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Fuel Cell System Development for Frigates

E.R. van Selow

G.J. Kraaij

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E.R. van Selow, G.J. Kraaij
Energy Research Centre of the Netherlands (ECN)
P.O. Box 1, 1755 ZG Petten, the Netherlands

For naval vessels, the replacement of gas turbines and diesel engines by fuel cells holds the promise of increased ship survivability as well as increased fuel efficiency and lower emissions. The fuel cell systems would need to be fuelled with logistic fuels such as naval distillate, NATO code F-76. One of the foremost technical challenges is the on-board production of hydrogen from this fuel with a sulphur content up to 1 %.

In a four-year Research & Technology project, industries and research institutes from Germany, the Netherlands, Turkey and the UK investigated and demonstrated the feasibility of fuel cell systems on board of naval frigates [1].

Starting with a sound system study, attention focused on selection of technologies with which the system would meet target values for costs, efficiency, size and weight. By thermodynamic modelling and simulation, various technologies and system configurations were analysed and optimised. The most promising – in terms of overall performance and realisable in 2010 – system included the following reactors: hydrodesulphurisation and sulphur stripping, pre-reforming, steam reforming, shift, preferential oxidation, and a proton exchange membrane fuel cell (PEMFC) stack [2]. Subsequently, a conceptual design was made for a 500 kW_e integrated system.

In the subsequent demonstration phase, the conceptual system design was scaled down, simplified and worked out to a detailed design of a 25 kW_e fuel processor demonstrator. The reactors were designed and constructed separately, and then assembled in a test rig at ECN. The desulphurising unit was designed as a multi-layered reactor with beds of NiMo hydrodesulphurisation catalyst and ZnO adsorbent for stripping of H_2S.

Experimental results show that the conversion of organosulphur species in the hydrodesulphurisation unit was insufficient to prevent catalyst poisoning downstream. The most refractory species were found to be alkylbenzothiophenes and alkyldibenzothiophenes, which is in agreement with experimental studies from others [3 – 9]. In order to prevent poisoning of the pre-reformer catalyst by sulphur, the NATO F-76 fuel was replaced by City diesel with less than 10 ppm sulphur. This fuel was fully converted by an adiabatic pre-reforming reactor and a steam reformer, heated by a diesel burner. The axial temperature profile in the pre-reforming reactor changed in time, indicating deactivation of the catalyst. After flushing with steam the catalytic activity was restored. After passing a CO clean-up train of shift and preferential oxidation reactors the reformate gas contained 76 vol.% hydrogen and less than 10 ppm carbon monoxide (dry basis). Feeding of the produced reformate gas to a 2 kW_e PEMFC showed stable operation, thus confirming the quality of the reformate gas. The observed fuel processor efficiency at full load was calculated to be 82 % (LHV basis). The fuel processor was operated for 18 hours continuously.

Account

The project partners were: Howaldtswerke-Deutsche Werft (HDW), HDW Fuel Cell Systems (HFCS), Marmara Research Centre (MRC), QinetiQ, Siemens, Stork Product Engineering (SPE), TNO, and University Duisburg-Essen. The conceptual design of the 500 kW_e system was made by QinetiQ. Reactors for the demonstrator were designed and constructed by ECN, HFCS, and SPE. The presented system study and presented experimental results were done by ECN. Catalysts were provided by Süd-Chemie.

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