IP-SOFC Multi-cell Modules.

Scale-up of the IP-SOFC to multi-tens of kW level

M F - S O F C

Objectives

In the late 1980s Rolls-Royce undertook an evaluation of fuel cell technologies and concluded that the Solid Oxide Fuel Cell (SOFC) was likely to be the most competitive fuel cell technology for stationary power generation applications. Rolls-Royce developed the Integrated Planar Solid Oxide Fuel Cell (IP-SOFC) which combines the benefits of conventional planar and tubular approaches. The concept is based on series connected cells fabricated on a fuel carrying porous support tube. The MF-SOFC project aims to scale-up the technology from kW to tens of kW.

Problems addressed

The project covers a wide range of challenges which need to be resolved to allow successful scale-up. The work packages of the project focus on the areas of stack design, scale-up of manufacture, cell performance, mechanical modelling and testing.

Project structure

The consortium brings together the wide range of skills and experience required to achieve the goal, from fundamental materials science to end user knowledge.

Advanced Ceramics Limited, a 'Small to Medium Enterprise', has extensive experience of technical ceramic manufacture and, within this project, is responsible for the implementation of technology to prove the concept and capability of production scale-up. The cell development effort has been carried out in close collaboration with Risø National Laboratories. Risø have many years of experience in SOFC research and development and there is a long history of collaboration with Rolls-Royce spanning several EC programmes. Extensive studies were carried out at Imperial College London with the objective of assessing and improving the mechanical reliability of the cells and stacks in both manufacture and operation. Work on module and stack testing has been led by Gaz de France (GdF). As one of the worlds largest public service utilities, GdF has extensive knowledge of end users' requirements, ensuring commercial imperatives are taken into account.

Expected impact and exploitation

Extensive market and system studies have concluded that capital cost targets for the stack and system would be best met by a pressurised hybrid system at 1MW scale. This work also showed that the most important parameters in reducing system cost ($/kW) is stack volume (kW/litre) and correspondingly weight. An evaluation of the first generation multi-channel support module in this context revealed that an improvement in stack volumetric power density was required to meet the cost targets. An agency company Roll-Royce Fuel Cells Systems (RRFCS) has been formed to bring this technology to commercialisation. This company is wholly-owned by Rolls-Royce plc and draws support from a number of internal organisations for specific services in research and development, finance, quality and human resources. This project forms an essential first stage in the move from technical evaluation to technology scale-up. Results will be fed directly into the development programme of RRFCS with the aim of a commercial 1MW pressurised hybrid product.

Progress to date

The support structure was re-worked resulting in a revised concept based on tubes with significantly reduced thickness. These tubes are manifolded in a serpentine arrangement. A major advantage of this design is its ability to provide overall geometrical compliance, even if built from stiff ceramic materials. This broadens the range of concepts that can be used when manifolding the bundles into larger stack units or 'strips'. The strips each produce several kW and the MF-SOFC stack will consist of an array of these strips. Strip level manifolding requires an order of magnitude less components than would otherwise be required to manifold individual tubes if the serpentine bundle design was not used.

An investigation was carried out to evaluate the applicability of ceria-NiO anodes in the IP-SOFC concept. Modules containing both YSZ and ceria

Testing facilities at Gaz de France in Paris used to evaluated IP-SOFC Multi-cell Modules.

Results of Stress Analysis of Bundle Assembly: Modelling carried out at Imperial College London.

based cermets were studied and detailed comparison between the two revealed that the Ni-CGO anode gave only a slightly improved performance over those based on Ni-YSZ. The Ni-CGO was more active than Ni-YSZ for direct CO oxidation, whereas there was little difference between them when operating on H_2-CO_2 mixtures, where a mixture of H_2 and CO would be present. This suggests that Ni-YSZ anodes should be suitable for operating on reformed hydrocarbon mixtures, provided that they display sufficient durability. Work has also been carried out to optimise the cathode microstructure. This work has revolved around manipulation of the composite and current collecting layers. This has resulted in stable structures that have exhibited excellent durability. Similar levels of durability have been demonstrated in module tests.

Mechanical analysis modelling has been used to compute the stresses induced in the modules and bundles resulting from the thermal fields or misalignments in manufacture. The analysis is fully elastic and requires as input the measured values of the elastic moduli of the constituent materials. This analysis has proved invaluable in the verification of the module and stack design under a range of operating conditions. This work is carried out in parallel to the stack design activity. Utilisation of these tools have provided a direct link to further steer the design process and provide critical input into the final design for modules and bundles.

During the initial stages of the programme, parallel testing facilities were set up in the UK and France. Both testing facilities allow detailed experimentation to be carried out and the multi-cell modules can be evaluated in a computer-controlled system under an extensive range of gas compositions and flow rates. The test results obtained in the two facilities showed good correlation for open circuit voltages and when tested under load. Each facility has used modules fabricated in a similar manner and the similar test results provide a high level of confidence in the validity of the testing procedure. The testing programme also showed an excellent reproducibility. This has provided confidence in the baseline upon which the effect of changes in design or manufacturing process can be evaluated. Test results have shown the effect of fuel flow on performance for the higher power density module design. The dependence on fuel flow is markedly less than experienced with the multi-channel design. The results showed very little performance improvement above very low fuel flow rates. Extrapolation of results of dilution studies from single module to bundle size indicate that 75% fuel utilisation is achievable under commercial operating conditions.

INFORMATION

References: ENK5-CT-1999-00003

Programme:
FP5 - Energy, Environment, Sustainable Development

Title:
Scale-up of the IP-SOFC to multi-tens of kW level (MF-SOFC)

Duration: 42 months

Partners:
- Rolls-Royce Fuel Cells Systems (UK)
- Risø National Laboratory (DK)
- Imperial College of Science, Technology and Medecine (UK)
- Gaz de France (F)
- Advanced Ceramics (UK)

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