

Welding of Clad Carbon Steel Coated By Nickel Base Alloy

By

Mohamed Morsi Mohamed Farag

**A Thesis Submitted to the Faculty of Engineering at Cairo University
in partial fulfillment of the requirements of**

Doctor of Philosophy

In

Metallurgical Engineering

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Under the supervision of:

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Summary:

The objective of this thesis is to provide a new welding procedure to get substantial cost saving without impairing corrosion resistance or mechanical properties. The suggested procedure was made by welding first and second passes only using AWS A5.14 ERNiCrMo3 and subsequent passes by AWS A5.1E7018. Unfortunately typical welding parameters recommended by filler metal supplier gave unacceptable mechanical properties. Microstructure evaluation demonstrated that: cracks were formed along type II boundary in second inconel pass and a martensitic layer was formed in carbon steel pass (3rd pass). In this investigation hydrogen was removed from the weldment by baking at 280°C but this hydrogen removing operation did not prevent cracking, indicating that hydrogen cracking is not the controlling mechanism of failure. High residual tensile stresses induced during welding and subsequent solidification are thought to be the main reason for cracking along type II grain boundaries. Reducing residual stresses by increasing preheat and interpass temperatures did not prevent cracking. Thus nonconventional techniques are required. A trial was attempted to prevent cracking along type II boundary in 2nd pass by controlling martensitic start temperature (T_{MS}) of the 3rd pass to induce compressive residual stresses. Three levels of T_{MS} (approximately 350, 200, and 50°C) are obtained. Cracks along type II boundary were prevented at T_{MS} lower than 200°C; however type II boundary itself was prevented at T_{MS} lower than 50°C. Although cracks were prevented by reducing T_{MS} of the 3rd pass and accept side bend properties were obtained, impact toughness properties were still not acceptable due to the formation of martensite in the 3rd pass. Thus tempering was necessary which requires cost. To avoid PWHT, AWS 5.11 ENi-1 as nickel rich filler metal was used to weld the 3rd pass and subsequent pass were welded by AWS A5.1E7018. As a result the microstructure of the 3rd pass was iron nickel martensite instead of iron martensite and average impact toughness increased from 22 to 47 Joule at 0°C.

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