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Effect of width of repair welding on stress distribution of dissimilar metal butt weld of nuclear piping

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1. Introduction

In the past few years, many numerical and experimental works have been made to assess a structural integrity of cracked components subjected to primary water stress corrosion cracking in dissimilar metal weld (DMW) using Alloys 82/182 in nuclear industries worldwide [1]. These works include a prediction of weld residual stresses in dissimilar metal weld by either numerical or experimental works since an accurate estimation of residual stress distribution in dissimilar metal weld is the most important element for integrity assessment of components subjected to primary water stress corrosion cracking.

During an actual welding process, in general, a repair welding is often performed when a defect indication is detected during post-welding inspection. It has been revealed that such a repair welding could lead to higher tensile residual stress in dissimilar metal weld, which is detrimental to the crack growth due to primary water stress corrosion cracking. Thus, the prediction of residual stress considering a repair welding is needed, and then many efforts were made on this issue [2].

In the present work, the effect of width of repair welding on stress distribution of dissimilar metal butt weld of nuclear piping is evaluated based on the detailed 2-dimensional non-linear finite element analyses. For this purpose, the welding residual stress due to repair welding is firstly investigated, and stress redistribution behavior due to hydrostatic and normal operating pressure is also investigated.

2. Finite element analysis

Fig. 1 denotes geometry of dissimilar metal butt weld of the nuclear reactor piping considered in the present work. Repair welding is made at the weld root of DMW.

Materials of each part were as follows: SA 508 for the nozzle, Alloys 82/182 for the buttering, repair welding and DMW, ER 316L for SMW (similar metal weld), Austenitic stainless steel for the piping and cladding and TP 316 for the safe-end. The general purpose finite element program, ABAQUS [3] was used. 2-D axi-symmetric thermal and mechanical stress analyses were performed. Therefore, it is assumed that repair welding is performed along the full circumference of pipe. During welding process, the DMW is firstly simulated and then repair welding is conducted at the root of DMW. After simulating repair welding, the SMW is simulated. After finishing overall welding process, the pressures corresponding to hydrostatic test and normal operating condition are applied.

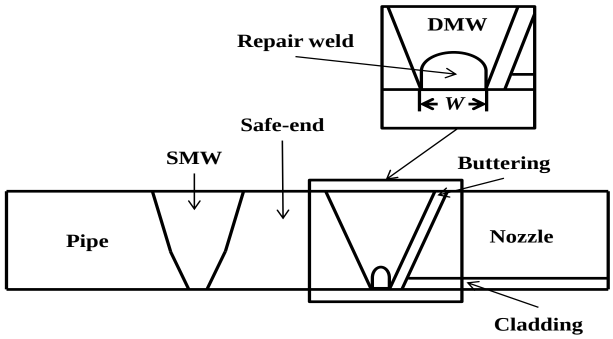


Fig. 1. Geometry of dissimilar metal butt weld considered in the present study

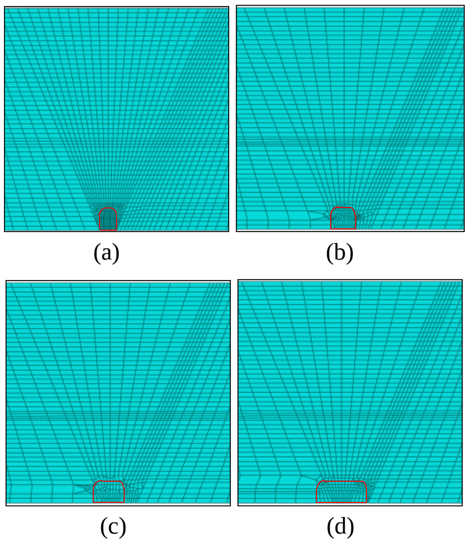
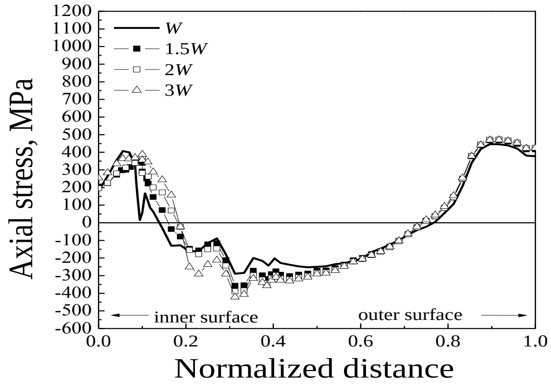


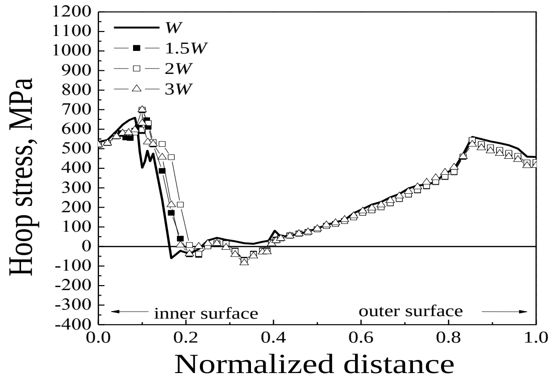
Fig. 2. Typical finite element meshes of repair welding; (a) *W*, (b) 1.5*W*, (c) 2*W* and (d) 3*W*

As described above, in order to evaluate effect of width of repair welding, 4 different values of repair welding width are considered, i.e., *W*, 1.5*W*, 2*W* and 3*W*, where *W* is width of DMW.

The depth of repair welding is assumed to be 10% of wall thickness of pipe. Based on the finite element stress analyses results, the stresses due to repair welding and normal operating pressure are obtained along the thickness at the center of DMW, respectively.

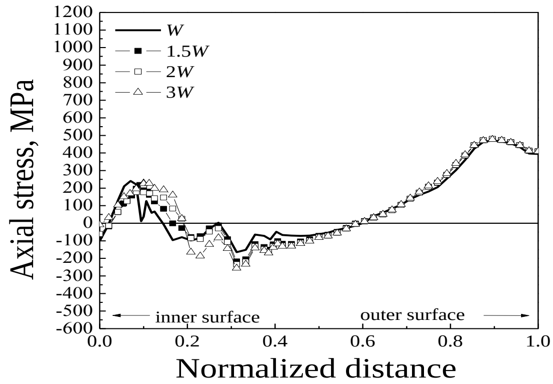


(a)

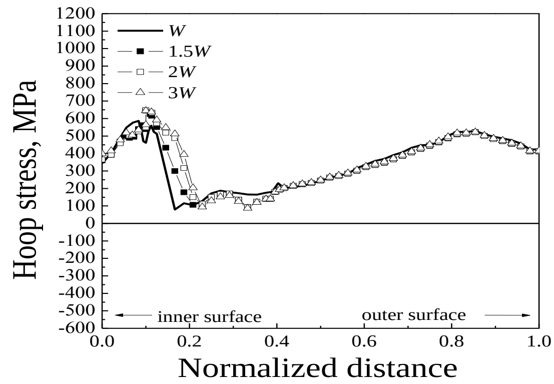


(b)

Fig. 3. Welding residual stress distribution along the wall thickness in the center of DMW after repair welding; (a) axial stress and (b) hoop stress



(a)



(b)

Fig. 4. Stress distribution along the wall thickness in the center of DMW considering normal operating pressure; (a) axial stress and (b) hoop stress

3. Results

Fig. 3 shows the welding residual stress distribution due to repair welding along the wall thickness of pipe in the center of DMW. The results for 4 different repair welding width are given in this figure. As shown in Fig. 3(a), due to repair welding, the large tensile axial residual stresses are produced at the inner surface of DMW, i.e., PWSCC sensitive region, which is detrimental element to PWSCC. The hoop stress distribution along the thickness is given Fig. 3(b). Identical to axial residual stress due to repair welding, large tensile hoop stress is produced at the inner surface of DMW region, and value of hoop residual stress in the inner surface of DMW is about 2.5 times higher than that of axial residual stress.

As shown in Fig. 3, it is revealed that the effect of width of repair welding on residual stress distribution due to repair welding is not significant.

Fig. 4 shows stress distribution after applying hydrostatic and normal operating pressures.

Comparing Fig. 3 with Fig. 4, although large tensile residual stresses (both axial and hoop directions) are generated in the inner surface of DMW due to repair welding, the magnitude of tensile residual stress in the inner surface of DMW is reduced by hydrostatic and normal operating pressures. In the case of axial component, the tensile residual stress in the inner surface is changed into compressive stress after considering hydrostatic and normal operating pressure, while hoop stress is still in tensile manner but the magnitude is reduced by ~165 MPa.

4. Conclusion

In the present work, the welding residual stress due to repair welding and the stress redistribution behavior due to primary pressure are investigated via 2-dimensional non-linear finite element analyses. In particular, the effect of repair welding width on stress distribution is emphasized. Although, large tensile residual stresses are produced at the PWSCC sensitive region due to repair welding, these stresses are highly reduced due to stress redistribution caused by primary load. Based on the present finite element results, it has been revealed that the effect of width of repair welding on stress distribution is not significant.

Reference

[1] EPRI, Materials Reliability Program, "Welding Residual and Operating Stresses in PWR Alloy 182 Butt Welds (MRP-106)," 2004.
[2] C. R. Limpus, D. G. Dijamco, R. Bax, N. G. Cofie, Effect of Size of Butt Weld Repairs on Weld Overlay Residual Stresses, PVP, San Antonio, 2007.
[3] "ABAQUS/Standard User's Manual," ABAQUS Version 6.11-1, Simulia Corp.