Residual Stress Estimate for Various Welded Components for Performing Fitness for Service

Jong-sung Kim,[a] Seung-gun Lee,[a] Tae-en Jin,[a] P.Dong [b]
a. Korea Power Engineering Company, inc., Structural Integrity and Materials Dept.,360-9, Mabuk, Yongin
kimjs@kopec.co.kr
b. Battelle, Center for Welded Structures Research, 505 King Avenue, Columbus, OH
dongp@battelle.org

1. Introduction

To perform fitness for service assessment, we performed residual stress estimate for girth welded component. At first, a comprehensive girth weld residual stress analysis for various wall thickness(t) and radius to thickness ratio(r/t) is performed. Once some of the critical controlling parameters that govern through-wall residual stress distribution characteristics are discussed, a parametric description of the residual stress distributions is provided and validated. Finally, the effects of hydro proof tests on weld residual stress re-distributions are evaluated.

2. Residual Stress Analysis

In order to characterize girth weld residual stress distribution patterns, a series of parametric studies are performed using FEA method. Adequacy of the FEA method for residual stress estimation is well validated in previous studies[1,2].

2.1 Thickness and thickness ratio effects

Fig. 1 shows the residual stress analysis results with t and r/t. For a given r/t ratio with approximately constant pass size(or same welding parameters or linear heat input), an increased pipe wall thickness promote the self-equilibrating component as a thicker pipe wall becomes more difficult to bend. For a given thickness, a larger r/t ratio increases pipe wall flexibility(decreases pipe wall bending stiffness), also promoting self-equilibrating component.

2.2 Heat input effects

To clarify heat input effects on residual stress, artificial one pass model was used as an extreme case to gain insight on the maximum possible shrinkage force can promote the global bending type of axial residual stress distributions. We use result for t=0.25" and r/t=10 in Fig. 1 as a reference case, and then another analysis are performed with doubled the heat input. As shown in Fig. 2, the changes in overall residual stress distributions are insignificant. Therefore, as long as other parameters are not drastically changed, the overall residual stress types tend to remain the same.

2.3 WM/BM strength mismatch effects

To identify mismatch effects on residual stress, related analysis were performed by using different material properties between base and weld metal. The overall trend in the axial residual stress distributions are of self equilibrating type. With various mismatch conditions, local magnitudes vary depending approximately upon a given mismatch ratio(30% overmatch means that the weld metal yield strength is 30% higher than base metal). However, the overall residual stress distributions remain of same type, as shown Fig. 3.

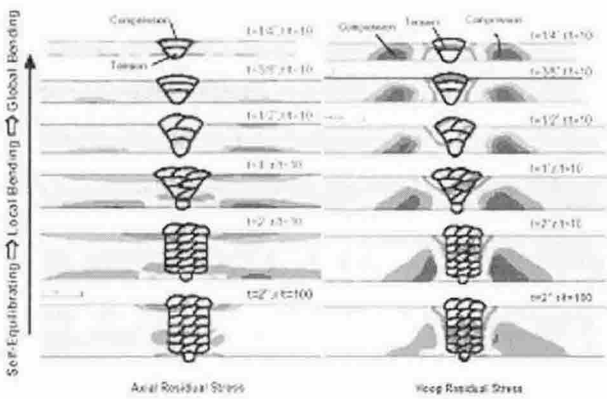


Fig. 1 Effects of pipe wall thickness (t) and pipe radius to thickness ratio (r/t) on residual stress development

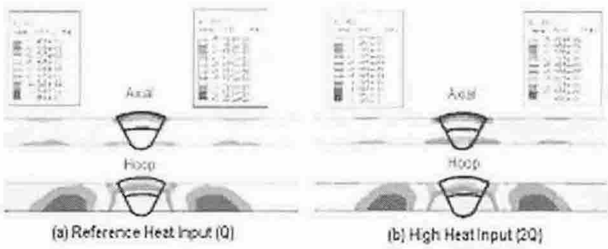


Fig. 2 Comparison of linear heat input effects on residual stress (t=0.25", r/t=10)

2.4 Hydro proof test effects

Two levels of hydro proof test pressure(75% and 110% of the yield strength of the pipe mat.) were applied for a girth weld with t=0.24" and r/t=10 to relieve residual stress. After applying a pressure at which the pressure-induced hoop stresses (pr/t) reaches to 75% of the yield strength of the pipe material, both axial and hoop residual stress are increased. After releasing pressure loading, the reduction of residual stresses from the as-welded conditions become significant as shown in Fig. 4, particularly for the hoop residual stress component.

If the pressure loading is further increase to 110% yield, the reduction becomes even more significant. At such a pressure level, plastic deformation becomes more wide spread.

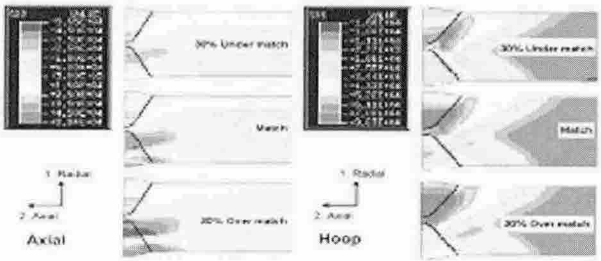


Fig. 3 Effects of yield strength mismatch on residual stress distribution (r/t=80, t=1.5", BM yield strength:45ksi)

3. Conclusions

(1) For a small thickness girth welds, axial residual stresses are the global bending types with a counter bending away from the weld center. When thickness increases, axial residual stresses become the local bending type for small r/t ratio with high tension at the outer surface and high compression at the inner surface, and there is no counter bending near or away from the weld. Axial residual stresses are closed to the self-equilibrating type with a thicker wall and a bigger r/t ratio.

(2) With variation of weld heat input, the changes in overall residual stress distributions are insignificant.

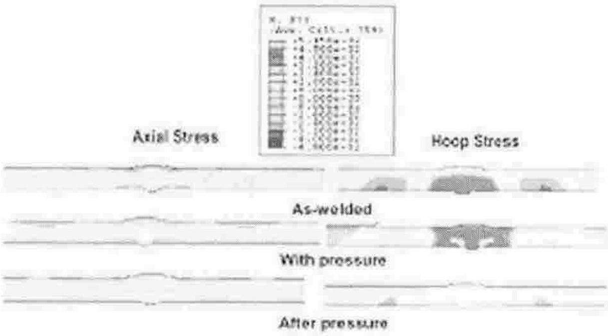
(3) With various mismatch conditions, local magnitudes vary depending approximately upon a given mismatch ratio. However, the overall residual stress distributions remain of same type.

(4) Reduction of residual stresses from the as-welded conditions becomes significant as hydro proof test pressure increases, particularly for the hoop residual stress component.

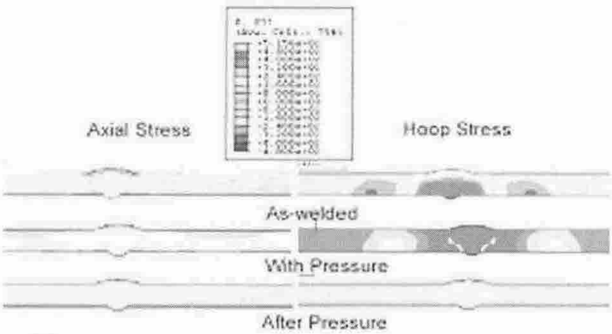
REFERENCES

[1] J.S.Kim, T.E.Jin, P.Dong and M.prager, Development of residual stress analysis procedure for FFS assessment of welded structure, Transaction of KSME A, Vol.27, No.5, pp713-723, 2003.

[2] P.Dong, Z.Cao, and J.K.Hong, Investigation of weld residual stresses and local post-weld heat treatment, PVRC, 2002.



(a) hoop stress at the 75% of yield strength of the pipe mat.



(b) hoop stress at the 110% of yield strength of the pipe mat.

Fig. 4 Hydro pressure test with hoop stress (0.25", r/t=10, 2 passes)