Industrial Technologies Program

Development of a New Class of Fe-3Cr-W(V) Ferritic Steels for Industrial Process Applications

The New Ferritic Alloy Will Lead to Weight Reduction, Reduced Fabrication Time, and Energy Savings

This project dealt with the development of a new class of Fe-3Cr-W(V) steels for use in the construction of chemical processing equipment, such as hydrocrackers, hydrotreaters, and heat recovery systems. The key attributes targeted for the new steel include: (1) 50% higher tensile strength up to 550 to 600ºC as opposed to the currently available materials, (2) potential for not requiring postweld heat treatment (PWHT) for certain welding processes, (3) reducing the equipment weight by 25%, and (4) resulting impact properties of approximately 100 ft-lb of upper shelf energy and a ductile-to-brittle transition temperature (DBTT) of -10ºF.

Quite a number of chemical processing equipment is currently fabricated from Fe-2.25Cr-1Mo steel, commonly known as Grade 22. Some of the equipment fabricated from this steel has to use section thickness up to 10 in. and can weigh as much as 100 to 300 tons. Most of this equipment is built to ASME Code rules and thus, if PWHT is required, once erected, no equipment modifications are possible. The 50% higher tensile strength of the newly developed steel will reduce the section sizes to nearly half and thereby reduce the equipment weight size from 100 to 300 tons down to 50 to 150 tons. Furthermore, since some welds are made by the gas tungsten arc (GTA) process, they require no PWHT and once the equipment is erected, it can be modified by using the GTA welding process.

Examples of hot-rolled plate and tubing produced using the newly developed Fe-3Cr-W(V) Steel

Benefits for Our Industry and Our Nation

The development of the advanced steel that meets the project goal will result in energy savings from a combination of several factors including:

- *Elimination of energy needed to produce 25 to 50% less steel for fabricating components*
- *Significant reduction in energy needed to weld 25 to 50% thinner steel sections*
- *Reduction in energy by eliminating PWHT for certain weld practices, such as GTA*
- *It is estimated that by 2020, full-scale implementation of the advanced alloy developed in this project will result in an energy savings of 21 trillion Btu/year.*

Applications in Our Nation's Industry

Target industries for this product include:

- Chemical and Petrochemical
- Forrest Products
- Steel
- Welding

Project Description

The goal of this project was to reduce the weight of large pressure vessel components (ranging from 100 to 300 tons) by approximately 25% and reduce fabrication cost and improve in-service modification feasibility through development of Fe-3Cr-W(V) steels with combination of nearly a 50% higher strength, a lower DBTT and a higher upper-shelf energy, ease of heat treating, and a strong potential for not requiring PWHT.

Barriers

- Low strength properties of current alloys require thicker sections
- Increased thickness causes heat-treatment issues related to nonuniformity across the thickness and thus not achieving the optimum properties
- Fracture toughness (ductile-to-brittle transition) is a critical safety issue for these vessels, and it is affected in thick sections due to nonuniformity of microstructure
- PWHT is needed after welding, making fabrication more time-consuming with increased cost and limiting any modifications of the large vessels in service

Pathways

The goals of this project were realized through research and development conducted by a team consisting of chemical and petrochemical industries, materials producers, a component fabricator and welding process developer, a weld wire producer and process developer, a heat recovery unit construction company, and a national laboratory. Industry participated by: (1) identifying reactor vessels and other components that can take advantage of the new steel, (2) conducting component testing, (3) assisting in producing production-size heats of the new steel, (4) assisting in component fabrication and process development, and (5) developing the welding process.

Results

The newly developed steel showed the following attributes as compared to the commonly used 2.25Cr-1Mo steel and a recent high-strength version known as T23:

- 60 and 25%, respectively, higher yield at room temperature as compared to 2.25Cr-1Mo (Grade 22) and T23
- 110% higher yield strength at 482ºC (900ºF) as compared to 2.25Cr-1Mo and 45% higher at 600ºC (1110ºF) as compared to T23
- 50 and 33%, respectively, higher ultimate tensile strength at room temperature as compared to 2.25Cr-1Mo and T23
- 50% higher ultimate tensile strength at 482ºC (900ºF) as compared to 2.25Cr-1Mo and 33% higher at 600ºC (1110ºF) as compared to T23
- Charpy-impact upper shelf energy of approximately 100 ft-lb and 50 ft-lb and DBTT of -20 to -40ºF
- Creep-rupture strength values higher than the high-strength T23 grade temperatures of < 593ºC (1100ºF)
- New steels can be welded by all common welding processes [gas tungsten arc (GTA), submerged arc (SA), and shielded-metal arc (SMA)]

Commercialization

Significant progress towards commercialization of the new steels developed in this project was made through the following steps:

- Approval of specifications in ASTM
- Got closer to obtaining ASME Pressure Vessel and Boiler Code approved design allowable stresses by submitting a comprehensive mechanical properties data package to the code committees
- Retaining Dr. Maan Jawad as a consultant to the project for participating at the ASME Code Committee Review meetings to answer any questions that might arise during deliberations

Project Partners

Nooter Corporation
St. Louis, MO
(Maan Jawad: maanjawad@aol.com)

Oak Ridge National Laboratory
Oak Ridge, TN

ExxonMobil
Baytown, TX

BP-Amoco
Naperville, IL

DuPont
Wilmington, DE

ISG Plate
Coatesville, PA

Elwood Materials Technologies
New Castle, PA

Elwood National Forge
Elwood City, PA

Plymouth Tube Company
Warrenville, IL

Stoody Company
Bowling Green, KY

Nooter-Eriksen
St. Louis, MO

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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