Residual Stress Analysis of an Overlay Weld on a Repair Weld

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1. Introduction

In recent years, the dissimilar metal, Alloy 82/182 welds used to connect stainless steel piping and low alloy steel or carbon steel components in nuclear reactor piping system have experienced the cracking due to primary water stress corrosion(PWSCC) [1]. It is well known that one reason of the cracking is the residual stress by the weld. But, it is difficult to estimate the weld residual stress exactly due to many parameters of a welding. In this paper, the analysis of 3 FEM models is performed to estimate the weld residual stress on the dissimilar metal weld exactly.

2. Methods and Results

3 FEM models were made by ABAQUS/CAE Code[2]. These are Butt model, Repair model and Overlay model, and the plane–strain 2D model. The thermal analysis and the stress analysis are performed on each model and the residual stresses on each model were calculated and compared respectively.

2.1 Butt Model

Butt model is shown in Fig. 1 and consists of SUS316 plate(330x330x40 mm) and SA508 plate(330x330x40 mm). The edge of SA508 plate became the buttering by Alloy 182 and two plates were welded by the filler(Alloy 182). “Element birth” technique for the meshing and lumping method for the bead simulation is used.
Actually, this specimen was made and the residual stresses were measured by X-Ray method and Hole Drilling Technique. These results were compared with FEM result of Butt model and were represented in Fig. 2.

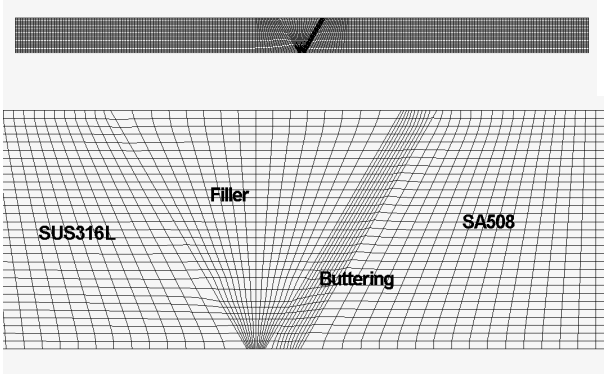

Fig. 1 2D FEM model of Butt weld

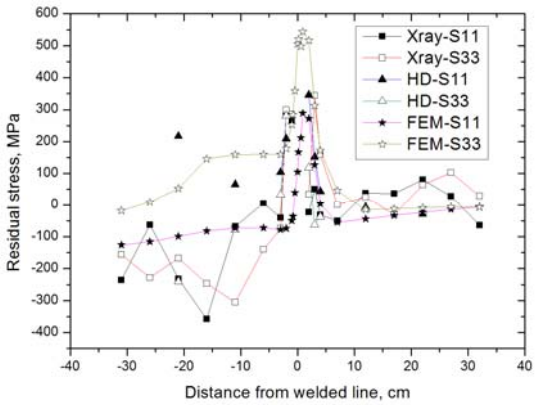

Fig. 2 FEM results of Butt weld

Where, S11(σ_x) is the transverse stress in the welding direction and S33(σ_y) is the stress in the welding direction. The experimental values by X-Ray method and Hole Drilling Technique have a large deviation, but these values have a trend which is in agreement with FEM results

2.2 Repair Model

Repair model is shown in Fig. 3. The bottom part of the plate was removed and was welded again by the filler (Alloy 182).

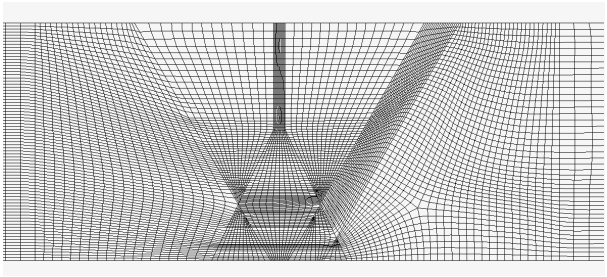

Fig.3 2D FEM model of Repair weld

The analysis results of this model are represented in Fig. 4. We know that the stresses of Repair weld are higher than that of Butt weld. Therefore, we know that Overlay weld needs to lower the stress.

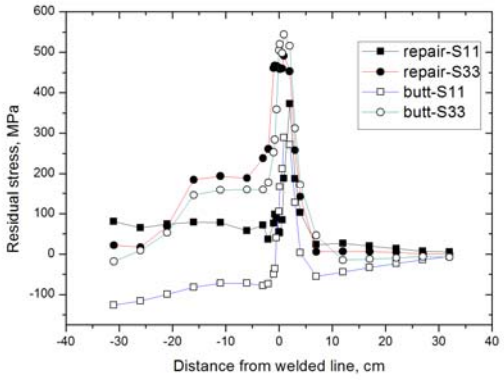

Fig. 4 FEM results of Repair weld

2.3 Overlay Model

Overlay model is shown in Fig. 5. The top part of the plate was overlaid by the filler (Alloy 182).

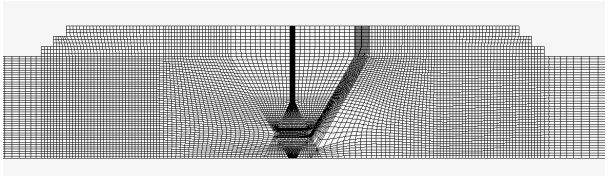

Fig. 5 2D FEM model of Overlay weld

Totally, 3 layers were overlaid. Whenever each layer was overlaid, the results were calculated respectively. The analysis results of Overlay model are represented in Fig. 6(stress according to the distance from the welded line) and Fig. 7(stress in the thickness direction). As shown in Fig. 6 and Fig. 7. , we know that Overlay weld lowers the stresses elevated by Repair weld. The stress value (S11=σ_x)by Overlay weld is lowered from 375 MPa to 75 MPa. In contrast to this, the stress value (S33= σ_y)by Overlay weld is elevated from 350 MPa to 550 MPa. Conclusively, Overlay weld lowers the stress in the welding part. The stress in the thickness direction as shown in Fig. 8 converges nearly to 0 MPa.

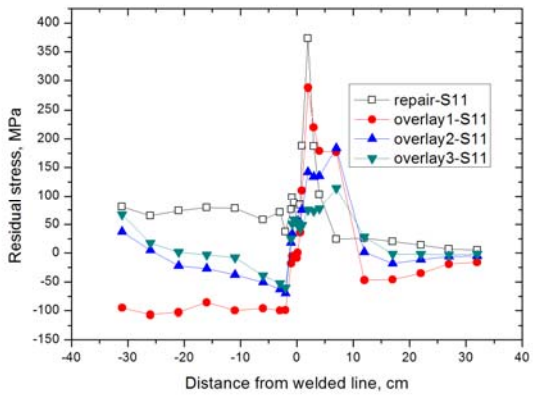

Fig. 6 FEM results of Overlay weld (S11)

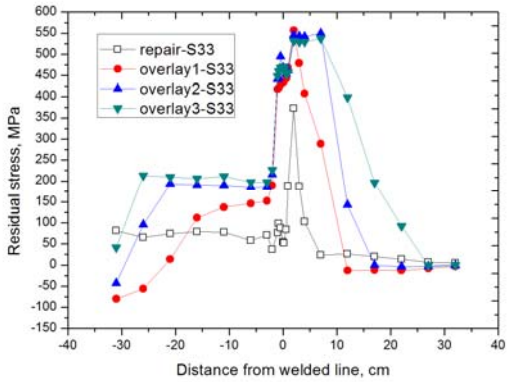

Fig. 7 FEM results of Overlay weld (S33)

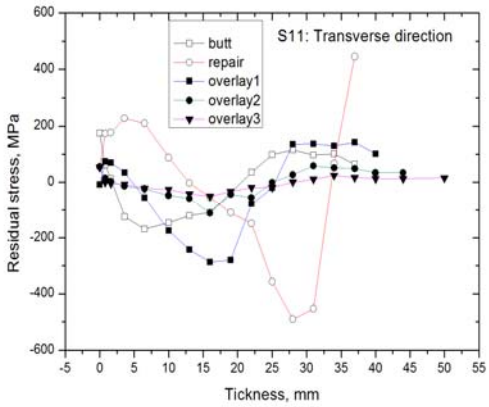

Fig.8 FEM results of Overlay weld (S11 through thickness)

3. Conclusions

The experimental values by X-Ray method and Hole Drilling Technique have a trend which is in agreement with FEM results. Repair weld elevated the stresses. Therefore, the relaxation of the stress in the welding part is needed. The stress in the thickness direction of Overlay weld converged to nearly 0 MPa. Overlay weld lowered the stress in the welding part. Therefore, Overlay weld has good benefits with a view to a stress relaxation and PWSCC.

Acknowledgements

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REFERENCES

[1] C. King, G. Frederick, “Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs (MRP-169)”, EPRI Topical Report, October 2005.
[2] ABAQUS, 2004. Standard User’s Manual, version 6.4. ABAQUS Inc., Pawtucket, RI, USA.