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PWSCC mechanism of Alloy 600

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1. Introduction

Nickel-based Alloy 600 have been used for nozzle penetration and the heat exchanger tubes of the steam generators in nuclear power plants. Alloy 82 and Alloy 182 which are similar to Alloy 600 in chemical composition are also extensively used for welding such as J weld and butt weld in nuclear power plant. Those materials are subject to stress corrosion cracking at high temperature by interaction of material, environment and stress [1]. Primary water stress corrosion cracking (PWSCC) has been occurred in relatively pure water while outer diameter stress corrosion cracking of steam generator tube has been generated in solution with high concentration of impurities in crevice. Mechanisms proposed to explain PWSCC are film rupture and oxidation, creep, hydrogen embrittlement and internal oxidation. Possible reactions for PWSCC are schematically shown in Fig.1. The film rupture and oxidation is classical model and seems to work in SCC in oxidizing environment. Among models proposed to explain PWSCC, internal oxidation is getting more attention nowadays because oxide ahead of a PWSCC crack has been observed with analytical TEM.

In the present work, internal oxidation mechanism proposed to explain PWSCC is reviewed.

2. Cracking Behavior of Alloy 600

MRP 55 curve on a PWSCC crack growth rate of Alloy 600 was derived by EPRI based on modified Scott equation (Fig.3). The MRP 55 curve was determined by statistical treatment of data obtained by many laboratories. Big scattering among data in MRP curve may be attributed to inherent property of localized corrosion. Localized corrosion may be represented by Weibull distribution or Boltzman distribution. Besides this inherent properties, inconsistency in experimental condition among laboratories may be one of the big scattering. A PWSCC crack growth rate showed peak around Ni/NiO equilibrium potential. Corrosion potential of Ni base alloy in primary water is controlled by pH and hydrogen partial pressure. That is, crack growth rates are very sensitive to the deviation of corrosion potential from Ni/NiO equilibrium potential, even though hydrogen content is within EPRI guideline.

Difference in degree of deviation of corrosion potential from Ni/NiO equilibrium potential can be one of factors affecting data scattering. However, it is not clear why PWSCC rate shows peak at Ni/NiO equilibrium potential.

3. Oxides on free surface and crack

To understand PWSCC, characterization of oxide on free surface and crack has been extensively performed. The oxide on free surface is made up of three layers such as internal layer, intermediate layer and external layer. (Fig.2) Internal layer which is a few nm thick of Cr2O3 is probably main protective layer. Intermediate layer of a spinel type is a Cr rich oxide containing both Ni and Fe. External layer is a nickel ferrite. The oxide on crack is very similar to that on free surface.

4. Oxide ahead of crack tip

Recent observation with analytical TEM showed that the oxide ahead of crack tip is enriched with Cr and depleted with Ni. (Fig.3) Grain boundary damage model has been proposed based on these observations: Formation of intergranular oxide and possible penetration of oxygen ahead of intergranular oxide with formation of oxide nodules occurred. Formation of Cr depleted zones in the metal along oxidized grain boundary and ahead of the intergranular oxide occurred. And Condensation of vacancies ahead of the intergranular oxide with possible formation of nanovoids occurred.

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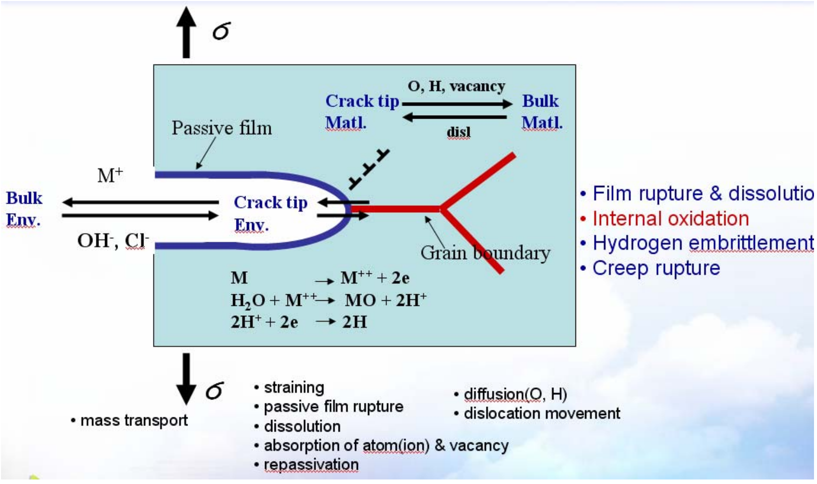

Fig. 1 Possible reactions for PWSCC.

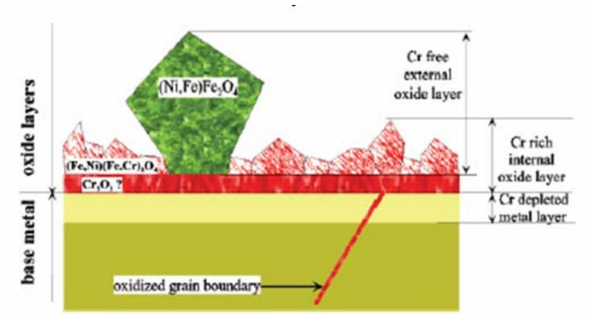

Fig.2 Schematic drawing of oxide on free surface.

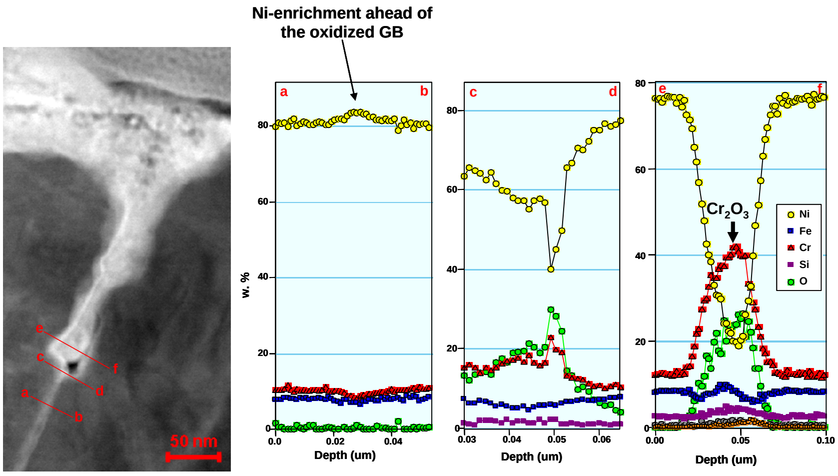

Fig.3 Composition profile of oxide ahead of crack tip.