UK-US Collaboration on Fossil Energy R&D

Advanced Materials

background

Under the auspices of the UK-US Memorandum of Understanding (MOU) and the associated Implementing Agreement for Fossil Energy Research and Technology Development, a number of organizations from the UK and US have participated in a five-year collaboration on advanced materials supported by the UK Department of Energy and Climate Change (DECC) and the US Department of Energy (DOE).

As one of the areas under the MOU, advanced materials was identified as a key underpinning technology. The development, characterization and understanding of advanced materials will help the UK and US fossil energy industries to develop new and cleaner power generation systems with lower cost, improved time-to-deployment, and reduced technical and commercial risk.

A developed understanding of advanced materials is a key prerequisite which must be satisfied in order to achieve the targets of any future energy policy. Stringent environmental and efficiency targets will necessitate the development of more advanced materials and components, systems, manufacturing methods and improved life assessment methods. The impact of changes such as; fuel type, plant operating cycles/environments and the introduction of CO_2 capture technology will also place severe demands on the materials and components used in power plant equipment.

objectives

The key objective of the UK-US collaboration was to share and develop the partners' knowledge and expertise in the key area of high-temperature materials for advanced fossil energy power plant applications.

This would be achieved through such mechanisms as: sharing of test facilities and best practices, development of common tools and methods, and industrial secondments. The opportunity to develop long-term cooperation in advanced materials from the experience gained during project collaborations was also recognized.

More specific technical objectives related to:

- Optimized test methods, data analysis and storage
- Development of life time prediction tools
- Materials evaluation techniques and ranking methodologies
- Joining and thermomechanical processing

These were to be delivered through five technical tasks, approved under the Implementing Arrangement, covering:

- Steam oxidation
- Boiler corrosion
- Gas turbines fired on syngas and other fuel gases
- Standards and databases
- Oxide Dispersion Strengthened (ODS) alloys

work programme and key results

The five technical tasks were selected as being those most appropriate for equitable collaboration, where both UK and US partners could maximise the value and benefits to their organizations. The criteria adopted in selecting these tasks included:

- Nature of the technology challenge
- Added value of collaboration
- Complementary skill sets
- Absence of any IPR issues
- Ability to share and use outputs
- Equality of inputs from both countries

1. Steam oxidation

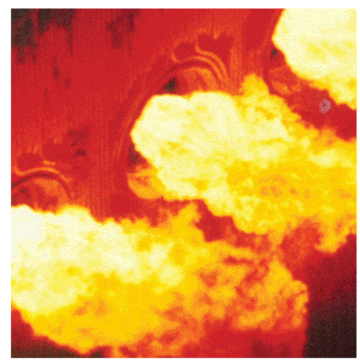
This task was driven by the need to develop and qualify materials for high efficiency ultrasupercritical (USC) steam power plant which are capable of operating at higher temperatures (up to 760°C) and pressures. The programme comprised three discrete areas.

- A state of the art review of steam oxidation data
- Steam oxidation testing to fill gaps and extend data coverage
- Development of models to simulate oxide growth and exfoliation

Key results

- Over one million hours of new steam oxidation data generated for thirty alloys
- Two new high pressure steam test facilities commissioned and fully operational
- Improved oxide growth and exfoliation models developed for use in life prediction methodologies and future power plant design

2. Boiler corrosion



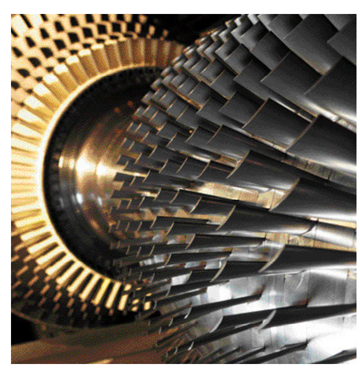
The driver for this task was to gain a better understanding of the mechanisms and the monitoring of fireside corrosion, which is a key life limiting factor in existing power plant boilers. Boiler corrosion is becoming more of an issue as a result of the more arduous operating conditions associated with current and future developments, such as NOx emission control, co-firing, USC steam technology and oxy-fuel firing. This programme focussed on two main areas:

- The development of representative laboratory scale boiler corrosion tests and the evaluation of their results
- The development, implementation and assessment of fireside corrosion probes to measure corrosion rates on-line

Key results

- Comprehensive high temperature corrosion data generation and analysis allowed ranking of the performance of boiler materials in a variety of atmospheres to be carried out
- Effects on corrosion of more novel technologies such as oxy-fuel and co-firing have been measured
- Corrosion probe technologies have been evaluated and demonstrated under real operating conditions providing important indicators for commercial probe development

3. Gas Turbines fired on syngas and other fuel gases



In moving towards higher efficiency power generation systems, the use of gasification-based combined cycle technologies have become increasingly attractive. These technologies produce fuel gases derived from a range of feedstocks including coal, biomass and waste. All of these fuel gases contain contaminants detrimental to the gas turbine system, compared to natural gas, and these effects need to be quantified to identify the best operating conditions and to aid materials selection. This task focussed on two areas:

- Assessment of future fuels and their effects on the operating environments on hot gas path components
- Ranking of a range of candidate alloys and coating systems through high velocity burner rig testing, simulating a range of operating conditions

Key results

- Materials damage and degradation mechanisms have been identified and measured which can be used in lifetime modelling of hot gas path components
- High-velocity, high-temperature burner rig tests under simulated operating environments of future gas turbine systems, combined with advanced analytical techniques, have facilitated the ranking of various alloy and coating systems. This will assist in materials selection for future components

4. Standards and databases

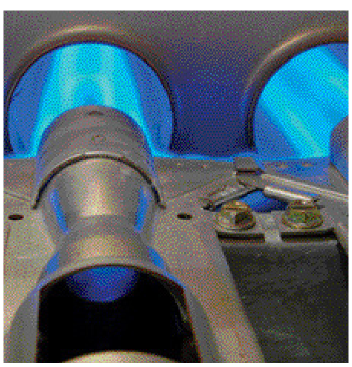
The continued drive for the development of new and improved materials and the optimum use of existing materials in a cost-effective manner is leading to a critical need to ensure data from different sources can be combined. Whilst this is highly cost effective, it is essential that such shared results and test methods are truly comparable and meaningful. To achieve this, it is vital that the methods used and the results from each source are evaluated, shared, stored and analyzed using agreed standard methods. This task recognized the fact that this collaboration would generate data from different laboratories using a range of methods. The following activities were undertaken to explore the comparability of data from these sources:

- A review of existing standards and test methods
- The development of a data exchange and storage tool, accessible by all partners
- An inter-laboratory comparison of the test methods used for boiler corrosion and steam oxidation testing

Key results

- A standard method of data collection, exchange, analysis and storage (including microstructural) has been designed and demonstrated
- Inter-laboratory tests have demonstrated the clear need for improved standardization of high-temperature corrosion and oxidation testing

5. Oxide dispersion strengthened alloys (ODS)



Due to their excellent high temperature properties, ODS alloys have potential for application in the next-generation high-temperature power plant, where good creep strength and oxidation resistance are required. However, due to the nature of the material, their use in service requires a number of challenges to be overcome, including (i) low creep strength of joints fabricated by conventional fusion welding methods and (ii) the optimization of secondary recrystallization to produce microstructures where large grains can be custom-oriented with respect to the maximum stress in service. This task set out to evaluate and overcome some of these challenges, by:

- Addressing joint strength through the evaluation of a number of different joining (friction stir, diffusion bonding) techniques
- Addressing ways to manipulate and customise secondary recrystallization through the development of techniques (eg cross-rolling, flow forming) to modify the microstructure of the material

Key results

- Joining technologies have been evaluated and the feasibility of producing joints with creep strengths comparable with the parent material demonstrated
- Thermo-mechanical methods for improving the microstructural evolution of ODS alloys have been successfully demonstrated allowing optimum strength to be aligned with the direction of maximum operating stress

benefits and future activities

The benefits of the collaboration to the UK and US fossil energy industries can be recognized through:

- The value of the collaboration through sharing data, facilities and experience, leading to reduced cost and effort
- The combination of the partners' experience to obtain better understanding of materials behavior and degradation mechanisms which may arise in future advanced fossil-fired power plant operation
- Identifying and resolving problems when comparing data from different sources and recognizing the importance of standardization
- Developing combined analysis and predictive tools (and hardware) to improve future component development and lifetime prediction methods
- Establishing a solid platform for future collaborations with agreed equitable programs

Continued UK-US collaboration on advanced materials will help accelerate the development of competitive low-emission power plant solutions with significantly reduced development costs and technical risk. These future programs will include further work on steam oxidation, boiler corrosion, syngas in gas turbines and ODS alloys. Additional programs in the area of Plant Asset Management are also being considered. It is anticipated that these programs will commence in 2009.

project duration

April 2004 - April 2009

project partners

UK:

Alstom Power
Cranfield University
Doosan Babcock Energy Ltd
Liverpool University
National Physical Laboratory
RWE
Siemens Industrial Turbomachinery Ltd

US:

Alstom Power
Covanta Energy
Honeywell Process Solutions
Intercorr International
Interface Welding Inc
MER Corporation
NETL
Oakridge National Laboratories
Reaction Engineering International
Siemens
University of California
University of North Dakota

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