Final Project Report

Date of Report: January 6, 2012

Contract Number: DTPH56-10-T-000015

Prepared for: United States Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Pipeline Safety

United States Department of Interior
Bureau of Ocean Energy Management, Regulation, and Enforcement

Pipeline Research Council International (PRCI)

Project Title: Optimization of Multi-Wire GMAW Welding Procedure for Heavy-Wall Offshore Pipeline Construction

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Invoice for this quarterly period: E10-J01-01-DOT-In02

Project Status Summary

DOT/PHMSA, in a communication with CRES on July 27th of 2011, decided to terminate the project. The project team stopped working on any technical work since then. On the 30th of November 2011, the final contract modification for project termination was signed.

It was agreed that CRES would provide a brief final report at the termination of the project.

(a) Technical Status

Besides the project management activities, only part of the technical activities of Task 2 was performed. This final report will briefly describe the activities and the related results.

Task 2: Model Development and Calibration

This section briefly describes the research activities and results.

In order to predict the thermal cycles and microstructures of X70/X80 girth welds, including the weld metal and the heat-affected zone (HAZ) made with GMAW and its multi-wire variants, the fundamental responses of both weld metal and HAZ to welding thermal cycles are needed. For this reason, the past research works on HAZ and weld metal microstructure and mechanical properties were reviewed. Data for X70 and X80 pipe steels and their girth welds were collected. As presented in the PHMSA-sponsored X100 welding project reports[1,2], the integrated model was able to predict the thermal cycles and hardness profiles within a pipeline girth weld. The microstructure model was originally developed toward its application to X100 girth welds. Calibrating the microstructure model against the X70 and X80 data would expand the model's range of application to X70 and X80 girth welds.

HAZ Data

X70 and pipe steels in general have ferrite- perlite while X80 steels have bainite-ferrite or bainite-ferrite and pearlite microstructures. This is in contrast to the bainite-martensite microstructures in typical X100 pipe steels.

There have many microstructure studies on X70 or X80 steels through the examination of their responses to thermal cycles by using Gleeble thermal simulations. By applying thermal cycles with different cooling rates typical of those in girth welding of pipeline, the microstructure, hardness profile, and mechanical properties of the pipe materials were

[1] Chen, Y., Wang, Y.-Y., Quintana, M.A., Rajan, V.B. and Gianetto, J.A., "Thermal Model for Welding Simulations", Final Report 278-T-07 to PHMSA per Agreement # DTPH56-07-000005, September 2011.

[2] Chen, Y., Wang, Y.-Y., Quintana, M.A., Rajan, V.B. and Gianetto, J.A., "Microstructure Model for Welding Simulations, Final Report 278-T-08 to PHMSA per Agreement # DTPH56-07-000005, September 2011.

examined. The work by Denys [3], for instance, examined 5 pipe steels (3 X70 steels and two X80 steels) using Gleeble simulation with different cooling rates and peak temperatures. The microstructures and hardness in the coarse-grained HAZ (CGHAZ) were evaluated as a function of the cooling rates and peak temperatures. Tensile tests and Charpy tests were also performed on the simulation-tested materials for tensile and toughness properties. The X100 welding project also provided an in-depth investigation on one X80 pipe steel.

Among the studies on X70/X80 HAZ evaluations, perhaps one of the technical gaps is the microstructure behaviors of pipe steels under reheating conditions. There are very limited amounts of research data in public. One recent work [4] investigated the impacts of peak temperature on the microstructure and toughness of CGHAZ of X70 pipe steels.

Weld Metal Data

Compared to HAZ, experimental studies on the microstructure of weld metal are more limited because of its complexity and uncertainties. There have been many qualitative, theoretical studies on weld metal behaviors such as those by Bhadeshia. But very few provided a platform for practical implementation with a complete formulation that includes all the values of the relevant material and empirical parameters. One of those that does was by Nevasmaa [5].

One part of the PHMSA-sponsored X100 welding project [6] provided an excellent source of data for weld metal properties under different thermal cycles. Although these weld metals (5 types) were designed for X100 girth welds, the less-alloyed (LA90, LA100, or even Ni Mo80) can be potential candidates for X70/X80 welds under lower cooling rates.

In summary, these are enough amount of X70/X80 HAZ data that are readily available for model calibration after the review of public literature. For weld metal, however, the data is still limited and additional experiments may be needed before the model can be calibrated.

Task 8: Meetings and Project Management

The project team and DOT had several communications in the process of project termination. Final contract modification was completed, including an agreed final invoice to DOT.

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[3] Denys, R. M. and Lefevre, T., "Effects of Welding on HAZ Softening of X70/X80 TMCP Linepipe Steels," PRCI Report Catalog No. L51926, Contract PR-202-9635

[4] Li, C, Wang, Y., and Chen, Y., "Influence of peak temperature during in-service welding of API X70 pipeline steels on microstructure and fracture energy of reheated coarse grain heat-affected zones," J. Mater. Sci., 46:6424-6431, 2011

[5] Nevasmaa, P., "Predictive model for the prevention of weld metal hydrogen cracking in high-strength multipass welds," Ph. D. thesis, University og Oulu, 2003.

[6] Gianetto, J.A., Goodall, G.R., Tyson, W.R., Quintana, M.A., Rajan, V.B. and Chen, Y., "Microstructure and Properties of Simulated Weld Metals", Final Report 278-T-04 to PHMSA per Agreement # DTPH56-07-000005, September 2011.

Task 9: Reports and Presentations

The project team submitted all required monthly and quarterly status updates before the project termination was initiated.

(b) Business Status

A final invoice was issued to DOT to cover the project spending of the project management activities up to the fourth quarter, and part of the research activities of Task 2.

(c) Schedule

(d) Payable Milestones

Table 1 lists the payable milestones for the final period. These were included in the final invoice.

Table 1 Payable milestone status for final report

Task No.	Item # Per MS	Task Description	Status	Scheduled Completion Date	Payable Milestone (Item No)
2	2	Model development	incomplete	6/31/2011	MS
8	9	Meeting and Management	100%	3/31/2011	MS
9	10	Report and Presentation	100%	3/31/2011	MS
8	15	Meeting and Management	100%	6/30/2011	MS
9	16	Report and Presentation	100%	6/30/2011	MS
8	21	Meeting and Management	100%	9/30/2011	MS
9	22	Report and Presentation	100%	9/30/2011	MS