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

Faculty of Engineering, Cairo University

GIZA, EGYPT

2015

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

Under the supervision of:

Prof. Dr. Mohamed Raafat El- Koussy,
Department of Petroleum, Mining and Metallurgy,
Cairo University

Faculty of Engineering, Cairo University

GIZA, EGYPT

2015

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

Approved by the Examining Committee:

Prof. Dr. Mohamed Raafat El- Koussy, Thesis main advisor

Prof. Dr. Ahmed Mohamed Elsheikh, (Internal examiner)

Prof. Dr. Tarek Ahmed Fouad Khalifa (External examiner)
Professor of production Engineering, Faculty of Shoubra, Benha University

Faculty of Engineering, Cairo University

GIZA, EGYPT

2015

Engineer's Name: Mohamed Mosi Mohamed Farag
Date of Birth: 8/6/1975
Nationality: Egyptian
E-mail: Moh_mmmf@yahoo.com
Phone: 01068240575
Address:

Registration Date: 17 / 3 / 2009
Awarding Date : / /
Degree: Doctor of Philosophy
Department: Mining, Petroleum and Metallurgy

Supervisors:

Prof. Dr. Mohamed Raafat El- Koussy, Cairo University

Examiners:

Prof. Dr.Eng. Tarek Ahmed Fouad Khalifa, (External examiner)

(Professor of production Engineering, Faculty of Shoubra, Benha University)

Prof. Dr. Ahmed Mohamed Elsheikh, (Internal examiner)

Prof. Dr. Mohamed Raafat El- Koussy, (Thesis main advisor)

Title of Thesis: Welding of Clad Carbon Steel Coated By Nickel Base Alloy

Key Words: - Clad carbon steel- Inconel 625- Grain boundary type II – Martensite –Tensile and compressive stress weld-cracks)

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 (3^{rd} pass). In this investigation hydrogen was removed from the weldment by baking at 280^{o}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 gain 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 2^{nd} pass by controlling martensitic start temperature (T_{MS}) of the 3^{rd} pass to induce compressive residual stresses. Three levels of T_{Ms} (approximately 350, 200, and 50^{o}C) are obtained. Cracks along type II boundary were prevented at T_{Ms} lower than 200^{o}C; however type II boundary itself was prevented at T_{Ms} lower than 50^{o}C. Although cracks were prevented by reducing T_{MS} of the 3^{rd} pass and accept side bend properties were obtained, impact toughness properties were still not acceptable due to the formation of martensite in the 3^{rd} 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 3^{rd} pass and subsequent pass were welded by AWS A5.1E7018. As a result the microstructure of the 3^{rd} pass was iron nickel martensite instead of iron martensite and average impact toughness increased from 22 to 47 Joule at 0^{o}C.

ACKNOWLEDGMENTS

First of all I want to express my gratitude to my company; PETROJET, for providing me the financial and technical support to obtain my P.HD degree in Cairo University.

I would like to express my sincere thanks to my supervisors, Professor Mohamed Rafaat Elkousy, Profssor Nahed Abdel-Raheem and Dr. Morsy Amin for their support, professional guidance, patience encouragement, and affection through the course of my work.

My acknowledgment also goes to my friends, especially Mohamed Adel, Mohamed Fathy, and Tamer Nabil who helped me to accomplish this work.

Finally I would like to thank my parents. They raised me, support me, taught me, and loved me. Especial appreciation and gratitude is given to my loving, and supportive wife for her encouragements and patience, for listening to my complaints and frustrations, and for believing in me.

This thesis is dedicated to my children, Mena, Moaaz and Mariem.

Contents

List of Tables

List of Figures