PWSCC Potential on the Drain Tubes of WEC Model 51F Steam Generators in Domestic Plants

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1. Introduction

The drain couplings of Westinghouse Model 51F steam generators that had been operated in the domestic Nuclear Power Plants were modified and repaired in accordance with the corrective action of replacing the existing Alloy 600 weld build-up with Alloy 690(Alloy 52/152) weld build-up in order to increase its resistance to primary water stress corrosion cracking (PWSCC).

The drain tube made of alloy 600, however, was not replaced and left susceptible to the PWSCC. Among the environmental, metallurgical and mechanical factors controlling a susceptibility to the PWSCC, it is believed that tensile stresses play an important role[1,4,5].

The objective of this study is to conservatively estimate stress state of the drain tube during fabrication and when exposed to normal plant operations, and to investigate its potential for the PWSCC.

2. Estimation of Stress Level

The tensile stresses on the inside diameter surface of the drain tube are of primary concern, which can be from residual stresses due to roll expansion or weld build-up, and from operational stresses due to service loading.

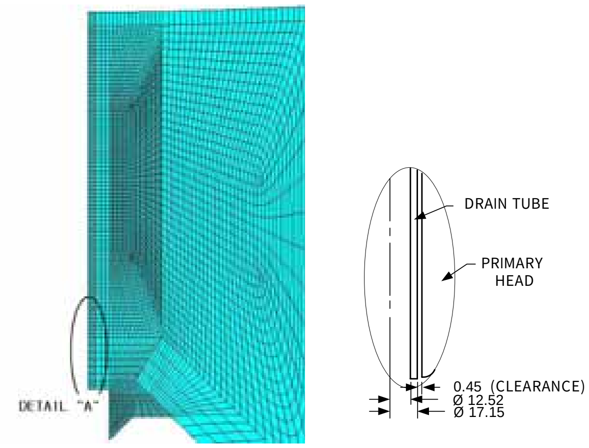
2.1 Mechanical Tube Roll Expansion

During the drain tube installation, a Alloy 600 drain tube was rolled into the hole already drilled through the primary head thickness in accordance with the maximum 5% wall reduction requirement.

To calculate the residual stresses induced by the roll expansion process two dimensional(2-D) nonlinear axisymmetric FE model was made[2, 3]. The geometry and dimensions of the model are illustrated in Fig. 1.

The calculated residual stresses on the inside diameter of the drain tube are plotted in Fig. 2 as a function of distance in the direction of outer surface of primary head.

The axial residual stress varies from about 105 MPa in tension to -151 MPa in compression. The hoop residual stress remains compressive through the drain tube length except the region adjacent to the inside surface of the primary head where tensile stress is located.



DETAIL "A"(mm)

Fig.1 FE Model showing Roll Expansion

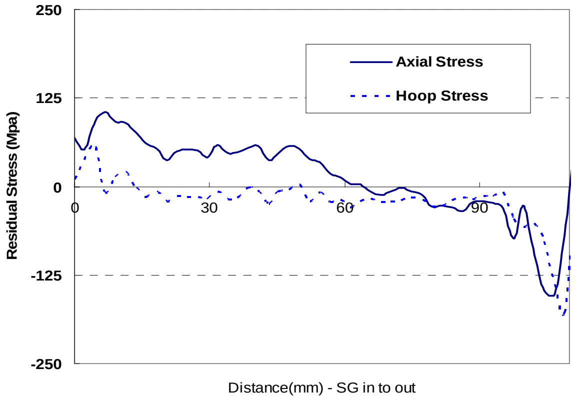


Fig.2 Roll Expansion Residual Stress Distribution

2.2 Seal Weld and Weld Build-Up

Following the roll expansion, the sleeve was manually welded at its top end to the stainless steel cladding and at its lower end to the Alloy 600 weld build-up. The drain coupling repair required the removal of all of the existing Alloy 600 weld build-up, resulting in new seal weld at the lower end of the drain tube and new weld build-up using Alloy 690 (Alloy 52/152) weld filler metal. In order to estimate residual stresses on the drain tube caused by the welding described above a finite element analysis was conducted, in which the roll expansion residual stresses were included as initial stresses[6].

The welding parameters adopted are described in Table 1, and geometries are shown in Fig. 3.

Table 1. Welding Parameters

Type	Current	Voltage	Heat Input
Seal Weld	110 A	13 V	4 KJ/cm
Build-Up	110 A	13 V	12 KJ/cm

The results are presented in Fig. 4, which shows that both axial and hoop stresses are changed to become compression stresses and the order of 6.6 MPa max in tension at the lower end of the drain tube.

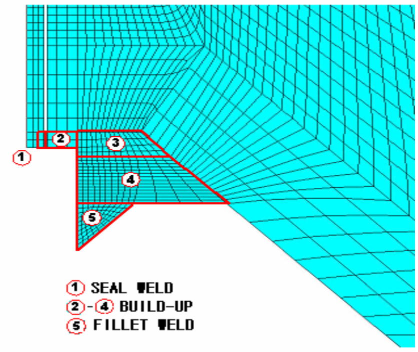


Fig. 3. FE Model of Weld Region

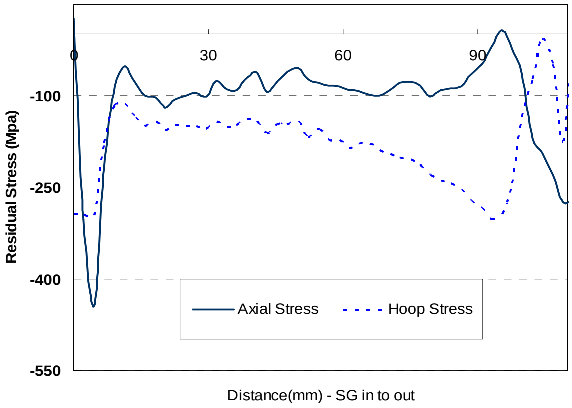


Fig. 4. Residual Stress Distribution
(Roll Expansion + Weld)

2.3 Operating Pressure and Temperature

The operating stresses must be added to the residual stresses discussed in the section 2.2 to obtain the actual stress distributions along the drain tube length. This is accomplished by including the welding residual stresses as initial stresses in the FE model which are geometrically the same as the welding FE model. The stress analysis for operating pressure and temperature is performed with representative loading condition of steam generator full power operation, that is, 15.5 MPa and 326°C.

Hoop and axial residual stress distributions in the inside surface of the drain tube under full power condition, including the effects of the roll expansion and welding, are presented in Fig. 5. The results show that hoop stresses are relatively higher than axial stresses over the length of the drain tube. Of great concern is the tensile residual stress level which is on the order of about 143 MPa and far less than the threshold value of 400 MPa for PWSCC initiation[1].

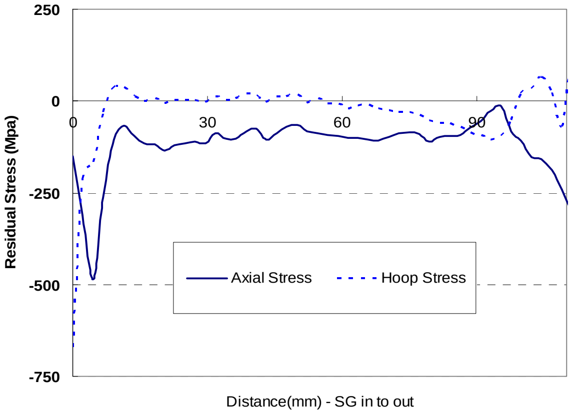


Fig. 5. Total Residual Stress Distribution
(Roll Expansion + Weld + Operating Conditions)

3. Conclusions

Based on the study for states of stresses on the inside surface of the drain tube, it could be concluded that the drain tube has no potential for the PWSCC from the stress view point since the tensile stress level is far below the threshold value of PWSCC initiation.

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