International Journal of Offshore and Polar Engineering
Vol. 5, No. 1, March 1995 (ISSN 1053-5381)

Initiation and Growth Behavior of SCC in Notch Root on High Strength Steel

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ABSTRACT

The experiment is conducted by notched three-point-bending specimens on high strength steel in a 3.5% NaCl solution environment. Crack growth behavior of SCC at the initial stage is detected by using acoustic emission (AE) techniques. The AE total energy method is an effective measurement which detected exactly small crack growth behavior of the inside of the specimen in a corrosive environment. AE total energy is increased stepwise with a growing small crack; it is supposed that SCC is grown discontinuously. The value of the aspect ratio on a small crack is of high value at the initial stage, its value decreased with a growing small crack, and it approximated to the constant value. The small crack is grown below the K_{ISCC} of the long crack, and its growth rate is faster than the long crack itself. The grain boundary fracture area of the small crack near the K_{ISCC} is shown to be of higher value than that of a long crack.

INTRODUCTION

The fracture patterns in actual machines and structures often occur starting from a crack which existed in the surface of materials, to be called small crack. It is important to grasp the growth behavior of SCC (Stress Corrosion Cracking) from the notch root at the initial stage and to evaluate the remaining life. Many investigations on the SCC, however, have been performed from penetrated crack through thickness direction, to be called long crack, based on linear fracture mechanics. It is difficult to apply linear fracture mechanics to a small crack (Pearson, 1975). For example, a small crack in the fatigue crack grows undergone the effect of plastic zone in notch-tip, and its crack grows up out of effecting zone to be a long crack. In the initial stage of crack growth, its crack growth rate is inversely proportional to crack length. After its rate shows minimum value, it accelerates again or to be stopping crack. This will lead us further into a consideration of a new concept about the behavior of a small crack. So far, many investigations on the SCC have been done about long crack; little attention has been given to the behavior of small crack. In this study, the SCC tests are conducted for AISI 4340 steel using three-point-bending specimens 3.5% NaCl solution environment. Attention is focussed on the growth behavior of SCC until a small crack penetrates through thickness direction. Furthermore, the behavior of small crack on SCC is grasped by AE techniques, and the mechanism of small crack is discussed in this connection.

EXPERIMENTAL PROCEDURE

Material and Specimen

The material used is AISI 4340 steel. The chemical composition of the material is as follows (wt. percent): 0.39C, 0.28Si, 0.74Mn, 1.38Ni, 0.78Cr and 0.23Mo. The specimen provided is a three-points-bending specimen, as shown in Fig. 1. The notch-tip of the specimen is machined carefully by a wire cut electrical discharge machine (Sodic AW-330), and electro-polishing is carried out. The heat treatment of specimens is carried out normalizing at 1153K for 1 h, oil quenching at 1123K for 1 h, and tempering at 473K for 2 h. Mechanical properties after the heat treatment are: yield stress σ_Y = 1530MPa, tensile stress σ_B = 1880MPa, elongation ε = 4.5%

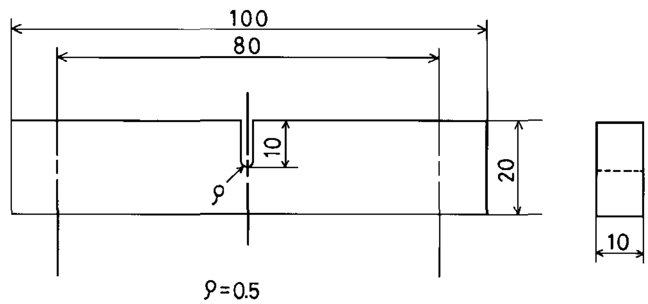

Fig. 1 Dimensions of three-point-bending specimen (in mm)

Measurement of Acoustic Emission

The AE technique is carried out by the method of 2-channel coincidence. AE sensors (anticorrosion type, NAIS Σ 2215) are put on both sides of the specimen symmetrically to the notch root. The amplification factor of preamplifier is 46dB, main amplifier's 30dB and threshold voltage V_{th} is 80μV. The AE measurement is performed by the change of AE total energy, E, plotted by the recording apparatus with respect to time.

Stress Corrosion Cracking Test

The equipment used for tests is the compression type, which gives the constant displacement (Hirose, 1992a). The apparent stress intensity factor K_ρ is calculated by the load, P, and the crack length, a_0, as shown in Eq. 1 (ASTM, E-399):

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Received January 28, 1994: revised manuscript received by the editors October 31, 1994. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.
KEY WORDS: Stress corrosion cracking, small crack, long crack, grain boundary fracture area, delayed phenomenon, high-strength steel, AE method.