Fracture Toughness and Strength in a New Class of Bainitic Chromium-Tungsten Steels

A new ferritic alloy will be used to design hydrocracker and chemical reactors

Benefits

Fracture toughness data on a new class of Cr-W steel will become available for use in designing and fabricating process vessels.

With the application of Fe-3Cr-W(V) ferritic steels in the chemical, steel, and forest-products industries,

- Significant energy and environmental benefits are anticipated.

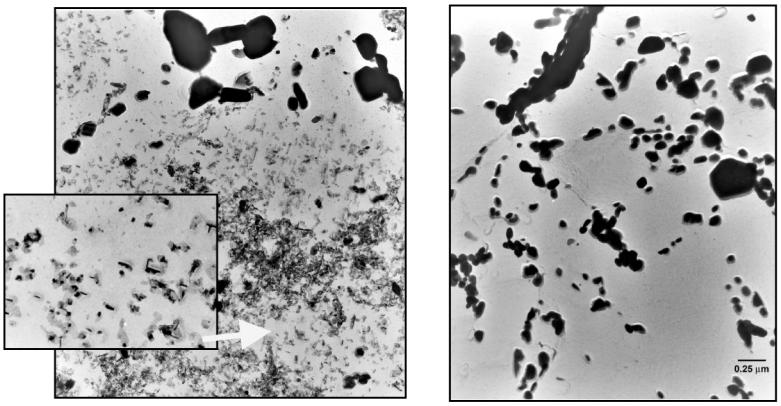
Applications

The alloys from this project will have the following applications in the **Chemical, Forest Products, Heat-Treating, Petrochemical, Process-Heating,** and **Steel** industries.

- Chemical reactor vessels for chemical industries.
- Heat recovery systems for chemical and petrochemical industries.
- Hydrocrackers for the petrochemical industry.
- Structural materials and coatings for steel-processing systems.

The project focuses on high fracture toughness and strength for a new class of Fe-3Cr-W (V) steels through understanding of their toughening and strengthening mechanisms. This class of steels has (1) 50% higher tensile strength at temperatures up to 550 to 600°C than current alloys, (2) high fracture resistance, and (3) potential for not requiring any postweld heat treatment (PWHT). However, this new class of Fe-3Cr-W(V) steels is not of sufficient maturity due to lack of understanding (1) microstructure-controlled strengthening and toughening, which can lead to further development of the steels, and (2) the fracture toughness relationship with microstructure in weldments before and after PWHT.

New microstructure design - finer and more stable precipitates



New: 2 1/4 Cr-2WV Previous: 2 1/4 Cr-Mo

Fracture toughness measurement system

Project Description

Goal: The goal of this project is to understand the toughening and strengthening of the new Fe-3Cr-W(V) steels and weldment so as to optimize microstructure through heat treatment and composition design of the steels.The ultimate goal is to reduce the weight of large pressure vessel components (ranging from 100 to 300 tons) by approximately 25%, 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, high fracture resistance, and a strong potential for not requiring PWHT.

Issues: This project will improve the current limitations in design and operations of industrial processing vessels.
Current materials have various issues:
– Low strength properties require thicker sections.
– Postweld heat treatment (PWHT) is needed and makes fabrication more time-consuming with increased cost.
– PWHT requirement also limits any modifications of the large vessels in service.
The major hurdles to be overcome in the R&D of the new W modified steels include
– Optimizing the steel composition and
– Identifying the microstructure of weldments for high fracture toughness while not requiring PWHT.

Approach: Experiments will be performed on the new class of Fe-3Cr-W(V) steels. Specimens will be prepared at the Oak Ridge National Laboratory (ORNL) by vacuum arc-melting, solidification, hot-rolling, austenitizing at 1050°C, and normalization in argon. Some of specimens will be tempered at 700°C. Welding will be also performed on the new class of Fe-3Cr-W(V) steels. The University of Pittsburgh will carry out the microstructure characterization by the use of transmission electron microscopy (TEM) and energy-dispersive spectroscopy (EDS), measure the tensile properties and characterize the microstructure of prestrained specimens by TEM, and determine the fracture toughness by performing J_{IC} tests and subsequent atomic force microscope (AFM) analysis of areas near the crack tip.

Potential payoff: The weight of large hydrocracker vessels (ranging from 100 to 300 tons) would be reduced by approximately 25%, and in-service modification would be feasable. The use of the Fe-3Cr-W(V) steels is anticipated to lead to significant energy benefits.

Progress and Milestones

- Sample preparation and weld processing.
- Characterization of precipitates by TEM and EDS.
- Complete TEM observation on predeformed samples (strengthening mechanism).
- Complete fracture toughness J_{IC} testing.
- Complete fracture toughening mechanisms examination by SEM and AFM.

Primary

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Project Partners

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