Burst Test of Stress Corrosion Cracked Stream Generator Tubes under Internal Pressure

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1. Introduction

Outside diameter stress corrosion cracking (ODSCC) has been observed on steam generator (SG) Alloy 600HTMA tubing during in-service inspection. There is tendency for the cracking to be parallel to the axis of the tube.

To prevent ODSCC tube burst due to internal pressure and maintain structural integrity, robust model to estimate burst pressure is required. EPRI and Westinghouse have proposed burst models to predict burst pressure of through-wall crack (TWC) and part-through-wall (PTWC) crack[1,2)]. These models should be validated on the basis of burst test data.

This paper presents experimental burst test results with stress corrosion cracked SG tubing. The results were compared with the existing burst pressure models.

2. Burst Pressure Model

The flaw geometry for a axial PTWC is shown in Fig. 1[1)]. The burst pressure equation[1,2)] for constant depth PTWC is proposed as function of yield strength, S_y, ultimate tensile strength of material, S_u, wall thickness, t, inner tube radius, R_i, effective crack length, L, and effective crack depth, d.

$$P_B = 0.58(S_y + S_u)\frac{t}{R_i}\left(1 - \frac{L}{L+2t}\frac{d}{t}\right) \qquad (1)$$

The burst pressure equation for TWC was proposed based on test results:

$$P_B = (S_y + S_u)\exp(-0.056119 + 0.927125\ln(G_M)) \qquad (2)$$

Where

$$G_M = 1.15\frac{t}{R_o}\left(\sqrt{4 + 1.61\frac{L^2}{R_m t}}\right)^{-1} \qquad (3)$$

R_o and R_m denote the outside and men radius, respectively.

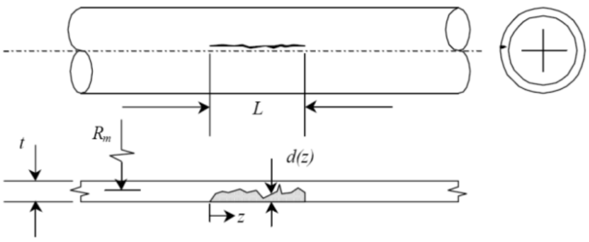

Fig. 1 Axial OD part through-wall crack model

Even though the ligament of crack is tore due to internal pressure, unstable burst may not occur. This phenomenon is likely to occur in a short and deep crack. Thus the estimated burst pressure of cracked tube is then obtained as the maximum value of the Eq. (1) and Eq. (2)[2)].

Because of the irregular nature of the crack profile, the effective crack length and depth can be calculated by 'Weak Link' to estimate the burst pressure[1,2)].

3. Tests

The KHNP test facility used in the burst tests can provides high pressure of water up to 100 MPa to a test specimen. Burst tests were conducted under room temperature and the pressurization rate was at less than 1.0 MPa/sec to minimize the effect of pressurization rate. To prevent the leakage through the crack, the sealing bladder and thin copper foil was inserted into the test specimens. The axial deflection of the specimens was not constrained. Pressure versus time data were recorded by a control computer. The burst pressure was determined by the maximum value of the pressure versus time plot[3)].

The test specimens were made of Alloy 600HTMA. Outside diameter and thickness of the specimens were 19.05mm and 1.07mm, respectively. Laboratory induced stress corrosion cracks were developed in specimen using KAERI SCC production facility. Thirty one specimens which have total lengths 4.6~29.8mm and effective depths 34.7~91.1%TW were tested.

4. Results

Figure 2 shows a typical post-test appearance of a specimen with an axial partial through-wall SCC. Rupture shape due to ductile tearing can be observed.

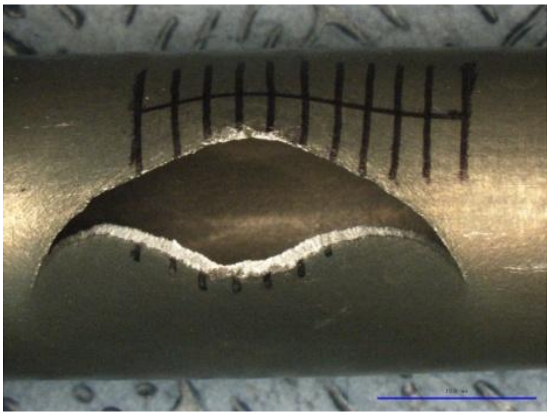
Fig. 2 Post-test appearance of a specimen with an axial partial through-wall SCC.

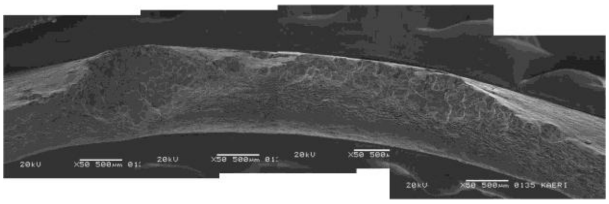
Fig. 3 SEM photograph of Post-test specimen

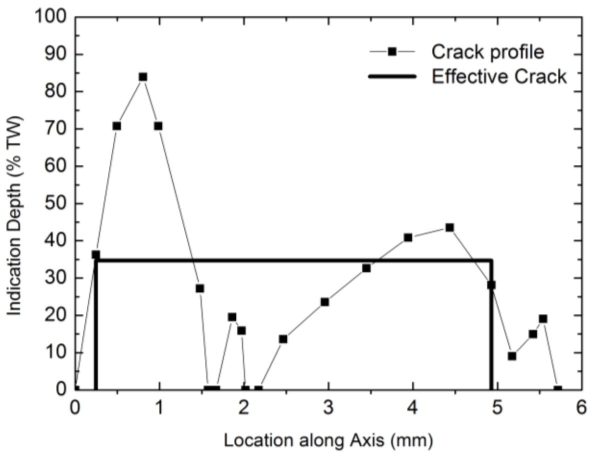

Fig. 4 Representative part through-wall axial crack profile with the Weak Link (effective crack) profile.

Figure 3 shows SEM fractograph of the fracture surface. Intergranular cracking due to SCC and the finer features of ductile tearing are clearly separated. Figure 4 shows the crack profile measured from SEM photograph of the post-test specimen. The bold and rectangular line depicts the effective crack depth and length, which are calculated by Eq. (3) and 'Weak Link' model. The predicted and tested burst pressures are 58.7MPa and 60.8MPa, respectively. The difference is 3.5%.

Figure 5 shows the comparison of the predicted burst pressures with the test results. The predictions agree well with the test results. The average error is -4.2% and the standard deviation of the errors is 8.6.

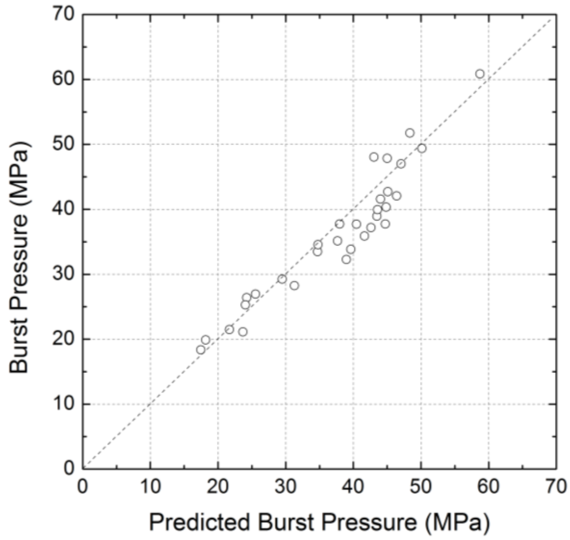

Fig. 5 Comparison of the predicted burst pressures with test results.

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