Fuel Cells in High Seas

K. Leites

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Fuel Cells in High Seas

Keno Leites, TKMS Blohm + Voss Nordseewerke GmbH, Germany

1 ThyssenKrupp Marine Systems

ThyssenKrupp Marine Systems (TKMS) is the first privately owned shipbuilding group in Europe. The main activities are related to submarines (also with fuel cells), navy vessels and Mega-Yachts. Further activities are related to components and repair/upgrade services.

With our submarine business we have developed the first ocean going commercial fuel cell application: the submarine classes 212A and 214. Their systems are based on pure hydrogen and oxygen supply.

2 Challenges in Ship Power

The shipping industry is today facing enormous challenges. Most noticeable is the rise of the fuel prices which affects consumer prices. While the prices have fallen dramatically after summer 2008, they have doubled since then. And they will rise further, at least due to the CO_2 surcharge.

Probably more present in the media is the relation of ship borne emissions to the global warming.

Even if a ship is the most efficient means of transport actually available, the absolute amount of emissions from ship engines is significantly high. The overall CO_2 emissions have a share of about 3% in the worldwide emissions. In a view from a ports perspective the share is quite higher.

Although SOx emissions are due to the coming regulations not so much in focus anymore, NOx emissions are of interest. Many ports and shipping regions have emission fees and even more will come up. The IMO has concluded the tier III limits [1], which can hardly be reached without secondary measures as semi-catalytic reduction. Further, particulate matter is under discussion [2]; filtering measures like in road traffic have already become a standard for large yachts and will go into merchant vessels as well. Finally noise and vibrations should not be forgotten. Consequently the authorities of several ports and favoured cruise destinations are considering prohibiting the use of harbour generator sets and to oblige the vessels to use shore based power.

An alternative to these shore based solutions would be to enhance the power conversion on board. Mainly two ways seem to be feasible nowadays:

1. Exhaust gas treatment [3]
2. Higher efficiency and advanced fuels

The second option leads directly to the proposed solution in this paper:

<u>A high temperature fuel cell with sulphur free or synthetic fuel.</u>

3 Forming the Lighthouse Initiative

Since this concept is interesting for different ship types, a so-called lighthouse project is initiated, which aims to bundle demonstration projects based on these issues for seagoing ships [4].

The lighthouse consists of a top project '*Toplaterne*' and a number of demonstration projects under this 'roof'. The whole lighthouse is government-funded from funds of the German 'national innovation programme for hydrogen and fuel cell technology' (NIP).

Partners of *Toplaterne* include, among others, a number of shipyards, classification societies, operators, equipment manufacturers and universities. These partners work together on questions like ecology and efficiency, economy and LCC and rules and standards.

Actually three demo-projects are applying for partnership in the lighthouse. The first one is the presented project called '***SchIBZ***', which is lead by TKMS.

4 Current Status

Today the diesel generator sets are surrounded by a number of secondary measures to achieve low exhaust gas and noise emissions.

The catalytic reduction of NOx requires very low sulphur fuel oil and ammonia [5], which is an additional chemical on board. Filter and catalyst need certain exhaust gas temperatures which will result in reheating. Finally all these components have to be maintained.

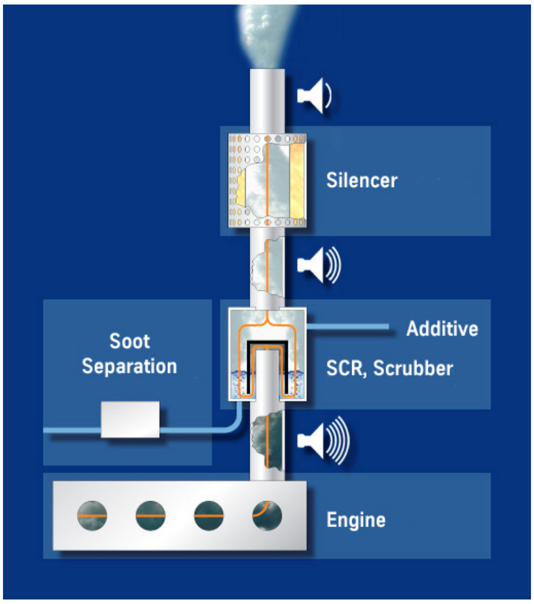

Figure 1: schematic of a sophisticated diesel generator set.

5 Choosing the Fuel

The marine industry is used to using oil as fuel. It is an easy to handle liquid with

- a high energy density,
- low fire risk,

- well proven system components,
- high efficiency when used in modern diesel engines.

Since the ecological influence of LNG is lower than that of higher hydro-carbons like diesel oil, many studies to use it are carried out. One big hurdle for the introduction onto ships is the storage with a high volumetric energy content [6].

From the above follows, that it is preferable to stay with diesel type fuel for the near future. Even better is synthetic fuel [7]. This fuel is produced using the Fischer-Tropsch-process. The fuels are called XtL, where X stands for Coal, Gas or Biomass-to-Liquid.

The above mentioned fuels have the advantage of fitting in existing logistics, do not need new or special safety measures and the personnel are used to handle such liquids.

The only additional effort needed is the installation of a completely separated piping system, to protect the sulphur free fuel from contamination by other fuels, if onboard.

6 Choosing the Fuel Cell

Fuel cells have in common, that they operate on gaseous fuels. The difference is that low temperature fuel cells like PEM only use and tolerate hydrogen, which has to be supplied in a very high purity. High temperature fuel cells tolerate CO_2 and generate electrical current from CH_4 and CO [8].

To utilize liquid fuels they have to be transformed into a gaseous state, this is called pre-reforming. In this process the liquid is under high temperature catalytically broken down to a gas mixture, which contains CH_4, H_2, CO and CO_2.

On vessels from around 80 m upwards space is an issue. Especially engine spaces in yachts are very tight, so the integration of such a fuel cell including the auxiliary components requires a major redesign. An intelligent modularisation of the components can ease the integration.

7 Energy Buffering

A high temperature fuel cell has a kind of “steady state dynamic”, which is in the range of 50% MCR in hours [9].

For this reason a fuel cell needs a supporting device, which compensates the load changes in the network until the fuel cell has followed. Depending on the power supply system set up, this may be an accompanying diesel generator set or an energy storage module like a battery.

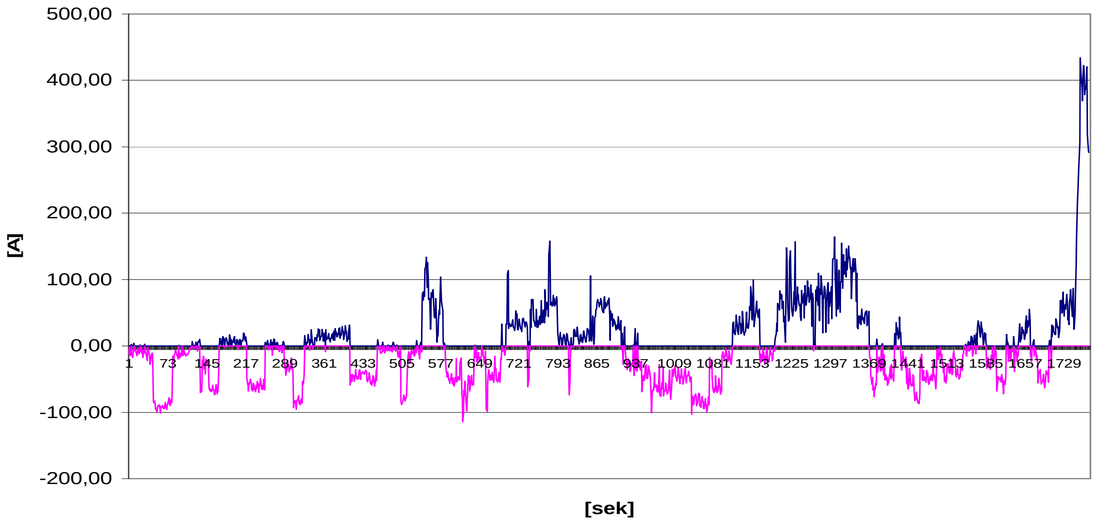

Figure 2: Typical power curve as deviation from the average.

The system suggested here shall be capable of operating in isle mode, without the aid of other combustion engines.

Very promising are the current improvements in the Li-Ion-technology. Depending on the material combination and sizing of active layers, a trade off between current and capacity can be made. With certain configurations a combined behaviour between battery and super cap can be gained. An important feature of Li-Ion batteries is that the lifetime increases over proportionally with a reduced depth of discharge (DOD).

This circumstance is fortunate because the battery cells must be sized to take several 100 kWh surplus energy, while the fuel cell is transferred to a different output level. In a steady state operation the battery cell has only to compensate smaller load changes [10]. This results in a low (DOD) and prolongs the lifetime drastically.

8 DC/AC Conversion

The board network of a ship is normally a 50 or 60 Hz system, while the fuel cell output is direct current.

To match this with the board network a specialised inverter will be used, which incorporates frequency control, voltage regulation and back-voltage prevention.

9 System Concept ***SchIBZ***

The project ***SchIBZ*** is a development undertaking for the above indicated fuel cell system. The system is intended to be a marine demonstrator plant, as close to a commercial application as possible.

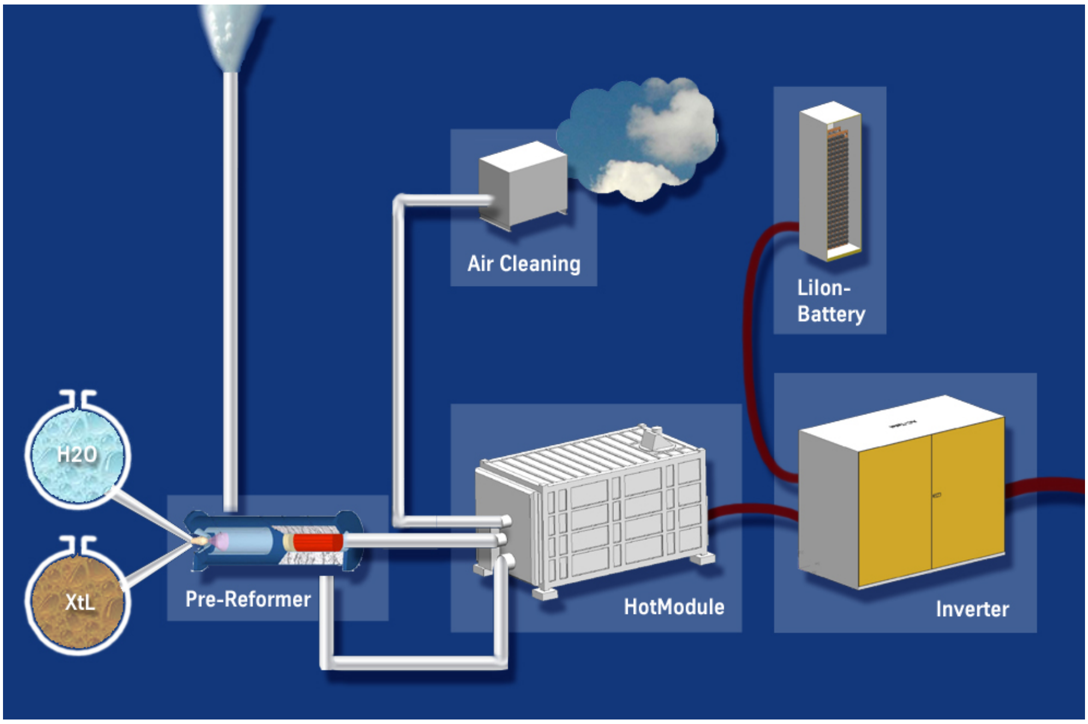

Figure 3: System concept of the fuel cell plant SchIBZ.

Core of the system is the MCFC from MTU Onsite Energy. The fuel cell is a revised and upgraded version from the well known HotModule. The most significant change is the new design of the stack, which is now self containing. This is important, since a ship is affected by forces in all three axes.

The fuel processing will be done by a pre-refomer from OWI Aachen. This unit cracks the supplied fuel and provides the fuel cell with CH_4, CO, CO_2 and H_2. A so-called steam reformer is chosen which does not need additional energy and can be thermally integrated with the fuel cell.

10 Partners

The project is carried out by a consortium of 8 partners.

Leader of the consortium is ThyssenKrupp Marine Systems (TKMS). The work package of TKMS is the ship integration, practically for the test installation as well as the theoretical investigation for newbuilds.

Supplier of the fuel cell is the aforementioned MTU Onsite Energy GmbH Fuel Cell Systems. The gas supply (pre-reformer etc.) is part of the work package of Oel-Waerme-Institut Aachen. They do also additional reforming tests with different fuels.

The general automation is developed by Imtech Marine Germany. This package includes remote control and monitoring and power management between fuel cell and battery.

The conformity with rules and regulations is supervised by Germanischer Lloyd. Their task is to control and consult design and manufacturing phase. The overall evaluation and analysis of the plant is carried out by the Helmut-Schmidt-University of the German Forces in Hamburg. They also develop a simulation system for automation purposes.

Figure 4: Demonstrator test vessel MS Cellus.

Finally, the vessel for the ship test belongs to the Reederei Braren. During the envisaged 11 months at sea the plant should experience every season and obtain many results for the development of a commercial version.

11 Challenges for Ship Bourne Applications

Even if we do see a ship not as a moving application like trucks or trains, it is a power plant in motion. This means, the equipment has to stand ongoing inclinations around two axes, accelerations and shocks along three axes and constant vibrations affecting all components.

Furthermore, the environment at sea and inside ships is challenging. The effects of temperature range, moisture and especially the salt-content of sea-air on the membranes are unknown.

MTU is working on a new marine design for the stack which will be tested in different applications.

12 Possible Application in Seagoing Vessels

The described system is best suitable for high-value seagoing vessels. Due to weight and size it is not very suitable for inland shipping, but for vessels operating a lot in coastal waters and with many harbour calls. Due to its characteristics it shall operate continuously, as a base load supply. The advantages in efficiency compensate for the higher fuel costs compared with MGO used in such operations. But even this will change in favour for the fuel cells with the upcoming IMO regulations on emissions and the emission trading.

According to first calculations more than half of the additional investment – compared with a state-of-the-art diesel generator – is compensated by the savings in fuel consumption. Including savings in maintenance and harbour emission fees the system is nearly cost neutral.

13 Time Frame

The project has started in June 2009 and runs for about 4 years. The superordinated *Toplaterne* runs 5 years, to have a phase for assessing the results of the demonstration projects [11].

14 Conclusions

The presented application of the fuel cell technology onboard sea-going ships shows a solution for the near term realisation of fuel cell based power generation.

The technologies and modules are today available, just the combination has to be developed. This is no basic research but advanced engineering.

Even the economies are in the range of a black "0", so that it is the right time to start using fuel cells.

We expect the availability of commercial systems in short time after finishing the project.

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