Evaluation of the Hydrogen Embrittlement on the Hydrogen Exposed Austenitic Stainless Steel Fatigue Specimens by Eddy Current Testing

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Background

Mechanism of the hydrogen embrittlement of the austenitic stainless steels is considered to be related to the martensitic transformation. Diffusion rate of hydrogen is about 10^4 higher at martensitic phase to austenite phase[1] and martensitic transformation occurs when stress is applied on austenitic stainless steel. Thus, detecting martensitic transformation during fatigue test might elucidate the mechanism of hydrogen embrittlement on the austenitic stainless steel and its fatigue life when used in hydrogen station.

In this study, the austenitic stainless steel AISI 304 is used to prepare hydrogen charged and non-charged fatigue specimens. Using eddy current testing (ECT), evaluation of the martensitic phase transformation due to crack growth is made and discuss the relationship between hydrogen embrittlement and martensitic phase transformation.

Specimen Preparation

The compact tension specimen compliant with ASTM-E647 as shown in Figure 1 is used in this study. The material is austenitic stainless steel AISI 304. Some specimens are exposed to high pressure gaseous hydrogen at 100 MPa, 270 °C for 300 h to charge hydrogen. Four specimens are prepared; (1) non-charged specimen with EDM slit, (2) hydrogen charged specimen with slit, (3) non-charged specimen with fatigue crack, (4) hydrogen charged specimen with fatigue crack. All the cracks' length are induced for $a = 22$ mm

The slit and fatigue crack on each specimen are induced for about 7 mm. Slit width is 0.3 mm. Fatigue testing is conducted under an atmospheric environment using the horizontal testing machine (Lab-5, SHIMADZU). Frequency f, stress ration R, and stress intensity factor ΔK are set to be constant at 1.0 Hz, 0.1, and 20 MPa・$m^{1/2}$, respectively.

Eddy Current Testing Setup and Results

The ECT was conducted on the four specimens. The transmitter-receiver(TR) type probe with two pancake coils shown in Figure 2 was used in this experiment. Test frequency is 50 kHz. The one dimensional scan vertical to the crack was made for each specimen at 2 mm from the crack tip.

The result of the ECT is shown in Figure 3. The clear difference between signal of hydrogen charged and non-charged specimen has been confirmed. The numerical analysis based on the reduced vector potential method[2] was conducted to analyze the experimental results. Figure 4 shows the results of the numerical analysis for scanning slits when the whole specimen is magnetized. Comparing Figures 3 and 4, it can be seen that a martensitic transformation occurs when hydrogen is induced. Figure 5 shows the numerical result assuming the martensitic transformation has occurred around the crack. Compared to the numerical result on Figure 5, signal amplitude of the experimental result on Figure 3 is smaller. This phenomenon might be explained by Figure 6, which is the numerical result when electrical conductivity is given to the crack. Giving crack conductivity means that crack is contact, and this kind of phenomenon is reported for intergranular fracture such as stress corrosion crack.[3]

Summary

In this study, ECT signal of cracks introduced on hydrogen charged and non-charged steels are compared. The results show that martensitic transformation has occurred when hydrogen is charged, and intergranular fracture might have occurred for hydrogen charged specimens. We will show and discuss the results of the fracture surface observations and EBSD analysis around the crack on the presentation.

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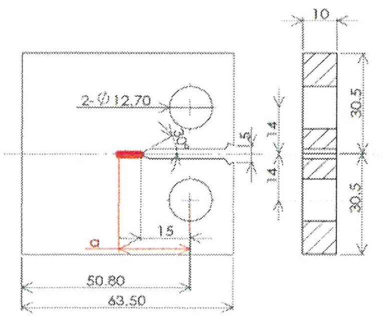

Figure 1. Dimension of the CT specimen

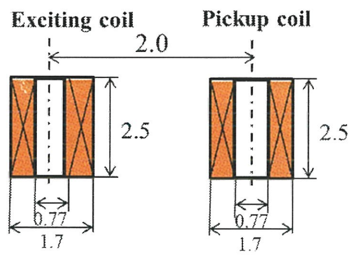

Figure 2. TR probe

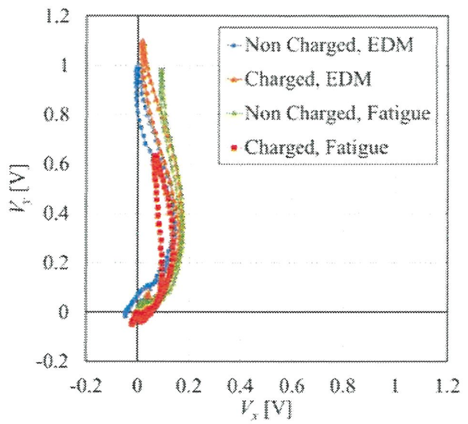

Figure 3. Experimental signal of the each specimen

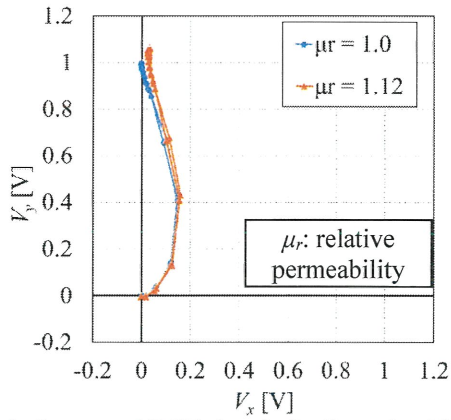

Figure 4. Computed ECT signals for Scanning EDM slit

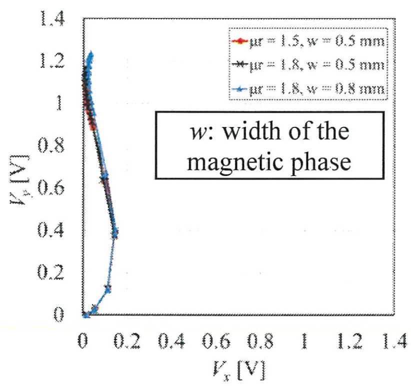

Figure 5. Numerical results of magnetic phase around the crack

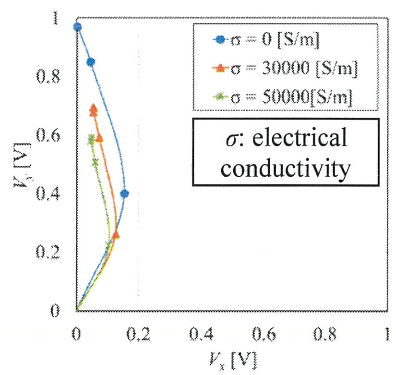

Figure 6. Numerical result of crack with conductivity