UK-US Collaboration on Fossil Energy R&D

Advanced Materials

project duration

April 2004 - April 2009

project partners

UK:

*University of Liverpool

Cranfield University

Siemens Industrial Turbomachinery Ltd

US:

*University of California, San Diego

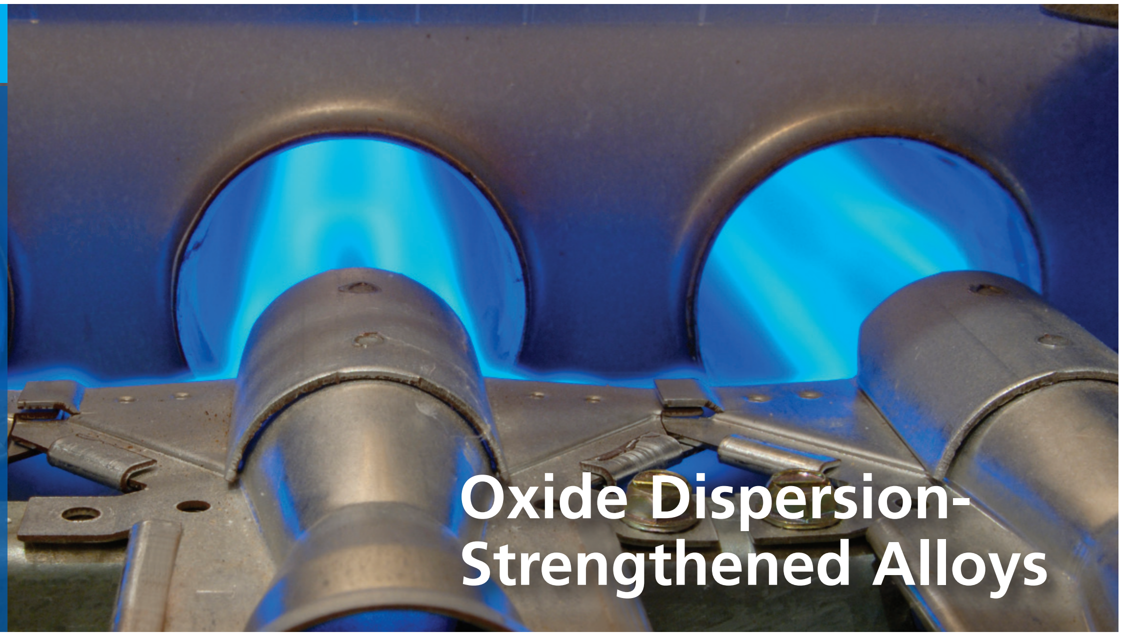
Oak Ridge National Laboratory

University of North Dakota

Interface Welding Inc

MER Corp

* *Task Leaders*



Oxide Dispersion-Strengthened Alloys

background

The global requirement for reducing CO_2 emissions from fossil power plant is driving the design and construction of plant with higher efficiencies, along with co-firing and CO_2 capture technologies.

Gains in overall cycle efficiency generally involve increasing the maximum operating temperature of the power plant. Such improvements have and will continue to be enabled by the development of materials with increasingly high temperature capabilities. Oxide Dispersion-Strengthened (ODS) alloys have excellent potential for use in next-generation high-temperature applications where superior creep strength and oxidation resistance compared to current alloys is required. Possible applications include tubing for high-temperature heat exchangers and sheet for burners and combustion chambers.

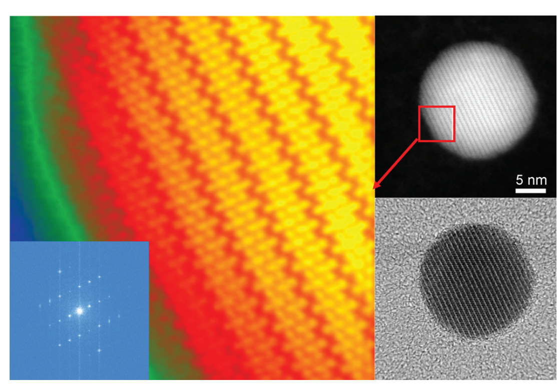
Three challenges exist that currently inhibit the use of these alloys:

- Relatively high processing costs
- Joints fabricated by conventional fusion welding techniques have low creep strength at high temperatures
- Secondary recrystallization needs to be optimized to produce microstructures where large grains can be custom oriented with respect to the principal hoop creep stress

This programme was established to address the latter two issues with the assumption that processing costs would be reduced if volume production were introduced. Hence optimized structures and joints could possibly be developed and incorporated in a demonstrator project during the next phase of this work.

objectives

- To establish and review the current state of knowledge regarding joining of (ODS) alloys
- To identify and quantify the properties of the most appropriate techniques for joining sheet and tubing, including non-fusion joining and fabrication protocols for high temperature heat exchanger components
- To establish and extend the current state of knowledge regarding the microstructural control of ODS FeCrAl alloys, especially in torsionally-orientated structures and hot-spun parts
- To establish and improve the maximum operating performance parameters of ODS alloy used in fossil-fuelled power plant including the application of coatings
- To establish and improve the critical hoop creep performance for ODS tube components by microstructural modification via thermo-mechanical processing



High resolution image of an Y-Al-oxide nanoparticle in a PM2000 alloy after heat treatment.

work program

Helical grain structure in a PM2000 tube.

UK Project Activities: The majority of the oxidation testing and coating production was carried out at Cranfield University, while the microstructures were evaluated at the University of Liverpool. Liverpool also characterized the friction-stir welded components which were supplied by Siemens and fabricated at The Welding Institute. Hot tube torsion trials (carried out by Forecreu SA and Kennametal Inc.) and selective laser melting were performed and evaluated by the group at the University of Liverpool.

US Project Activities: Microstructural modification and control of ODS alloy tubes (led by UCSD) was aimed at maximizing high-temperature performance under internally-pressurized service conditions. Hot rotary cross-rolling and ambient-temperature flow-forming techniques were pursued to modify and control alloy microstructural features. Identification of viable joining technologies for use in heat-exchanger fabrication focused on approaches capable of preserving specific features of the ODS microstructures. Emphasis was on non-fusion inertia welding (led by USCD) and variants of diffusion bonding (led by ORNL). The diffusion bonding work also involved MER Corp., U. North Dakota, and U. Liverpool; the UK task leader spent a three-month sabbatical leave at ORNL working on this effort.

key results

- Friction-stir welding, inertia welding, and pulsed plasma–assisted diffusion bonding were shown to be promising methods of joining ODS alloys, with the latter producing joints with a creep strength of 75% of the parent metal. Processing parameters for similar ODS-ODS inertia joints were established, and joints fabricated by commercial vendors achieved creep performance comparable to the parent metal
- Hot tube torsion methods successfully produced a helical grain structure in PM2000 tubing, which should lead to improved hoop creep strength in pressurised tubes. Both rotary cross-rolling and flow forming of tubes induced microstructural modifications, resulting in significant improvements in high-temperature creep response
- Microstructural investigations using electron backscattered diffraction techniques were used to characterize, in detail, the influence of deformation and heat treatment on the secondary recrystallization of ODS alloys, enabling better materials properties to be achieved. After both welding and heat treatment, high resolution electron microscopy demonstrated the transformation of yttria particles
- Oxidation studies showed that 2mm thick coupons of PM2000 sheet could survive for over 2,000 hours at 1200°C without the onset of breakaway oxidation. The application of thermal barrier coatings in conjunction with a weaker bond coat were applied successfully and the coating-substrate combination survived for over 2,000 hours when tested at 1200°C
- Selective laser sintering was used successfully to fabricate thin-walled, fully-dense PM2000 component precursors from alloy powder, while retaining a critical distribution of dispersed oxide strengtheners

future activities

- The characterisation and development of a new, reproducible range of ODS alloy powders and consolidated sheets and tubes being developed by a new European supplier – this would include nanoscale characterisation of oxide dispersions and their evolution with time and temperature
- The evaluation of low-cost flow forming alternatives for microstructural modification and control of secondary recrystallization. Techniques to incorporate severe ambient temperature deformation are of particular interest
- Further secondary-recrystallization trials on sheet and torsionally-deformed tubes
- The optimization of a new set of friction-stir welded components fabricated from the new alloy.
- The fabrication of elements of a demonstrator component, such as a simple heat exchanger, and evaluation of its high-temperature performance
- The evaluation of dissimilar alloy joint fabrication of the new ODS alloy with header material candidates in the demonstrator high temperature heat exchanger, and establish required property data base
- Continued high-temperature creep data evaluation for the new alloy, all microstructure modified materials and fabricated joints

Hot rotary cross rolling trial that produced grain alignment along the tube circumference.

Further information on the UK-US Collaboration on Energy Research and Development, please visit - http://us-uk.fossil.energy.gov/