PWSCC of Ni base Alloys

Hong Pyo Kim, Y. S., Lim, S. W. Kim, S. S. Hwang, D. J. Kim, S. S. Kim, J. S. Kim, J.Y. Park and M. K. Jeong
Nuclear Materials Research Division, Korea Atomic Energy Research Institute(KAERI), Yuseong, Daejeon, Korea, 305-600

1. Introduction

Nickel-based Alloy 600 and Alloy 690 have been used for nozzle penetration and the heat exchanger tubes of the steam generators in nuclear power plants. Alloy 82, Alloy 182, Alloy 52 and Alloy 152 which are similar to Alloy 600 or Alloy 690 in chemical composition are also extensively used for welding such as J weld and butt weld in nuclear power plant (Fig.1-2). Those materials are exposed to high temperature and high pressure coolants and are subject to stress corrosion cracking 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. Among impurities, lead is known to be one of the most deleterious species in the reactor coolants that causes outer diameter stress corrosion cracking of the alloy in steam generator.

In the present work, PWSCC research activities are briefly reviewed.

2. Alloy 600, Alloy 182 and Alloy 82

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. 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.

MRP 115 curve on a PWSCC crack growth rate of Alloy 182 and Alloy 82 was derived by EPRI (Fig.4). Higher growth rate in Alloy 182 than Alloy 82 can be attributed to higher Cr content in Alloy 82. Compositional variables other than chromium were reported to have minor effect on PWSCC. The crack growth rate is strongly affected by the microstructure of the weld and by the orientation of the crack growth with respect to microstructure (Fig. 5). The crack propagates along high energy boundary. PWSCC rate was discussed in terms of metallurgical parameters.

3. Alloy 690, Alloy 152 and Alloy 52

Alloy 690, Alloy 152 and Alloy 52 which have chromium content of about 30% are much more resistant to PWSCC than Alloy 600 as can be expected from higher content of chromium. However those alloys are not immune to PWSCC but sustained very slow crack growth rate of about 2-7 x 10^{-9} mm/sec were reported. Alloy 690 shows lower crack growth rate by about 70-400X than Alloy 600. Alloy 152 and Alloy 52 exhibited lower crack growth rate by 325-400X than Alloy 182.

3. pH and conductivity

On line crack growth rate was measured with DCPD in compact tension specimen for finding chemistry effect on crack growth rate. pH or conductivity was changed while DCPD was continuously monitored. It was found that changes in chemical parameter such as pH and B/Li chemistry around mid range pH essentially had no effect on PWSCC crack growth rate of Alloy 600.

4. Hydrogen

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. The location of the Ni/NiO phase boundary as a function of hydrogen depends on temperature. When analyzing data on PWSCC, hydrogen content corresponding to Ni/NiO and deviation of corrosion potential from Ni/NiO should be carefully examined.

REFERENCES

[1] B. P. Miglin and J. M. Sarver: Proc. of 4th Int. Symp. on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors, Houston, Texas, Aug. 6-10, p. 7(1989).
[2] Peter. Andresen: Seminar at KAERI(2007).

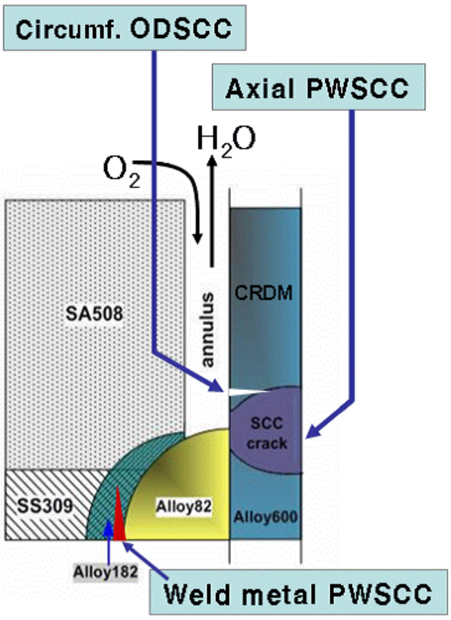

Fig. 1 J Welds

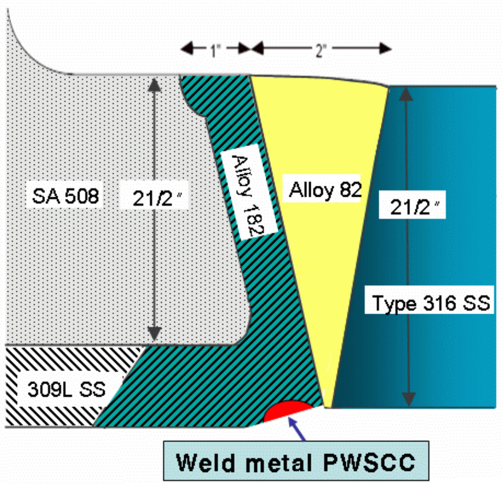

Fig. 2 Butt Welds

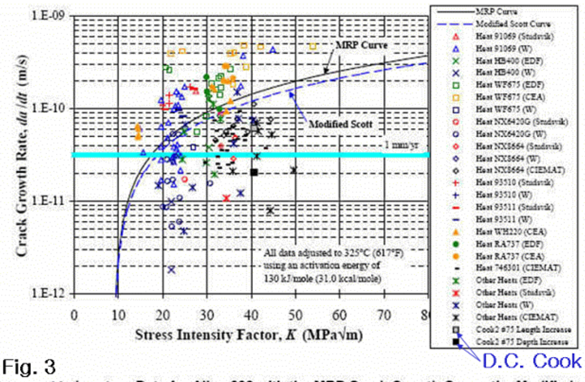

Fig. 3
Screened Laboratory Data for Alloy 600 with the MRP Crack Growth Curve, the Modified Scott Curve [1,2], and CGR Data for Cook 2 Nozzle #75 [33]

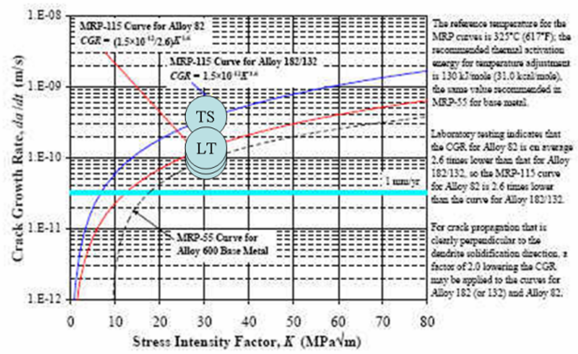

Fig.4
MRP-115 Deterministic Curves for Alloy 182/132 and Alloy 82 Weld Materials

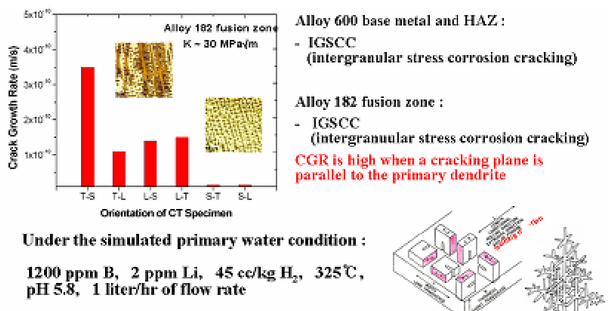

Fig. 5 Crack Growth Rates of Alloy182 Weld