Derivation of Through-Thickness Residual Stress Distributions from Surface Residual Stress for Fitness for Service Assessment

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1. Introduction

To efficiently improve the reliability and applicability of continuous compressions in estimating the life span of nuclear power plants in Korea, it is necessary to develop a less time and cost-constrained analytical technique and apply it to various cases. Therefore, in this study, a comparison analysis of weld residual stress was conducted on the Instrumentation Indentation Testing, Finite Element Analysis (FEA) and Hole-Drilling Method (HDM). This paper, the effect on the weld residual stress of stainless steel plate welds according to the rolled rate was considered using Hole Drilling Method and Finite Element Analysis, excluding continuous compression.

2. Residual Stress Measurement

This section describes a specification of Mock-up Specimen, and welding residual stress was measured according to the rolling rate of the specimen using Hole- Drilling method and FEA.

2.1 Mock-up Specimen

The parent metal was made of austenitic stainless steel, SUS304 and welded part was used INOX308. Fig.1 shows the shape and size of the mock-up specimen.

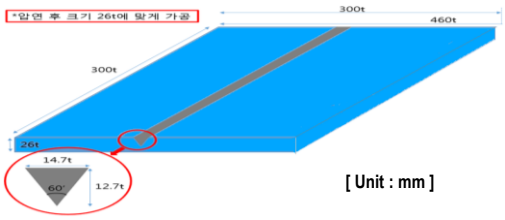


Fig.1 Size of mock-up specimen

2.2 Hole Drilling Method

The hole-drilling method was carried out in accordance with ASTM E837-13a [1] and Fig.2 is the measurement location and path setting of the residual stress by hole-drilling method.

Residual stress was measured in the direction of welding progress(path1) and the vertical direction (Path2). Fig.3 shows the measured transverse stress at path1 and path2.

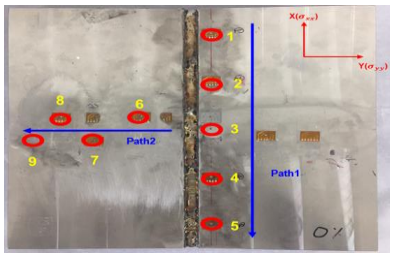
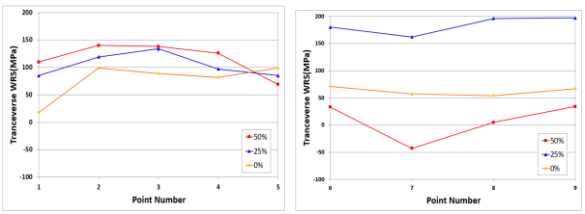


Fig.2 Measurement location and path setting



(a)Transverse (Path1) (b) Transverse(Path2)

Fig.3 Transverse stress at path1 and path2

2.3 Finite Element Analysis

2D finite element modeling using Abaqus program was performed and the transverse stress was obtained through thermal stress analysis after temperature analysis. Fig.4 depicts a finite element modeling.

The temperature analysis was conducted with thermal conductivity-based temperature analysis, the weld bead was welded at 1900℃ during welding, and the surface temperature except the weld area was set at 20℃. Thermal stress analysis used the CPE4 element, numbers of elements and nodes are 1673 and 1772.

Boundary conditions are tied to one point below the weld area.

Fig.5 shows the transverse stress according to the rolling rate.

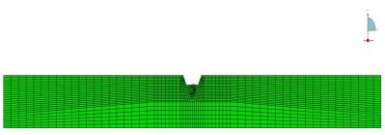


Fig.4 2D Finite element model

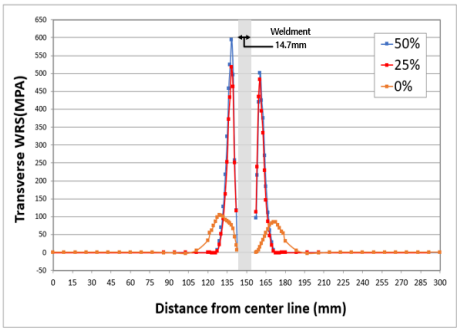
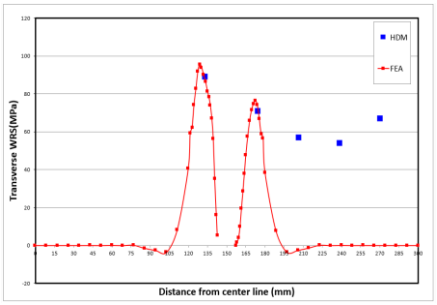


Fig.5 Transverse stress according to the rolling rate

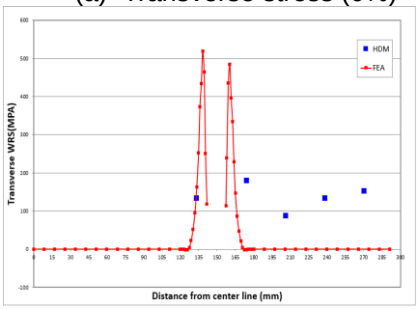
3. Comparison of FEM with HDM

Points measured by drilling method were not carried out in 3D in finite element analysis modeling, so the values corresponding to distance were defined in 2D modeling.

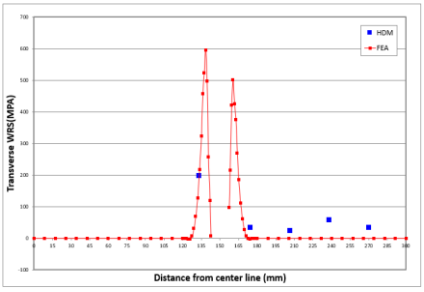
Fig.6 shows the comparison of drilling method with finite element analysis according to the rolling rate.



(a) Transverse stress (0%)



(b) Transverse stress (25%)



(c) Transverse stress (50%)

Fig.6 7 Comparison of Hole Drilling Method and the Finite Element Analysis

4. Conclusion

Measurement of residual stress using perforation method measured high stress around welds, and it was possible to identify the tendency to gradually decrease along the direction of progression of Path2.

Measurement results of Path2 residual stress with a rolling rate of 0% and 25% showed higher values than the analysis results.

Finite Element Analysis using ABAQUS, a commercial program, showed that Transverse Stress was formed high around the weld area.

The comparison between the residual stress measurement of welds with the perforation method and the finite element method showed that the two methods did not show much difference.

Acknowledgment

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References

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