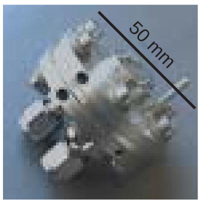

Figure 1: Fast and accurate CO sensor developed for use in a fuel processor.

On-board gasoline reforming for fuel cell vehicles

PROFUEL

Objectives

Fuel processors represent a fundamental enabling technology for the commercial success of fuel cells. By reacting readily available hydrocarbon fuels with steam, air or a combination of both, a hydrogen rich gas stream is produced which, after gas clean-up to reduce the carbon monoxide (CO) concentration to a few parts per million, can be fed to the anode of a fuel cell. Here the hydrogen combines electrochemically with the air supplied to the cathode to generate electricity.

A gasoline powered fuel cell vehicle has the potential to couple an available fuel infrastructure with the efficiency and environmental benefits of fuel cell technology. The objective of the PROFUEL project is to demonstrate such a system on a 10kWe scale. This size is small enough to have direct relevance for on-board auxiliary power units, whilst being large enough to illustrate the technical issues faced by developers of fuel processors targeted at replacing internal combustion engines.

Challenges

Developing an on-board fuel processor represents quite a challenge, and has been likened to installing a mini-oil refinery on-board a vehicle. Key issues for fuel processing systems are cost, size, weight, response time, efficiency and durability. Some of these can be addressed by identifying highly effective catalyst materials, but just as important is the development of the ancillary components such as pumps, valves, burners, sensors and control software. This dual emphasis on catalyst and component development is a key feature of PROFUEL.

Impact

Looking into the future, vehicle powertrains will have to meet increasingly more rigorous emissions regulations and efficiency standards. Fuel cell technologies offer the promise of improvements in both of these areas. The questions of how to create, deliver and store the fuel of fuel cell vehicles have been in focus for many years. Behind the apparent simplicity of direct hydrogen fuel cell vehicles lie the problems of hydrogen supply and on-board storage; these have no quick-fix solutions. The alternatives of generating hydrogen on-board from methanol, ethanol, gasoline or diesel all present their own problems ranging from fuel availability and infrastructure to toxicity and system complexity. However, it is clear that a successfully integrated on-board gasoline reformer would have many benefits in reducing the complications and capital investments needed to develop a fuel infrastructure that will support the emerging fuel cell vehicle market.

Project structure

Figure 3 shows the PROFUEL participants, and summarises their responsibilities.

Progress to date

The PROFUEL partners have had considerable success in developing long-life, low-cost catalysts for each of the fuel conversion stages. The catalyst systems in a fuel processor need to operate over a range of load demands, and remain physically robust and resistant to poisons. One of the principal poisons in gasoline is sulphur, present at levels above 10ppm even in modern low sulphur fuels. It has been dealt with in PROFUEL by developing reformer and high temperature shift catalysts that are sulphur tolerant, allowing it to be adsorbed downstream as hydrogen sulphide in a specially developed trap. (Figure 2)

The removal of CO from the reformate gas is critical to the performance of the fuel cell. This is achieved conventionally by a cascade of catalytic reactors, and such units have been developed for the PROFUEL specifications. However, additional work is underway to investigate the inclusion of a novel CO adsorber-desorber into a fuel processor system. A further key objective of the project is to develop a low-cost method to measure the residual CO. This is currently done by bulky and expensive infra-red analysers that are not suitable for integration into real systems. An accurate electrochemical based CO sensor that works rather like a mini fuel cell has been developed successfully. By measuring the effect that CO poisoning has on

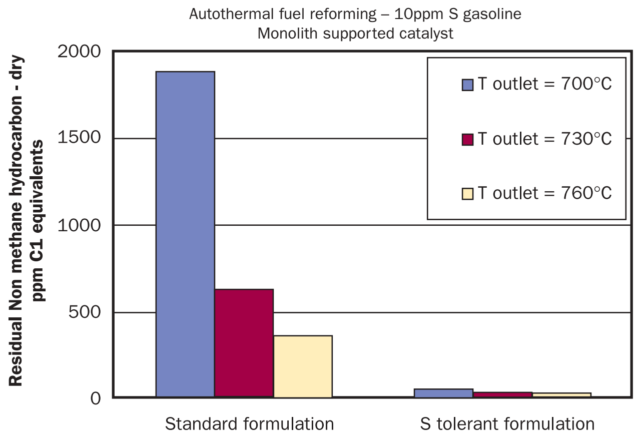

Figure 2: Performance improvement in gasoline reforming catalyst.

FEV - Motorentechnik (Germany)	Water supply Fuel supply Start-up burner
Johnson Matthey (UK)	Fuel mixing and vaporisation Autothermal reformer High temperature shift reactor
Centro Ricerche Fiat (Italy)	Sulphur trap Life cycle analysis
Politecnico di Torino (Italy)	CO oxidation and Sulphur trap materials Dynamic modelling
Ansaldo Ricerche (Italy)	Low temperature shift reactor Selective oxidation unit CO trapping
ECN (Holland)	CO sensing and O_2 dosage Component testing
Volvo (Sweden)	System modelling System integration Fuel processor testing

Figure 3: PROFUEL partners – project responsibilities.

the rate of decay of the base anode current, CO sensing is possible over the range 1-500 ppm on a millisecond timescale, with some scope for use up to 7000 ppm. This sensor will be integrated into the PROFUEL system downstream of the CO clean-up units, and used to control the units. (Figure 1)

The optimal integration of these catalytic stages is being accomplished by the use of simulations that balance the heat and mass flows around the system. Simple yet effective models of the compact heat exchangers, incorporated into the PROFUEL system as water vaporisers, are being used to predict transient response times and identify opportunities for performance enhancements. Similar outcomes are being obtained from dynamic models of the catalytic stages.

Another aspect worth highlighting is start-up and shut down of the fuel processor. The catalysts developed within PROFUEL are non-pyrophoric, allowing them to be purged with air. This is essential for materials destined for use on-board vehicles where pre-treatment and purge gases are not available. Also being developed in this project is a 7kWe start-up burner operating on gasoline. This will be used to rapidly preheat the catalytic components and heat exchangers to temperatures above which the fuel reforming reactions become self-sustaining.

The final phase of the project is to spatially and thermally integrate the sub-components and operate the unit as a complete system. The results from this, coupled with system modelling and Life Cycle Analysis, will give the partners a broad understanding of the issues involved in designing and operating complete fuel processors, as well as a view on their potential for inclusion into fuel cell vehicles. As a member of the wider FUERO cluster, the PROFUEL project will generate information that will enable valuable comparisons to be made between different fuel cell technologies.

INFORMATION

References: ENK5-CT-1999-00023

Programme:
FP5 - Energy, Environment and Sustainable Development

Title:
On-board Gasoline Reforming for Fuel Cell Vehicles (PROFUEL)

Duration: 36 months

Partners:
- FEV Motorentechnik (D)
- Johnson Matthey (UK)
- Centre Ricerche Fiat (I)
- Politecnico di Torino (I)
- Ansaldo Ricerche (I)
- Energieonderzoek Centrum Nederland (NL)
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Status: Ongoing