A Study on the Residual Stress Improvement of PWSCC(Primary Water Stress Corrosion Cracking) in DMW(Dissimilar Metal Weld)

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1. Introduction

Since 2000s, most of the cracks are found in welds, especially in (DMW) dissimilar metal welds such as pressurizer safety relief nozzle, reactor head penetration, reactor bottom mounted instrumentation (BMI), and reactor nozzles. Even the cracks are revealed as a primary water stress corrosion cracking (PWSCC), it is difficult to find the cracks by current non destructive examination.

The PWSCC is occurred by three incident factors, such as susceptible material, environmental corrosive condition, and welding residual stress. If one of the three factors can be erased or decreased, the PWSCC could be prevented.

In this study, we performed residual stress analysis for DMW and several residual stress improvement methods. As the preventive methods of PWSCC, we used laser peening(IP) method, inlay weld(IW) method, and induction heating stress improvement(IHSI) method. The effect of residual stress improvement for preventive methods was compared and discussed by finite element modeling and residual stress of repaired DMW.

2. Residual Stress Analysis

Fig.1 shows the pressurizer safety/relief nozzle for DMW and their materials. The nozzle is SA508 Class 2A and DMW of nozzle buttering-safe end(SA182 F316) is Alloy 82/182. PATRAN[1] was used for modeling of weld residual stress analysis used, and ABAQUS[2] was used for thermal and stress analysis. Fig.2 shows the axisymmetric finite element model, consisting of 11 lumped beads for DMW and 9 lumped beads for similar weld.

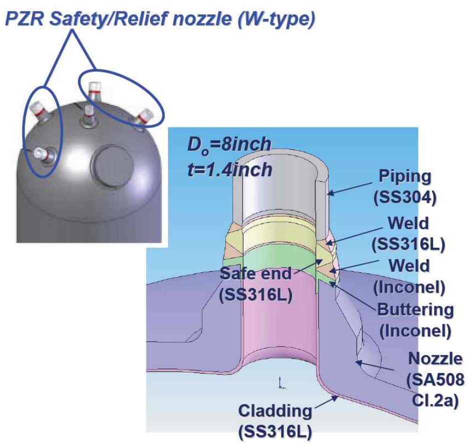


Fig.1 Pressurizer safety/relief nozzle (WH type)

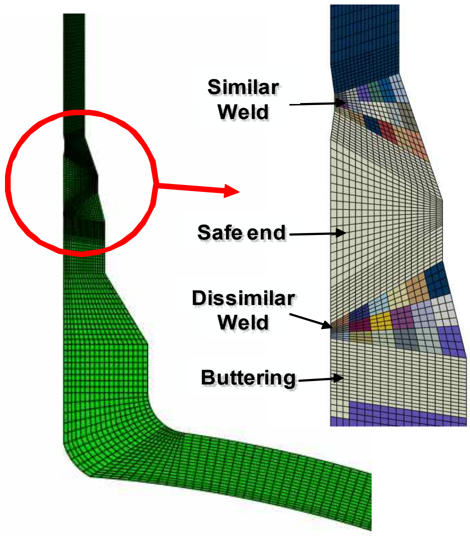


Fig.2 Axisymmetric finite element model for DMW

The lumped bead method[3] was used to reduce calculation time. The stacking sequence of weld bead was decided by the direction of safe end from the nozzle in DMW. We considered isotropic hardening to obtain conservative results, and also considered stress annealing effects.

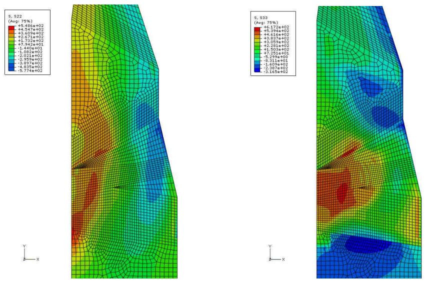
3. Results and Discussion

3.1 Initial Residual Stress Distribution in DMW

In previous study[4], we showed the initial residual stress distribution in DMW, especially in reactor outlet nozzle and pressurizer safety/relief nozzle. In case of the pressurizer nozzle, the hoop residual stresses are strongly positive in the outer portion of the DMW, while stresses near the inner surface of the DMW is negative.

3.2 Residual Stress after Repair Weld

In previous research[4], we confirmed that the residual stress was increased after repair welding, especially inside repair welding. Fig.3 shows the residual stress distributions in the pressurizer nozzle after repair welding. It gives us the residual stress in the inner surface of the DMW is tensile, which can make the PWSCC during reactor operation. Therefore, to reduce the residual stress, we need a residual stress improvement. The maximum tensile residual stress showed nearly same even though the repair depth was increased. We will discuss the several stress improvement methods for key DMW components.



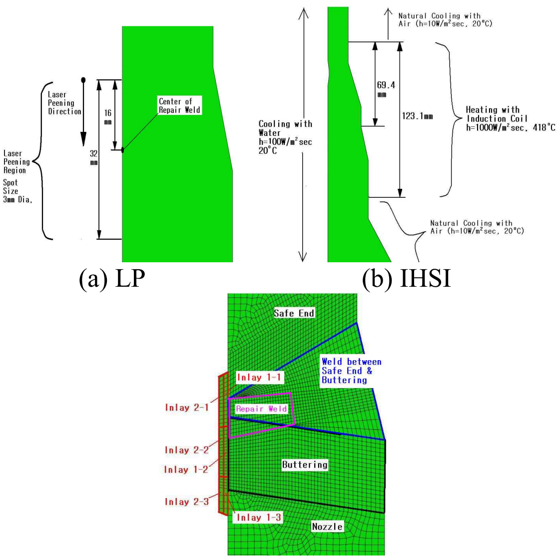
(a) Axial Stress (b) Hoop Stress

Fig.3 Residual Stress in DMW after Repair Weld

3.3 Residual Stress Improvement

Among the residual stress improvement methods, we used laser peening (LP), induction heating stress improvement (IHSI), and inlay weld (IW). The LP can make the compressive residual stress using a laser, and it can make a more deep compressive stress distribution than conventional shot peening. The IHSI can improve the residual stress by high frequency induction heating. And, the IW can make the inside of pipe to high resistance PWSCC weldment (such as Alloy 52). In this study, we will discuss the pros and cons of PWSCC preventive methods.

To review the effect of the residual stress improvement, the finite element analysis was performed for pressurizer nozzle DMW using the LP, IHSI, and IW. Fig.4 shows the finite element models for three preventive methods.



(a) LP (b) IHSI

(c) IW

Fig.4 Finite Element Model for Stress Improvement

Fig. 5 shows the results of residual stress distribution after repair welding following the preventive methods. Before the preventive stress improving, the results show high tensile residual stress distribution. But, if we performed LP and IHSI treatment, the inside of the nozzle was changed from tensile to compressive stress. This shows the positive effect of preventive stress improvement, even we assumed some of their condition.

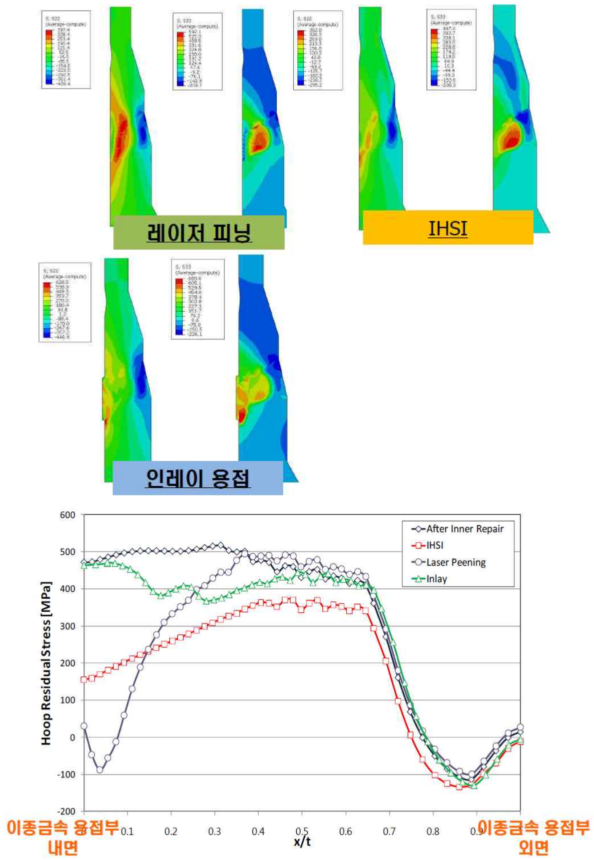


Fig.5 Residual Stress Distribution after Preventive Stress Improvement

In case of IW treatment, the residual stress was somewhat increased in axial stress rather than hoop stress. However, since the IW gives the high resistance PWSCC weld inside, it can make low PWSCC susceptibility.

4. Conclusions

We studied the effects of residual stress improvement for the repaired DMW which has high tensile stress. The LP improvement can decrease the residual stress in inside of nozzle, and the IHSI can decrease the residual stress in both sides. These two improvements are more effective than IW from point of residual stress. Also, we will present and discuss our next phase research items.

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