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Numerical Study of Overlay Welding Effects on Residual Stresses in Girth Welded Steel Pipes

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ABSTRACT: The overlay of the outer surface of a pipe by welding is one of the ways to decrease the residual stress. In this research, a finite element model by considering phase transformation effect is developed in the SYSWELD software for the simulation of circumferential welding process of two API X65 steel pipes. This model is validated using a hole drilling method. Then, the effect of overlay welding created by three types of welding filler on the residual stress is investigated. The results show that the overlay welding created by ER70s filer increases axial and hoop stresses. But ER304 and IN600 fillers cause reduction of hoop residual stresses. The stresses at the covered area are compressed because of the increase in heat input as an effective factor. Also, axial stresses due to these filers at low weld energy are greater than sample stress without a cover. However, the value of this stresses decreases when the weld energy increases. Thus, the proportional stress level can be obtained in the pipe using the overlay with filers of ER304 and IN600 associated with a high heat input and by selecting suitable overlay dimensions.

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1- Introduction

Overlay welding is used to prevent stress corrosion cracking, repairing of cracks and defects after welding and decreasing tension residual stress in the inner surface of pipes. In the weld coating method, after the initial welding operation between the two pipes, the welding operation is down circumferentially in the outer surface of the pipe [1] (Fig.1).

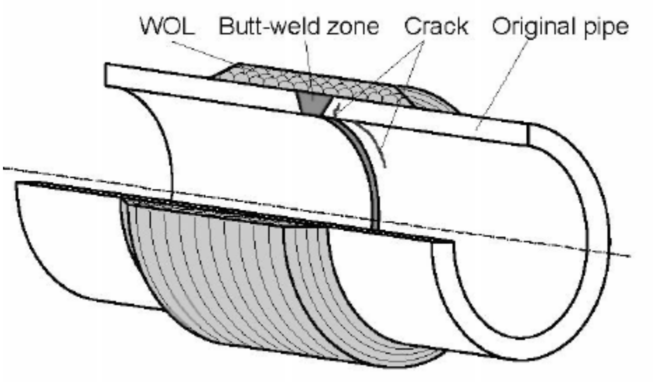

Fig. 1. Overlay welding [1]

The length of the cover in the circumferential direction, the thickness of the cover, length of cover in the axial direction of the pipe, the property of cover layer and welding variables such as welding energy and the number of passes are effective variables in the weld coating method.

In the present study, first, a finite element model is constructed in SYSWEL [2]. The property of steel (API X46) is considered for the pipe [3]. Then the results are validated using the results of strain gage of the hole and reference [4]. Finally, the effects of covering with different materials on the residual stress are investigated using the validated finite element model.

2- Finite Element Model Verification

Test piece consists of two similar steel pipes (API X46) with diameter 152.4 mm, thickness 10 mm and length 400 mm. The values of circumferential and axial residual stresses on the outer surface of the pipe obtained from strain gage method and finite element model are compared in Fig.2. The good accordance between numerical and experimental results can be seen. Thus, other models with similar geometry and different conditions can be reliably modeled with this method.

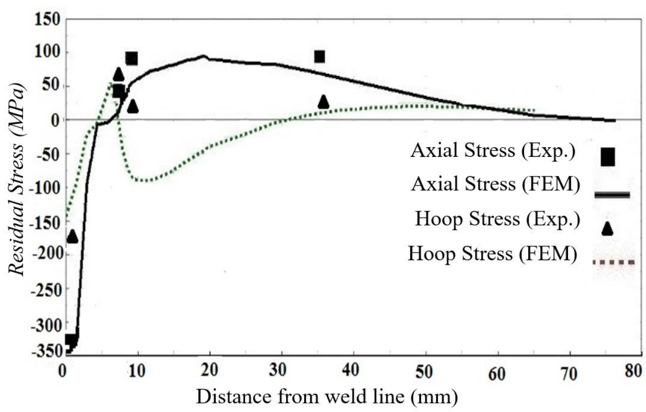

Fig. 2. Comparison of axial and hoop residual stress distribution in the finite element model and experimental sample on Outer Surface

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3- Overlay Welding Effects

Stainless steel 304, Inconel 600 [5] and ER70s electrodes are investigated as the cover. The cover at eight passes with a thickness of 3 mm and length of 50 mm is caused. Distribution of axial and circumferential stresses due to welding and covering for three materials and two weld energy 1500 and 3000 J are shown in Figs.3 to 6. Stress values at angle 180 from point of start welding are calculated.

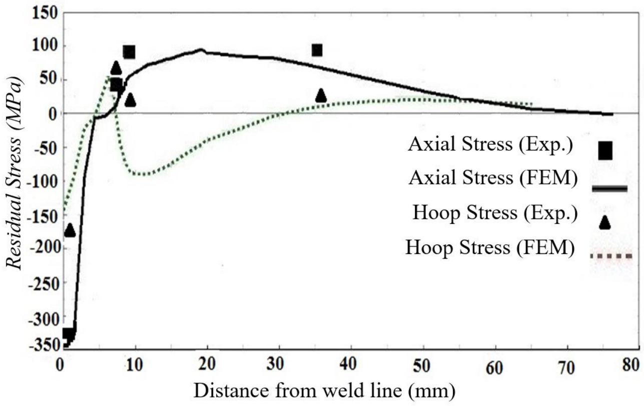

Fig. 3. Axial residual stress distribution on the inner surface of the pipe for three different filler with 1500 J heat input

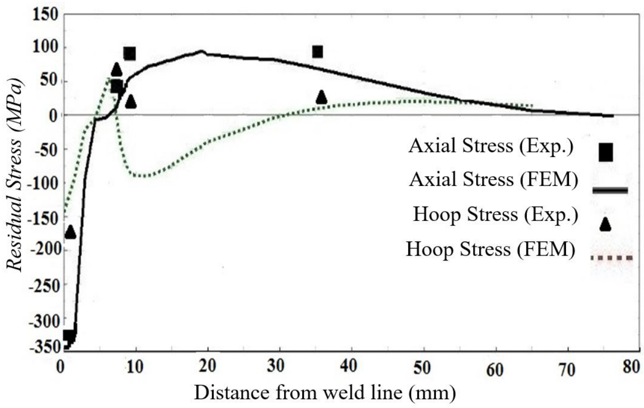

Fig. 4. Hoop residual stress distribution on the inner surface of the pipe for three different filler with 1500 J heat input

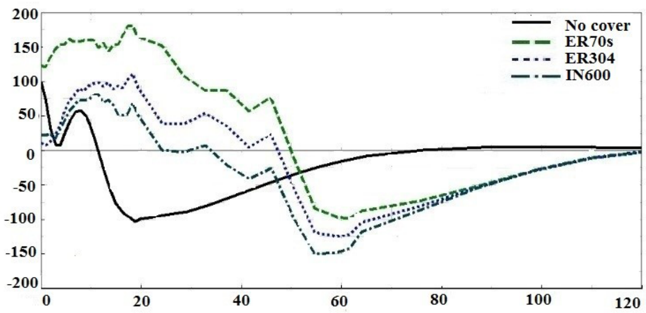

Fig. 5. Axial residual stress distribution on the inner surface of the pipe for three different fillers with 3000 J heat input

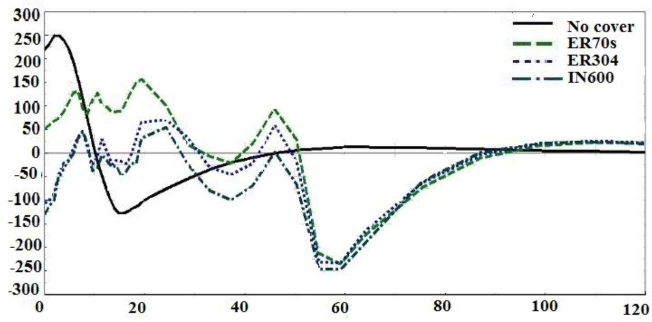

Fig. 6. Hoop residual stress distribution on the inner surface of the pipe for three different fillers with 3000 J heat input

4- Conclusions

The results of this study are as follows:

1. Using the similar electrode to base metal as a cover at the low weld energy increases maximum axial residual stress in the inner surface of the pipe up to 100%. In the covered area, the values of circumferential stress in the inner surface decreases and the maximum values of tension stress do not change and translates to 20 mm from the weld line. This electrode at high weld energy increases axial stress on the inner surface to 50%, decreases circumferential stress to 60% and translates tension stress to 25 mm from the weld line.
2. Using stainless electrodes ER304 and IN600 with a low weld energy decreases circumferential stress on the inner surface to 55%, increases axial stress to 95% and translates tension stress to 25 mm from the weld line. This electrode at high weld energy decreases the circumferential stress on the inner surface from 250 to 550 es
3. Mpa and the maximum values of axial stress do not change. Also, it causes compressive circumferential stress on the inner surface at the welding area. These electrodes have similar effects on the residual stress. However, the effect of ER304 is more considerable and makes the stress on the inner surface lower.
4. The use of cover welding, causes a change in stress distribution and increases the area of tensile stress for the axial and circumferential states. Thus, the area of maximum stress is translated.

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