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Stress Corrosion Cracking of AISI 4340 Steel Under Controlled Electrode Potential

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ABSTRACT

The effect of hydrogen contents on crack nucleation time was achieved by using compact tension specimens of 473K tempered AISI 4340 steel in three kinds of solutions under various electrode potentials. The crack nucleation at the notch root is determined by the electrical potential drop method. When the crack initiates, the voltage differences between the notch mouth start to increase. The crack initiation times depend on hydrogen contents and the apparent stress intensity factors. These dependencies are successfully explained by a dislocation pile-up model with hydrogen atom interaction.

INTRODUCTION

Considerable work has been done to clarify the crack nucleation mechanisms of hydrogen-assisted cracking (Beachem, 1972; Hirose and Tanaka, 1977; Oriani and Josephic, 1974; Page and Gerberich, 1982; Troiano, 1960; Van Leeuwen, 1975).

In the present paper, the effect of hydrogen contents on crack nucleation time was investigated for 473K tempered AISI 4340 steel in three kinds of solutions: distilled water, 3.5% NaCl solution and 0.1N H_2SO_4 solution.

A new dislocation model is proposed to explain the crack nucleation phenomenon. Experiments are performed to compare with the present theory.

EXPERIMENTAL PROCEDURE

The material used was AISI 4340 steel (weight %: 0.39C, 0.74Mn, 1.38Ni, 0.78Cr, 0.23Mo). Compact tension specimens (Fig. 1) with notch radius of $\rho = 0.5$ mm and thickness of $B = 5.5$ mm were machined from cutting a slice at the right angle to the axis from a hot rolled round bar 100 mm in diameter. The specimens were normalized at 1153 K for 1 h and austenized at 1123 K for 1 h and then oil-quenched and tempered at 473 K for 2 h. After the surface layer was removed by grinding, the notch was carefully made by an electrical discharge machine to minimize the worked layer. The specimens were finally finished by electrolytic polishing. The mechanical properties of the material after heat treatment are given in Table 1. The yield strength is 1530 MPa.

The testing machine used was a simple lever type and the load was adjustable to maintain a constant stress intensity factor (Hirose et al., 1982; Hirose and Mura, 1984a, 1984b, 1984c, 1985a, 1985b). Crack initiation was measured by the AC electrical potential drop method as shown in Fig. 2.

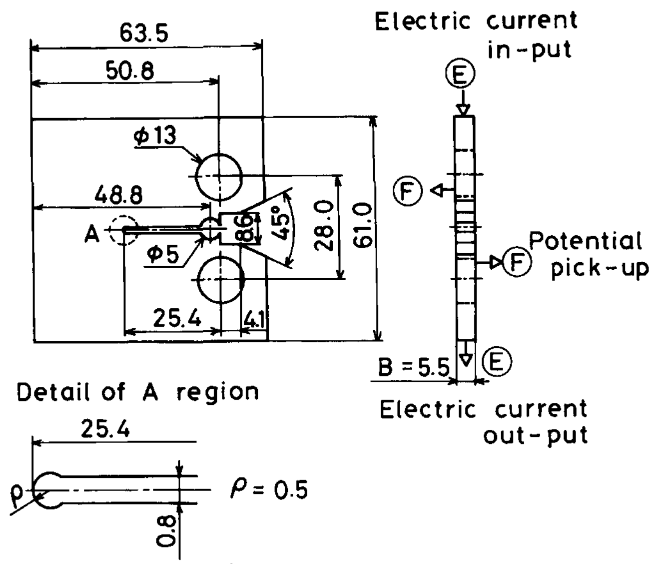

Fig. 1 Dimensions of compact tension type specimen and electrical potential pick-up position (in mm)

Heat treatment	Yield strength σ_Y(MPa)	Tensile strength σ_B(MPa)	Elongation ε_f(%)
Oil-quenching (1123 K × 1 h) Tempering (473 K × 2 h)	1530	1880	4.5

Table 1 Mechanical properties and heat treatment

The value of the stress intensity factor (SIF), K, was calculated from the load and crack length, and the apparent SIF, K_ρ, for blunt notches was calculated by taking $\rho = 0$. The corrosive environments are distilled water, 3.5% NaCl and 0.1N H_2SO_4.

The temperature of solution was kept at 298±2° K. Platinum plate was used for counter electrode, and reference electrode was

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KEY WORDS: Hydrogen content, crack nucleation time, electrode potential, notch root, apparent stress intensity factor, dislocation pile-up model, micromechanics.