UK-US Collaboration on Fossil Energy R&D

Advanced Materials

project duration

April 2004 - April 2009

project partners

UK:

Alstom Power Ltd

* Cranfield University

Siemens Industrial Turbomachinery Ltd

US:

Oak Ridge National Laboratory

* Siemens

Task Leaders

Gas Turbines Fired on Syngas and other Fuel Gases

background

In moving towards higher efficiency power generation systems that produce lower CO_2 emissions, the use of gasification based combined cycle technologies becomes increasingly attractive. These systems can be used to generate fuel gases from a wide range of solid fuels including coal, biomass and waste products. These fuel gases need to be cleaned before use in gas turbines, but they can also be processed to remove CO_2 and so produce fuel gases that have high hydrogen contents.

This task was focused on investigating the impact of changes expected in the future use of fuel gases in power generation gas turbines focusing in particular on the impact on hot gas path components in the power turbine such as blades, vanes and combustor cans. Enhanced corrosion, erosion and deposition on these components as a result of using gasifier derived fuel gases could reduce component lifetimes and so reduce the viability of such gas turbines. However, the correct selection of advanced materials including corrosion resistant and thermal barrier coatings provides a route to counter the effects caused by future fuel gases with higher levels of contaminants.

objectives

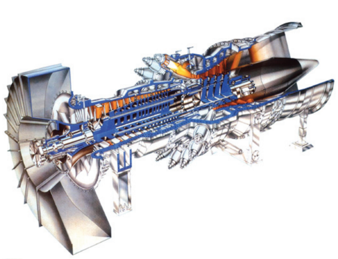
To quantify the major degradation effects on gas turbine materials operating with fuel gases, including coal- biomass- and waste-derived syngas, in order to improve component design and life prediction methods.

- To characterize the range of fuel gas atmospheres anticipated in solid fuel fired gasification systems
- To expose selected alloy/coating combinations in burner rig testing and determine deposition rates and the erosion and corrosion resistance of state-of-the-art gas turbine materials systems over the appropriate operating temperature ranges
- To identify candidate alloy and coating systems, that are appropriate for use in fuel gases

work programme

The work program was divided into two main activities:

- Assessment of future fuels for power generation gas turbines and their effects on the operating environments around critical components in the gas turbine hot gas path. This used thermodynamic and kinetic modelling to follow major, minor and trace elements from a fuel, through processing stages, into a gas turbine combustion chamber and through a power turbine. For example, UK/US coal and biomass fired gasification systems with differing degrees of hot gas cleaning before fuel gases combustion
- Carrying out four 1000 hour high velocity burner rig exposures at Cranfield University. Gaseous, vapor phase and solid contaminants were added adjacent to the natural gas/air flame to generate four target environments from the fuels indicated below:
    - Diesel fuel with maximum allowable contaminants
    - IGCC syngas
    - High H2 IGCC syngas
    - Pyrolysis derived gases



Siemens power generation gas turbine (F class)

Materials were exposed on a series of cooled probes in the contaminated combustion gas streams produced.

- Twenty four materials systems were evaluated (with 12 recommended and manufactured by UK partners and 12 by USA partners):
- Eight base alloys (four only with coatings)
- Nine thermal barrier coatings / bond coatings
- Eleven corrosion resistant coatings

After their exposure materials underwent detailed examinations and comparison with materials performance in current fuel systems.

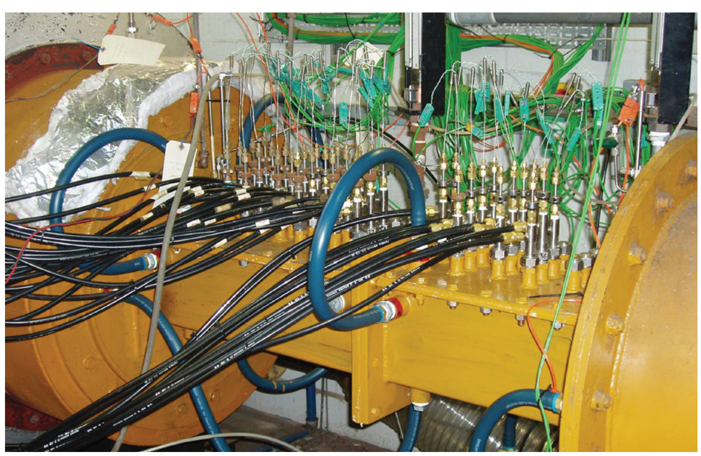
key results

Blade from first stage of a used Siemens F class gas turbine showing thermal barrier coating and some of the cooling air exit holes

- Assessments have been carried out of the potential compositions of coal, biomass and waste derived syngases that could be used in power generation gas turbines, in terms of both the major and minor chemical species anticipated in these gas streams
- The composition ranges of the combusted syngases have been modelled to determine the ranges of exposure conditions anticipated for critical components in the gas turbine hot gas path, in terms of both gases and deposits
- Four 1000 hour burner rig tests have been carried out to expose current candidate gas turbine materials systems to environments simulating those anticipated in future advanced gas turbines. These materials systems have included single crystal and conventionally cast substrates with a range of thermal barrier and corrosion resistant coating systems
- Characterization of the gas turbine materials has been carried out using routine and advanced analytical techniques to identify the forms of materials damage and their causes, as well as to determine quantitatively the extent of damage
- These data have been used to rank the performance of the advanced gas turbine materials exposed, and also the aggressiveness of the different environments

future activities

- The identification of the fuel/operating conditions and the optimal candidate alloy and coating combinations which are most appropriate to different future power systems that use gas turbines
- The development of predictive models for corrosion of advanced materials and their response to changes in operating environments
- The development of improved methods of monitoring damage to coated gas turbine components



Cranfield University burner rig during first exposure period with materials probes installed.