

Electrochemical evaluation of crevice corrosion of 430 ferritic stainless steel using the microcapillary tube technique

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Abstract

The aim of this study was to investigate the initiation of crevice corrosion for ferritic 430 stainless steel in artificial crevice electrode cells using the IR drop mechanism. The 430 stainless steel artificial crevice electrodes were potentiodynamically polarized in solutions of sodium chloride with different concentrations. The potentiostatic polarization was measured for various artificial crevice sizes by measuring the potentials in the crevice by the depth profile technique using a microcapillary tube which was inserted into the crevice. The criterion for $IR > \Delta\Phi^*$, where $\Delta\Phi^*$ is the difference between the applied potential, E_{SURF} , and the electrode potential of the active/passive transition, $E_{\text{A/P}}$, was also measured during the process of crevice corrosion. The potentials in the crevice were successfully measured from -220 mV vs. SCE to -360 mV vs. SCE, which is lower than that of the external surface potential of -200 mV vs. SCE. Thus, these results show that evaluation of corrosion using the IR drop mechanism in the crevice was more objective and easier to reproduce than other existing methods.

Keywords: Crevice corrosion; Ferritic 430 stainless steel; Artificial crevice electrode cell; IR drop mechanism; Microcapillary tubing method

1. Introduction

Ferritic stainless steel is an Fe–Cr series alloy containing 12–30% Cr, which retains its body centered cubic structure even after heat treatment in the normal temperature range [1]. Its corrosion

resistance and strength improve with increasing Cr content. Furthermore, it is an inexpensive material since no Ni is used. Austenite stainless steel is very sensitive to stress corrosion cracking in a hot chloride environment, whereas ferritic stainless steel is known to be extremely resistant to such an environment [2–4]. Therefore, the use of ferritic stainless steel in automobiles, domestic

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electric appliances, and water heaters is on the increase. Meanwhile, the phenomenon of crevice corrosion is very difficult to examine in detail due to the variation in the time and location of corrosion initiation and velocity of corrosion propagation [5], which causes the results obtained with the crevice corrosion study method to be difficult to reproduce, thereby making it difficult to explain the mechanism of progression of crevice corrosion. In addition, despite the increasing consumption of ferritic stainless steel, little research has been done on crevice corrosion.

The existing mechanisms of crevice corrosion rely solely on acidification, mass transport, and other features, but completely exclude the electrode potential, E , and its distribution, E_x , within the crevice cell. The IR drop mechanism focuses on the outer surface of the passive sample and the difference in electric potential that exists inside the crevice. That is, active crevice corrosion can develop at a certain depth inside the crevice while the outer surface of the sample still maintains the passive state. Especially, it has been proven by several researchers that there is an IR drop inside the crevice, which has been shown experimentally and by mathematical modeling to be related to the IR drop theory, and is thought to be involved in the progression of crevice corrosion originating from chemical changes in the crevice solution [6–11]. However, studies involving the electrochemical evaluation of crevice corrosion are limited by the small size of the crevices. Also, in previous studies, the IR mechanism during the crevice corrosion induction period was not able to be identified.

This study focuses on ferritic 430 stainless steel, which shows great potential in various fields of application, but for which problems of reproducibility have been encountered in previous studies involving the crevice corrosion method. The sizes of the artificial crevice samples were 0.1 mm, 0.2 mm and 0.5 mm. The solution, which is an important factor in the corrosion environment, was also made separately, and the

experiment was conducted based on the potentiostatic polarization by measuring the current density-time curve in each solution. Additionally, the potential drop inside the crevice was measured by inserting a microcapillary tube into it in order to examine the mechanism of crevice corrosion related to the IR drop.

2. Experimental

The typical composition of 430 stainless steel is shown in Table 1. All of the samples used in this study measured 10×20×5 mm and were obtained as sheet material. They were mounted in a fast-curing epoxy with a copper wire soldered on one side, and ground to expose the 10×20 mm crevice surface. The 430 stainless steels were mechanically ground with increasingly fine SiC paper through 1200 grits and finally polished with aluminum oxide (Al₂O₃) powder. Prior to the study the samples were cleaned ultrasonically with ethyl alcohol. The 3×16 mm artificial crevice was formed in the same position on each sample, and three different crevice widths were used: 0.1, 0.2 and 0.5 mm; the crevices were formed using Plexiglas.

The experimental sample containing the artificial crevice and the microcapillary tube placed in the crevice are shown in Fig. 1. The micro-

Table 1
Composition of 430 stainless steel.

Elements	Weight percent
Fe	82.26
Cr	16.46
Ni	0.32
Mn	0.50
Si	0.36
Mo	0.0024
P	0.035
S	0.004
C	0.055

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