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Testing of a De Nora polymer electrolyte fuel cell stack of 1 kW for naval applications

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Abstract

In a previous study calculations were carried out for a navy frigate with respect to the energy consumption of a propulsion/electricity generation system based on fuel cells. The fuel consumption for the 'all-fuel cell' ship was compared with the consumption of the current propulsion/electricity generation system based on gas turbines and diesel engines; it showed potential energy savings of a fuel cell based system amounting from 25 to 30%. On the basis of these results and taking into account various military aspects it was decided to start tests with a polymer electrolyte fuel cell (PEFC) stack. For this purpose a De Nora 1 kW PEFC was chosen. Results of the first tests after installation are satisfying.

Keywords: Polymer electrolyte fuel cells; Naval applications

1. Introduction

The development of fuel cells for stationary and transport applications is recognized worldwide to be an important step towards the implementation of energy efficient systems combined with low emission to the atmosphere. Electric power generation on board of naval ships for ship services (including weapons and sensors) and propulsion is of a growing importance in the future, because there is a tendency towards an 'all-electric' ship concept. Important features of such an all-electric ship concept are decentralized electric energy generation and storage. Fuel cells can be easily fitted into such a system.

Other advantages of fuel cells on naval ships as compared with competing technologies such as diesel and gas turbine, are: (i) favourable part load performance; (ii) relatively little maintenance; (iii) low noise and vibration level (low detectability); (iv) low emission, and (v) modular construction (flexibility in system location).

Due to trends towards more stringent emission's legislation and signature reduction requirements for future naval combatant ships, fuel cells have the potential to become an important competitor as a component in the energy system of future (naval) ships.

On the basis of the above-mentioned aspects and on the results of energy calculations for a Dutch frigate [1], the Royal Netherlands Navy decided to start a feasibility study at TNO, Delft, into the various aspects of application of fuel cells on board of naval ships.

2. Energy calculations

The energy supply system of the M-frigate of the Royal Netherlands Navy was used as a reference for energy calculations. The propulsion (CODOG: combined diesel or gas turbine) and electricity generation system consists of: (i) two diesel engines of 3880 kW each for velocities up to 20 knots; (ii) two gas turbines of 12 750 kW each for velocities in the range of 20–30 knots, and (iii) four diesel engines/generators of 650 kWe each.

A schematic presentation of this system is given in Fig. 1.

Comparative calculations were carried out for both the molten carbonate fuel cell (MCFC) and the polymer electrolyte fuel cell (PEFC). A schematic setup of a possible fuel cell based system is given in Fig. 2.

The calculated savings in fuel consumption when using fuel cells for propulsion and electricity generation are about 25 to 30% in typical peace-time use [1]. The savings for MCFCs were slightly higher compared with the conventinal techniques, due to the higher energy efficiency. However, taking into account the development to be expected and the accuracy of the calculations, the differences are not significant in order to make a choice of the preferred type. More detailed calculations for both systems are therefore necessary.

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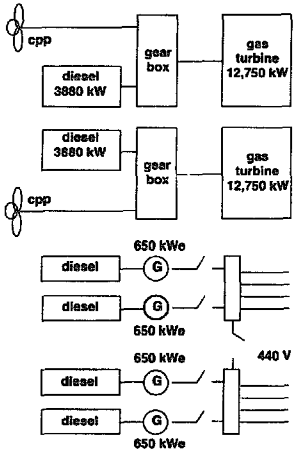

Fig. 1. Propulsion system of the M-frigate.

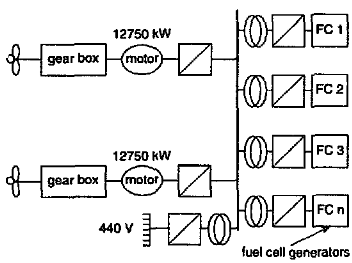

Fig. 2. Schematic setup of an energy supplying system based on fuel cells.

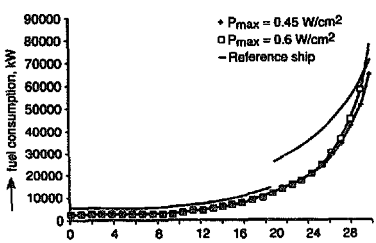

Fig. 3. Fuel consumption vs. speed PEFC systems [1].

The energy saving calculated consists mainly of the relatively high part load efficiencies of fuel cell systems. In Fig. 3, the fuel consumption (kW) versus speed is given. There is only a slight difference between the fuel consumption, because the energy efficiencies for both systems are about the same at full load of the diesel engines or gasturbines. At decreasing load, however, the energy efficiency of diesel or gas turbine decreases continuously (equivalent to relatively high fuel consumption), whereas that of a fuel cell system remains relatively constant (at very low loads also the efficiency of the fuel cell system decreases, because of the power required by compressors, pumps, etc., remains fairly constant).

3. Choice of fuel cell type

Although MCFCs have a somewhat higher energy efficiency, we have chosen the PEFC as the best choice for the ship application: (i) high power density (low system volume); (ii) low temperature (low detectability); (iii) low (predicted) investment cost (when car application is realized), and (iv) good shock and vibration resistance.

4. Test programme

As part of the feasibility study, it was decided to do tests with a polymer fuel cell stack of a (small) size representative for practical application. For this purpose, a stack of 1 kW developed by De Nora (Italy) was chosen, containing 20 cells (200 cm^2 active electrode area) in series. This stack is of the same type as the 8 stacks of 5 kW delivered by De Nora to Ansaldo (Italy) for a fuel cell hybrid bus.

In the summer period of 1995 this stack was delivered to TNO and built into a test installation previously designed, constructed and used in order to test an Elenco alkaline fuel cell stack for submarine application. A picture of the stack is given in Fig. 4.

The following test programme is/will be carried out with the De Nora stack: (i) acceptance tests (together with De Nora); (ii) static tests (current–potential curves, power etc.); (iii) dynamic tests with programmable load (simulated cycles for the ship application(s) to be defined); (iv) other fuel types (not yet decided), and (v) tests under simulated ship environmental conditions.

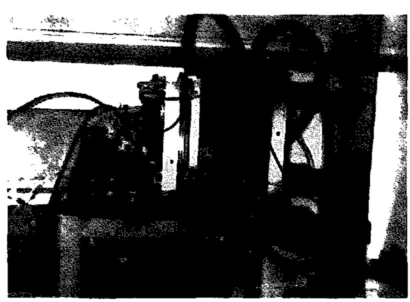

Fig. 4. Photograph of the 1 kW De Nora stack.

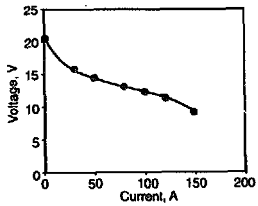

Fig. 5. Polarization curve of a 1 kW De Nora stack.

In the 1 kW stack the Nafion 117 membrane of Du Pont is used. The electrodes and bipolar plates are proprietory technology of De Nora.

During the project, improvement obtained in the stack design at De Nora, e.g. thinner membranes and bipolar plates, will be incorporated.

The experimental programme has been started with hydrogen as a fuel and oxygen from the air. In a later stage other fuels might be also applied, requiring the inclusion of a reformer in the system.

A system demonstration of the technology on a representative scale on board of a test ship is planned to be started in 1999.

5. Test results 1 kW De Nora stack

Some of the results of the acceptance tests and the first static tests are given in this Section. In Fig. 5 the polarization curve of the stack and in Fig. 6 the power–current curve are given. Fig. 7 gives the single cell voltages at a current of 80 A.

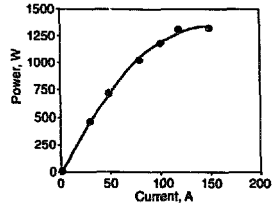

Fig. 6. Power curve of a 1 kW stack.

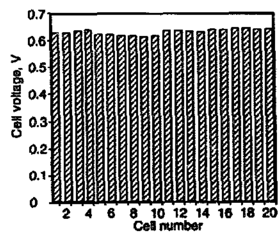

Fig. 7. Cell voltage of De Nora 1 kW stack at 80 A.

The first test results are promising. Although still in a preliminary stage to draw definitive conclusions, the robustness of the stack and the absence of any problem in the start-up phase are a first indication that the choice to apply PEFCs in ships is a right one.

References

[1] D. Schmal, M.J.E. Verschoor and I.P. Barendregt, Future applications of fuel cells on naval ships related to energy savings, *1994 Fuel Cell Seminar, 28 Nov.–1 Dec. 1994, San Diego, CA, USA.*