Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Analysis of the Residual Stresses Measured in Alloy 182 Butt Welded Plates

Ho-Jin Lee, Kang-Soo Kim, Ki-Baik Kim, Bong-Sang Lee, [a]Kyung-Bong Lee, [b]Jin-Gwi Byeon, [b]Kwang-Soo Park, and [b]In-Chul Jung
Nuclear Material Research Dept., Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong, Daejeon, Korea, 305-353, hjlee1@kaeri.re.kr
[a] Dept. of Automotive Engineering, Daewon Science College
[b] Doosan Heavy Industries & Construction, Corporate R&D Institute Materials Evaluation & Development Team

1. Introduction

Most of the butt welds at RPV inlet and outlet nozzles are single-V alloy 82/182 welds. It is known that the Alloy600/82/182 materials are susceptible to PWSCC (Primary Water Stress Corrosion Cracking) in PWR plant primary coolant environments. The residual stresses induced by the welding tend to be the dominant driving force for PWSCC initiation and crack growth. Because the residual stresses can have either beneficial or detrimental effects, the exact measurement and analysis of residual stress state in the welded structures are inevitable processes for estimating the performance of the nuclear power plant components[1].

In this research, the hole-drilling method and the X-ray diffraction method were used for measuring the residual stresses, and these results were compared with those of calculation. Two kinds of welded plate of SA508/182/SS316L are prepared to investigate the behavior of inherent surface residual stresses in the stainless steel plates, which are as-received and stress-relived.

2. Measurement of residual stresses

Residual stresses are present in most welded mechanical components due to production processes. The hole-drilling method and the X-ray diffraction (XRD) method are known as acceptable techniques among the quantitative residual stress measurement methods. Strain gages for the hole-drilling method, which are placed before measurement, respond to the deformation produced by relaxation of the stress with material removal[2]. The X-ray diffraction method, which does not require stress relaxation, offers a non-destructive alternative to the hole-drilling method. Because the residual stresses, which are measured by the hole-drilling method or the X-ray diffraction method, can be obtained only on the surface of welded structure, numerical modeling is needed to anticipate the residual stresses in the whole body of the welded structure.

3. Preparation of butt welded plates

Two kinds of welded plate are prepared to measure the residual stress distributions and to investigate the effect of the inherent surface residual stresses in the stainless steel plate, which may be induced by the process of machining or hardening before welding.

The SA508 steel plate of 330mm x 330mm x 40mm was buttered, and was post weld heat treated. The heat treated SA508 steel plate is welded to the stainless steel plate by using the Ni-base filler of Alloy182 as shown Fig. 1. Two kinds of stainless steel plates, one is the commercial grade plate and the other is the stress relieved plate heat-treated at 1050°C for 1h additionally after machining, are prepared to investigate the effect of the inherent surface residual stresses in the stainless steel plate[3].

Fig. 1 Butt welded plate of stainless steel type 316L and SA508 steel.

4. Modeling of butt welding

Two-dimensional modeling was performed by using a commercial FE code, and uncoupled thermo-mechanical analysis was used to calculate the heat flows and the residual stress distributions in the Alloy182 butt welded plate as shown in Fig. 2. Element rebirth technique was used to simulate the deposition of weld beads, and lumping method was chosen to reduce the calculation time. The nonlinear calculation was performed because of the temperature dependant material properties.

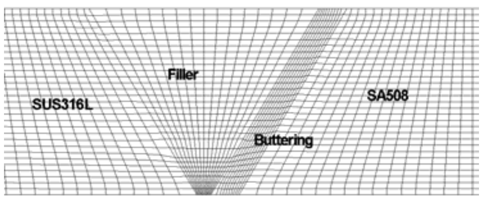

Fig. 2 Two-dimensional modeling of the Alloy 182 butt welded plate.

5. Analysis of measured residual stresses

The residual stresses are measured by hole drilling method and X-ray diffraction method. The variation of residual stresses with increasing depth from surface was measured to find proper chemical etching removal depth for X-ray diffraction method. The chemical etching is known as a proper method to eliminate the surface effect. As shown in Fig. 3, the residual stresses are rapidly changed with the depth from surface. When considering the behavior of the curves in Fig. 3, the variation of the residual stresses is thought to be induced during the surface machining of the plates. This behavior also can be confirmed by considering the measured strain curves obtained by the hole-drilling method.

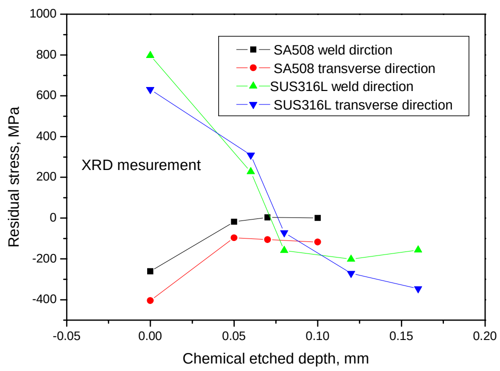

Fig. 3 Variation of residual stresses measured by XRD method with removed depth from the surface of as-received plates.

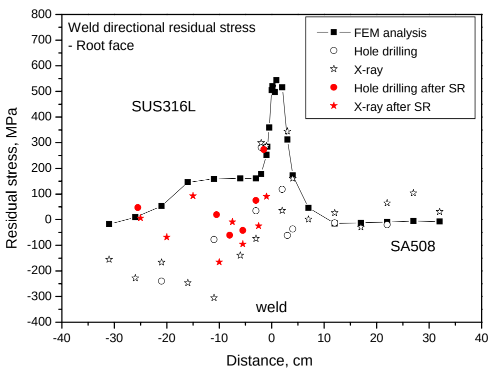

Fig. 4 Calculated and measured weld directional residual stress distributions on the root surface of welded plate.

Figure 4 and 5 show the calculated residual stresses and the measured residual stresses on the root surface of the welded plates. The measured residual stresses on the SA508 steel plate are agreed well with the calculated residual stress curve better than those measured on the stainless steel. Because the SA508 steel plate is post weld heat treated and the machinability is good, the surface effect on the measurement may be lower than that of the stainless steel plate. The data measured on the SA508 steel are also more stable than those measured on the stainless steel plate.

The residual stresses measured on the SR (Stress Relived) stainless steel plate which was additionally heat treated to relieve the inherent residual stress after machining, are agreed with the calculated curves better than those measured on the no additional heat treated stainless steel plate. The scattering of measured data obtained on the SR stainless steel is also lower as shown in Fig. 4 and Fig. 5.

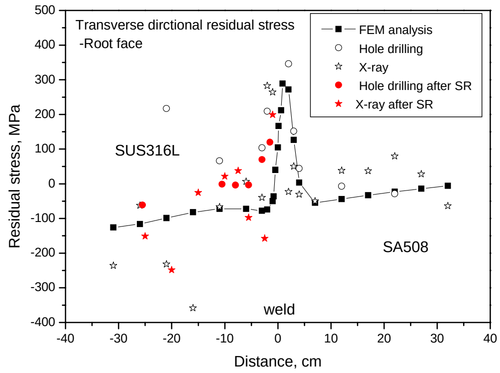

Fig. 5 Calculated and measured transverse directional residual stress distributions on the root surface of welded plate.

6. Conclusion

The rapid variation of the residual stresses with the depth from the surface was considered due to the inherent surface residual stresses induced during the machining of the plates. The residual stresses measured on the stainless steel plate which was heat treated to relieve the inherent surface residual stress after a machining, are more stable and also agreed with the calculated curves better than those measured on the no additional heat treated stainless steel plate.

ACKNOWLEDGMENT

This research was supported by Doosan Heavy Industry & Construction.

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