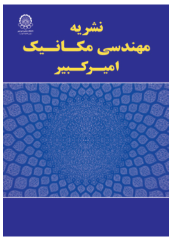

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Numerical and Experimental Investigation of Layer Number Effect on Residual Stresses in Cladding Process

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ABSTRACT: Weld residual stress is one of the most sensitive issues in the safety and reliability of structures such as nuclear reactor components. In order to prevent the corrosion caused by corrosive environments, the inner surface of containers made of carbon steel, is cladded in a layer of austenitic stainless steel. In this study, a steel plate of carbon steel A516-G70, will be cladded by the shielded metal arc welding method. In order to validate the results, hole drilling method is used to determine residual stresses. Finally, the residual stresses in samples with two and three layer cladding are examined. By giving the sources of error in testing, the results have a relatively good compliance. The results indicate that, the maximum amount of residual stresses in the clad layer, are tensile and in the stress limit, it is in submission of base metal and cladding layer. Also, by increasing the number of layers in the cladding layer thickness and steel plate, residual stresses are reduced. However, at the surface of the cladding layer stresses have inconsiderable changes. And on the border between the cladding layer and the plate, residual stress increases by increasing the number of layers.

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1- Introduction

The main pressure vessels and nozzles in nuclear reactors are made of ferritic carbon steel. Due to exposure to corrosive environments, the inner surface of this part of the nuclear reactors, are affected by corrosion [1]. In order to prevent this event and its harmful effects, and given the importance and the needs for safety and reliability of these structures, their inner surface is cladded in austenitic stainless steel. The existence of residual stresses which is caused by the cladding [2], is one of the critical issues. The tensile residual stress in cladding is largely due to the differences in the thermal expansion of the cladding and the base materials. Also the post-weld heat treatment is used to adjust the residual stresses. Although research has shown that even after PWHT [3] a high tensile stress remains in the cladding layer. This stress still remains after PWHT because the cladding and the base material aren't the same and have different thermal expansion coef?cients. Cladding over the major parts of the vessel inner surface, is applied by automatic submerged arc-welding (SAW) with strip electrodes of different sizes, normally 60 mm wide. Manual arc-welding process is used to clad local areas in nuclear reactors such as main coolant nozzles. In order to access the desired thickness, two layers strip cladding may also be used. The aim of this study is to evaluate the residual stresses resulting from the process of cladding carbon steel with manual arc-welding process, as well as the effect of the number of layers on the amount and distribution of residual stresses using the experimental and finite element methods.

2- Methodology

In this study, the process of cladding two steel plates with 210 mm of length, 190 mm of width and of 35 mm thickness of A516 Grade 70, through finite element simulation is examined. Cladding for two layers and three layers by electrodes coated with a thickness of 5.5 mm by 309L for the first layer and L308L to the second layer is done with manual electrode welding method. Coated electrodes for manual welding process are used. At the end, the results of thermal history and distribution of residual stresses in different areas will be examined and compared with each other. For this purpose, electrodes with a diameter of 4 mm are used. Tables 1 and 2 show the welding conditions for cladding with 2 and 3 layers.

Table 1. Welding parameter of two layers clad

	First layer(ER309L)	Second and Third Layer(ER308L)
Current [A]	150	150
Voltage [V]	25-27	25-27
Speed [mm/s]	3.5	3
Bead Number	14	14
Clad Thickness	3	2.5

Table 2. Welding parameter of two layers clad

	First layer(ER309L)	Second and Third Layer(ER308L)
Current [A]	150	150
Voltage [V]	25-27	25-22
Speed [mm/s]	3.5	4.5
Bead Number	28	28
Clad Thickness	2.5	1.5

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3- Results and Discussion

Fig. 1 shows the effect of the weld layer on transverse residual stress along the cladding thickness. Fig. 2 and 3 show the comparison between the distribution of residual stresses in the transverse and longitudinal directions. The results show that changes in the longitudinal and transverse residual stresses in the cladding layer surface is n, but in the border of cladding layer and plate steel plate, on the steel plate, there are more residual stresses in the three layers sample. On the surface of the cladding layer which is closer to the inside layer, residual stresses will increase. So after 15 mm, residual stress in the cladding layer is almost constant.

After reaching ambient temperature, strain measurement method is used to measure residual stresses in the hole drilling. By analyzing and comparing the obtained values from the results of two and three-layer model and finite element, a relatively good agreement between the results can be realized. Fig. 4 shows that the sample is cladded.

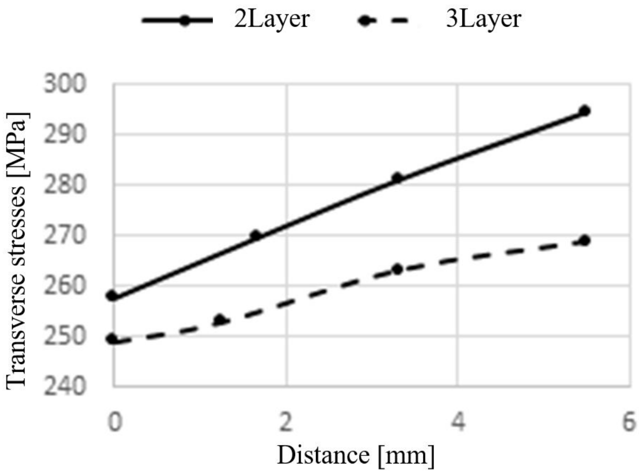

Figure 1. Transverse stresses comparison

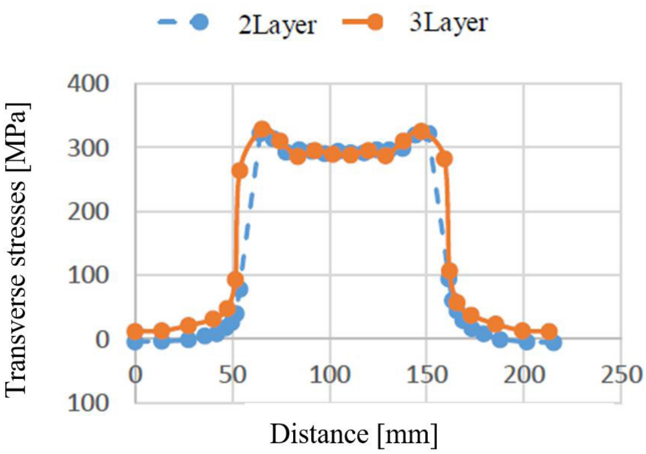

Figure 2. Transverse stresses comparison

4- Conclusions

By comparing the results of residual stress from two and three layer samples, it can be concluded that:

- Changes in the residual stresses, according to changes in the number of layers, can vary depending on the measuring position.

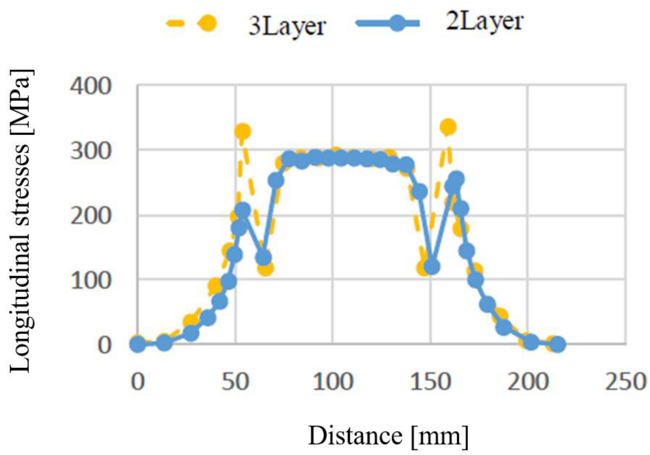

Figure 3. Longitudinal stresses comparison

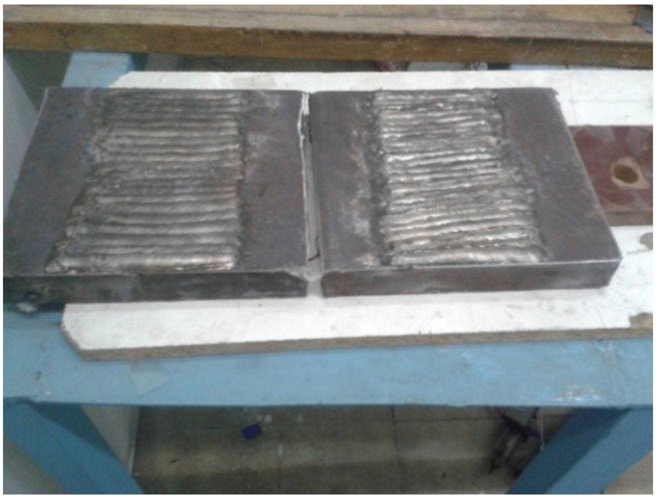

Figure 4. Cladded samples

- Tensile stresses with increasing number of layers, Have little effect at the surface of the clad,
- The length and width of the clad layer is large in relation to its thickness, It causes longitudinal and transverse tensions to be close together
- Given the dependence of residual stress in welded and because the transverse deformation of the cladding layer is greater than its longitudinal counterpart, transverse to the tension values are relatively higher
- Longitudinal residual stresses will increase in the direction of the thickness of the cladding layer. This is because the cladding layer has stronger constraint conditions.
- Residual stress values can be vary in different regions, so that there is less residual stress in the direction of contraction, and more in the border of the clad and the plate.

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