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Optimization of Crack Length Measurement by DCPD in DCB Specimens

Jian Yu
School of Engineering, Sheffield Hallam University, Sheffield, UK

Jeremy C. Barker
AEA Consultancy Services, Culham, Oxfordshire, UK

Ray Brook
Department of Engineering Materials, University of Sheffield, Sheffield, UK

ABSTRACT

The optimization of four-probe DCPD crack length measurement has been carried out experimentally for the NACE standard double cantilever beam (DCB) specimen with side grooves, for which the solution based on available analytical or numerical approaches remains difficult due to specimen geometry. The optimum lead positions give good combined sensitivities to both absolute output and relative DCPD ratio, as well as a good linear correlation with crack length. A DCB analogue with uniform thickness has also been further tested. The results show that the principles of the optimization hold for DCB specimens with or without side grooves. Technical points related to the four-probe DCPD method are discussed.

INTRODUCTION

The double cantilever beam (DCB) specimen has been used extensively in the research and development of structural steels for oil/gas industrial applications; it is the only type of fracture mechanics-based specimen specified, so far, by the NACE standard (NACE TM0177-90) to test the resistance of metals to sulphide stress corrosion cracking (SSCC). Although the specimen was intended, mainly, to determine the threshold stress intensity factor, K_{1scc}, and the existing standards (NACE TM0177-90, ISO7539:1989) do not address the measurement of crack growth rate, it has been realized that the monitoring of its crack growth is advantageous for the following reasons:

- To ensure that crack propagation has ceased, and hence the reliability of the related threshold value.

The test duration necessary to obtain K_{1scc} using DCB specimens is strongly dependent on the metal/environment to be tested. For instance, it can vary from just two weeks for high-strength low-alloy steels (HSLA) in H_2S saturated 5% brine (Heady, 1977, NACE TM0177-90) up to several months for 13%Cr stainless steel in 5% brine containing 20 ppm H_2S (Barker et al., 1993). The stress intensity factor initially applied may also affect the termination time of the test (ISO7539:1989). The test duration given by the NACE standard is empirical; only a minimum test time is suggested for a limited number of metals in the standard solution.

- To characterize the cracking behaviour.

Very useful information, e.g., da/dt vs. K^1, hydrogen delayed cracking and intermittent advance of the crack, etc. (Yu and Brook, 1991; Yu et al., 1994a) can be obtained and used for material selection and life prediction of components.

- To evaluate the testing methodology.

For example, an optimum displacement or initial K^1 may be justified for a newly tested metal/environment system, minimizing the delay of crack initiation without causing overloading of the DCB specimens, which are usually sensitive to crack branching (side-cracking) (NACE TM0177-90, ISO7539:1989, Yu et al., 1994b; Hadley, 1983; Heady, 1977; Smith and Piper, 1970).

- To allow prompt replacement of specimens which become invalid through side-cracking; this is the most economic way of ensuring that valid data is obtained from tests of long duration.

Amongst all the established methods (Dean and Richards, 1977), direct current potential drop (DCPD) is the one best suited to monitoring crack growth in DCB specimens. Obviously, all the techniques based on the principles of the change of compliance are inappropriate to specimens loaded in constant displacement. The environments in which DCB specimens are often tested can be so hostile that optical methods and sonic methods become very difficult and sophisticated. Either of the potential drop methods (AC or DC power supply) may be used, but DCPD, relatively, provides better operation for long-duration tests and utilizes simpler and more economic facilities.

There are two essential requirements to be met for DCPD measurement. Firstly, the loading arms must be insulated from each other; for DCB specimens, this can be achieved by using insulating wedges (Interrante and Low, 1981; Yu and Brook, 1991). Secondly, the lead positions should be optimized to provide DCPD output of good sensitivity and giving sufficient confidence in the calibration with crack length.

The two-probe DCPD method has been used by previous workers (Interrante and Low, 1981) in measuring da/dt vs. K_1 of HSLA steel DCB specimens in H_2S solution. They reported that one pair of leads symmetrically positioned near the edge of the specimen top-slot gave satisfactory sensitivity and good linear relationship between crack length and DCPD. However, in this two-probe method an additional reference specimen is needed in order to alleviate possible errors caused by the inevitable fluctua-

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