technique (4).

RESULTS

Following Heerens et al. (5) the attempt was made to identify the initiation point of environmentally induced cracks as the transition point from linear to non-linear portion in F-U curves recorded by DCPD (Fig. 2). Figure 3 gives an example of such a curve, recorded in this work.

Though in most of the slow strain rate tests on smooth specimens it was not possible to unambiguously identify the starting point for subcritical crack growth due to EAC, the crack growth velocities calculated with respect to the above mentioned transition point were in the same order of magnitude as those calculated using the simple approach suggested in ISO 7539-7. Both crack growth velocities were in considerably good agreement with velocities measured in the more sophisticated fracture mechanics tests.

An electron microscopy investigation of the fracture surfaces of specimens failed in a slow strain rate test and those which failed in a fracture mechanics test performed at a low displacement rate revealed similar fracture morphologies for both types of testing. The aluminium alloy exhibited the typical intercrystalline fracture, whereas the high strength steel showed quasi cleavage fracture. The ferrite grains of the two-phase Duplex steel failed by cleavage fracture with the austenite mechanically deformed to tear ridges.

The main difference between the testing of smooth and pre-cracked specimens was the amount of testing time that was required to obtain the information about the crack growth velocity. Whereas in a fracture mechanics type of EAC test the time took between one and two months, a slow strain rate test performed for the same corrosion system was often finished within one or two weeks.

Thus, it may be concluded that slow strain rate tests performed on smooth specimens can be a suitable means for obtaining rapid - although rough - information about the velocity at which the subcritical crack growth takes place in a given corrosion system. This information may then be used to determine the suitable displacement rate for a fracture mechanics EAC test, aimed at the determination of the threshold parameter for the onset of environmental cracking, K_{ISCC}, following the test procedure specified in ESIS P4-92 D (3).

REFERENCES

(1) Henthorne, M. and Parkins, R.N., Corr. Sci., No. 6, 1968, p. 357

(2) ISO Standard 7539: Corrosion of Metals and Alloys Stress Corrosion Testing; Part 7: Slow Strain Rate Stress Corrosion Tests, International Organization for Standardization, Geneva, 1989

(3) ESIS P4-92 D: Recommendations for Stress Corrosion Testing Using Pre-Cracked Specimens (1st Draft), ESIS Office, Delft, 1992

(4) Dietzel, W. and Schwalbe, K.-H., Z. Materialprüfung/Materials Testing, No. 28, 1986, pp. 368-372

(5) Heerens, J., Schwalbe, K.-H., Hellmann, D., Knaack, J. and Müller-Roos, J., "Application of the DC Potential Drop and the Partial Unloading Methods to Fracture Mechanics Tests", GKSS 85/E/16, GKSS-Forschungszentrum Geesthacht GmbH, Geesthacht, Germany, 1985

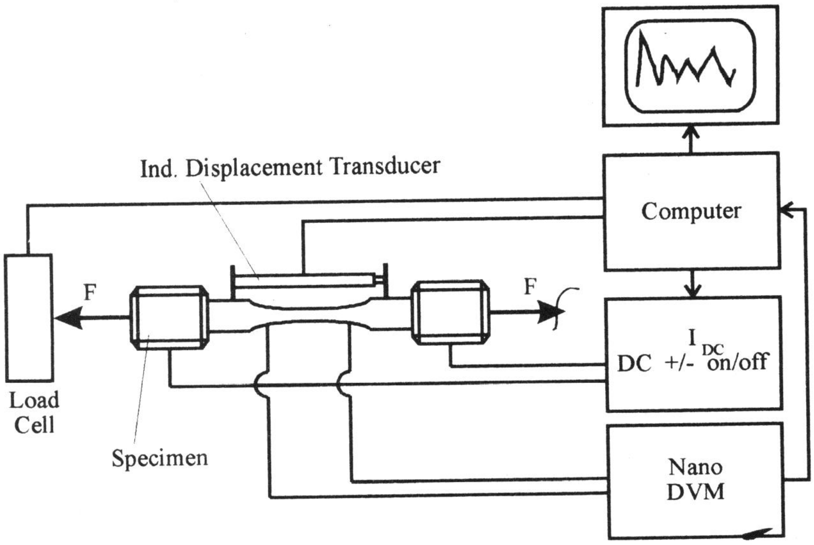

Figure 1 Experimental setup for slow strain rate tests using a DC potential drop technique for monitoring the onset of cracking

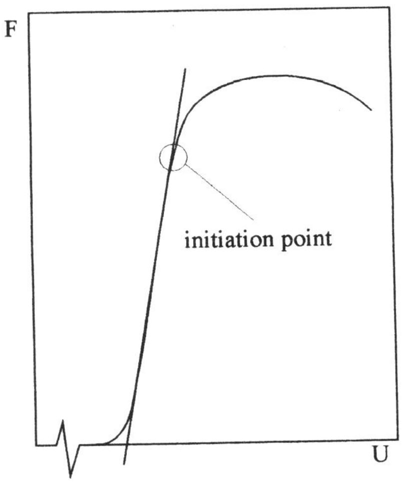

Figure 2 F-U curve indicating the initiation point for EAC (5)

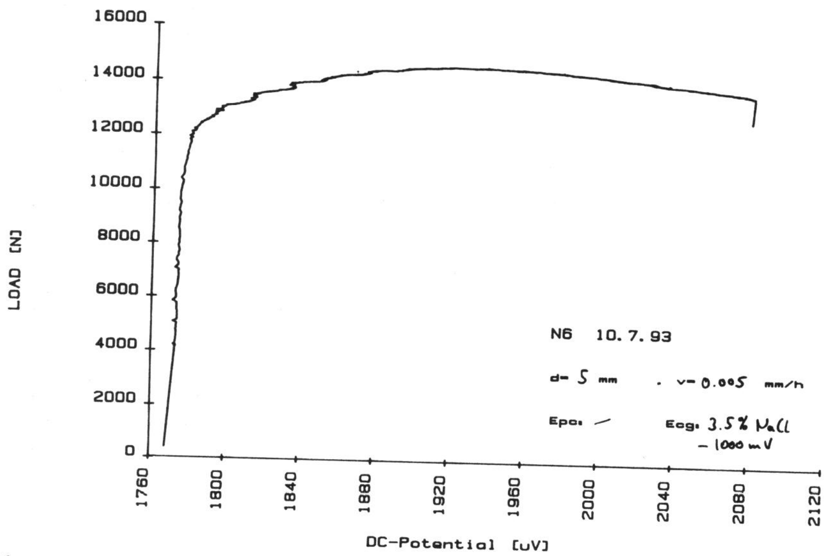

Figure 3 Load versus potential drop curve measured in a slow strain rate test on a smooth specimen (steel FeE 690 T, 3.5 NaCl solution, -1V vs. Ag/AgC)