Behavior of a crack within a Dissimilar Metal Weld Part by using an Overlay Weld

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1. Introduction

In recent years, the dissimilar metal welds, Alloy 82/182 welds, used to connect the stainless steel piping and low alloy steel or carbon steel components in a nuclear reactor piping system have experienced a cracking due to a primary water stress corrosion (PWSCC)[1][2]. It is well known that one reason for the cracking is the residual stress by the weld. But, it is difficult to estimate the weld residual stress exactly due to the many parameters for the welding process. In this paper, a Butt model weld specimen was manufactured and the residual stresses of the weld specimen were measured by the X-Ray method and a Hole Drilling Technique. These results were compared with the results of the Butt FEM Model to confirm the confidence of the FEM input. Also, an analysis of the Crack FEM models made by the ABAQUS Code[3] was performed to estimate the behavior of a crack within a Dissimilar Metal Weld Part (DMWP) when an overlay weld on the DMWP was done.

2. Methods and Results

2.1 Experimental measurement of the residual stress

Butt weld specimen is shown in Fig. 1. The plate size of the SUS 316L and the SA 508 is 330x330x40 mm respectively. The edge of the SA508 plate became a buttering region by Alloy 182, and two plates were welded by a filler. The material of the filler and the buttering was Alloy 182. The size of the groove bottom and the buttering was 3 mm and 6 mm respectively as shown in Fig. 2. Where, S11(σ_x) is the transverse stress in the welding direction and S33(σ_z) is the stress in the welding direction. The experimental values measured by the X-Ray method and the Hole Drilling Technique are shown in Fig. 3.

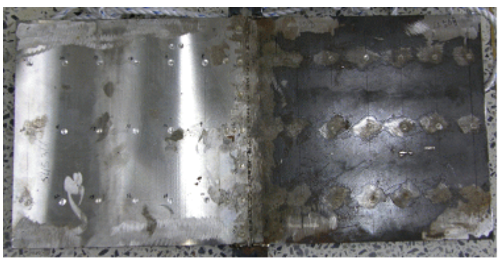

Fig. 1 Butt weld specimen

2.2 Butt FEM Model

Butt FEM Model is shown in Fig. This model is made by the ABAQUS/CAE Code and the 2D plane–strain model. A thermal analysis and a stress analysis were performed with this model and the residual stresses were calculated. “Element birth” technique for the meshing and a lumping method for the bead simulation were used. The 4-node DC2D4(Diffusive Heat Transfer or Diffusion Elements) was used for the thermal analysis and the 4-node CPE4R(Plane Strain Elements) was used for the stress analysis. The total nodes and elements of this model were 7140 and 7409 respectively. Total weld passes consist of 10 passes for the Butt FEM model. The residual stresses measured by the X-Ray method and the Hole Drilling Technique were compared with the results of the Butt FEM model. These results are represented in Fig. 3.

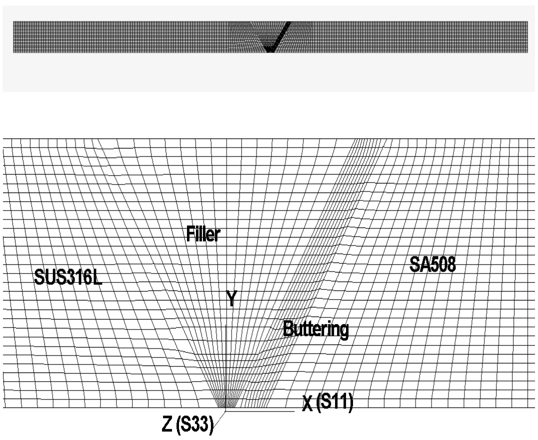

Fig. 2 2D FEM model of Butt weld

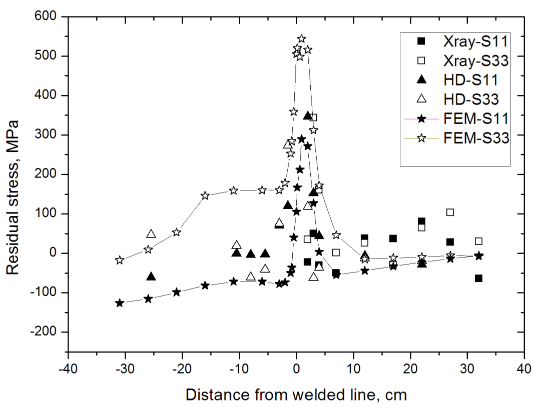

Fig. 3 FEM results of Butt weld

As shown in Fig. 3, as a whole, these experimental values have a good agreement with the Butt FEM Model.

2.3 Crack FEM Model

Crack FEM Model is shown in Fig. 4 and the detailed shape of the dissimilar metal weld part including the 20 mm crack is shown in Fig. 5.

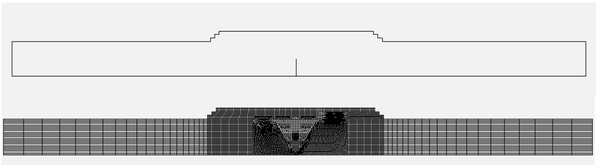

Fig. 4 2D FEM model of the Overlay weld

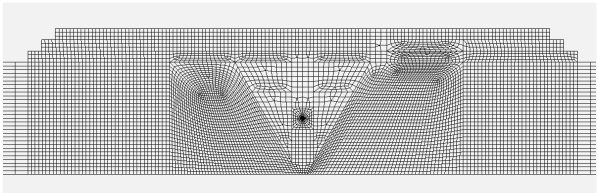

Fig. 5 Detailed shape of the DMWP

The top part of the plate was overlaid by the filler (Alloy 182). Totally, 3 layers on the dissimilar metal weld part were overlaid. Whenever each layer was overlaid, the behavior of the crack and the stress of the crack tip were investigated respectively. The deformation of the CMD (Crack Mouth Displacement) and the stress distribution (S11) after the 3rd overlay weld is shown in Fig. 6. The deformation of the CMD (Crack Mouth Displacement) and the stress distribution (S33) after the 3rd overlay weld is shown in Fig. 7.
The result of the CMD deformation after each overlay is shown in Table 1.

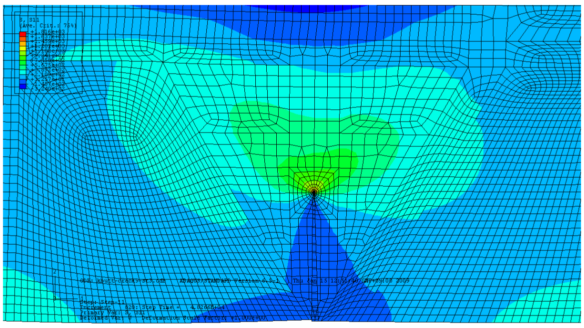

Fig. 6 Deformation of the CMD and the stress distribution (S11) of the 3rd overlay weld

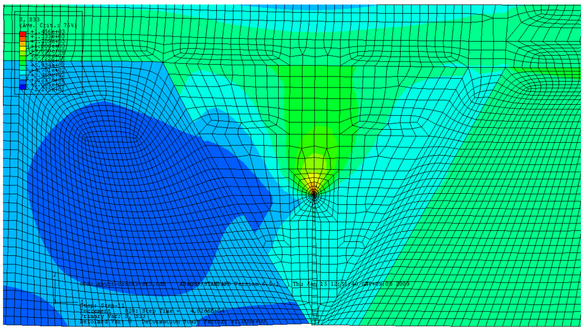

Fig. 7 Deformation of the CMD and the stress distribution (S33) of the 3rd overlay weld

Table 1. CMD deformation after each overlay weld

	Compression deformation length of CMD (mm)
1st overlay weld	0.026
2nd overlay weld	0.497
3rd overlay weld	1.069

The compression deformation length of the CMD is increased according to increasing the layers of the weld. This means that the overlay weld closes the CMD and has a benefit with a view to a PWSCC.

3. Conclusions

The experimental residual stress values measured by the X-Ray method and the Hole Drilling Technique have a good agreement with the FEM results. Therefore, FEM model can be trusted to analyze the residual stress of the dissimilar metal welds. Also, the crack within a Dissimilar Metal Weld Part (DMWP) is closed when the overlay weld on the DMWP was done. This means that the overlay weld has a benefit with a view to a PWSCC.

Acknowledgements
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