DNV·GL

MARITIME

Status of maritime Fuel Cell Technology

Regulations and ongoing projects

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Content

Introduction

Motivation

- Improvement of Ship Energy Efficiency
- Reduction of emissions to air
- Reaching insignificant noise and vibration level

Driver

- Environmental regulations to
  - Increase efficiency of ship operation
  - Reduce NO_X, SO_X, CO_2 and particle (PM) emissions

Introduction

Possible Solutions

- Ship and system design
  - Hull optimization
  - Alternatives fuels
  - Alternatives energy converters
- System and components operation
  - Optimization of given technologies
  - Optimization of power management
- Ship operation
  - Logistics optimisation
  - Speed selection
  - Routing

- ❖ Ship Energy Efficiency
- ❖ Emissions
- ❖ Noise & Vibration

Maritime Fuel Cell technology is promising to enhance ship design and operation

Introduction

Today's most promising project

- **e4Ships** – German funded Lighthouse project for maritime Fuel Cell application
- **Aim** – Development of Fuel Cell auxiliary power generator capable for serial production
- Developments are in line with the objectives of the German *"mobility and fuel strategy"*:
  - Introduction of *alternative and regenerative fuels*
  - Development of *innovative power technologies*
  - Aiming a big share of Hydrogen and Fuel Cell application for all modes of transport in a long-term view

e4ships (nip) Brennstoffzellen im maritimen Einsatz

A project of

nip Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

Funded by

Bundesministerium für Verkehr und digitale Infrastruktur

Coordinated by

NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Technology Overview

Fuel Cells for Transportation

- Fuel Cells Systems have been tested for all modes of transport
- Different Fuel Cell types were developed

Market survey shows that in terms of*

- Development status
- Efficiency
- Load change behaviour
- Fuel flexibility

PEMFC and HTFC are most suitable for maritime applications

*Market study conducted in parallel to the start of "e4Ships" project

Technology Overview

Suitable Fuel Cell Types

PEMFC

- High development status
- Dynamic load profiles possible

MCFC, SOFC (HTFC)

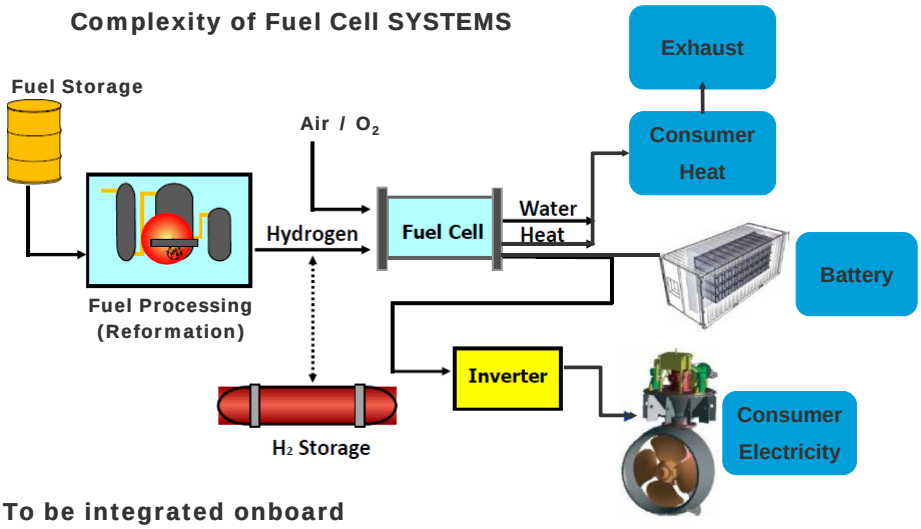
- High efficiency
- Low requirements on fuel and air quality (in comparison to PEMFC)
- High temperature exhaust air at 650°C to 1,000°C enables combination with CHP processes

Fuel cell type	Temperature (°C)	Electric efficiency (%)
Proton Exchange Membrane (PEM)	30-100	35-40
High Temperature PEM (HT-PEM)	160-200	~45
Molten Carbonate (MCFC)	~650	45-50
Solid Oxide (SOFC)	500-1100	45-50

Figures derived from project results including losses; increase of efficiency expected due to further development

Technology Overview

Complexity of Fuel Cell SYSTEMS



To be integrated onboard

Technology Overview

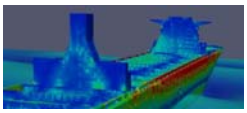
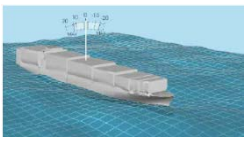
Challenges, in general

- Fuel Cell system lifetime
- Dimensions and weights
- Investment costs
  - Comparable with diesel engines at 400 $/kW, and thus the lifetime costs of the installation must be compared (investments and operation).
  - MCFC module prices by 3,000 $/kW and also significantly higher
  - A target of 1,500 $/kW has frequently been used which can be achieved between 2020 and 2025

Technology Overview

Challenges, maritime

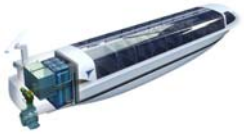
- Maritime Environment
  - ship motions
  - vibrations
  - humidity till 60 %
  - salty air
  - temperatures:
    - Full load capacity and efficiency till 45 °C
    - Full response for electrical equipment till 55°C
- Design requirements
  - testing criteria (different to land-based application)
  - reliability and availability
  - fuel storage, transport, processing onboard

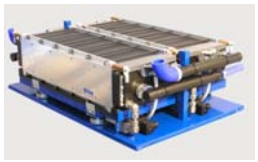





Maritime Applications

PEMFC demonstrations projects

- Submarines, yachts, ferries and boats have been fitted with PEM fuel cells running on hydrogen
- Examples are
  - the 2 x 50 kW units on the ferry *FCS Alsterwasser* in Hamburg
  - the 60-70 kW installation on the ferry *Nemo H2* in Amsterdam.
  - the 12 kW HTPEM installation on the harbour ferry *MF Vågen* in Bergen
  - A larger installation of HTPEM on a cruise vessel (tested within the Pa-X-ell project).





Maritime Applications

MCFC and SOFC demonstration projects

- Several commercial vessels have been fitted with Molten Carbonate and Solid Oxide fuel cells running on Methanol / Natural Gas
- Examples are:
  - A methanol-fuelled SOFC plant of 20 kW tested on board of the car carrier Undine
  - The LNG fuelled MCFC plant of 330 kW MCFC installed on board of the *Viking Lady* (FellowShip project)
  - A SOFC installation to be tested onboard of a commercial vessel during the SchIBZ project

Rules & Regulations

Current approval baselines

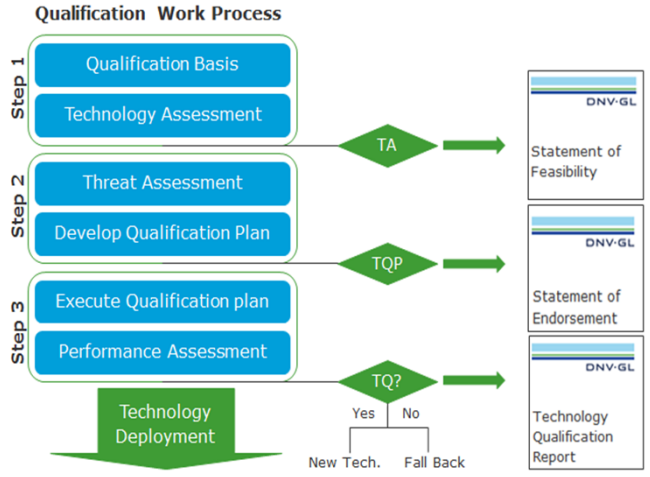
- Existing demonstrations projects were approved by classification society and administrations following different approaches
  - Risk based approaches considering applicable requirements from SOLAS and IACS
  - Following prescriptive requirements in existing FC Class rules

➢ Currently there is no international binding regulation defining prescriptive requirements for maritime Fuel Cell applications in force

…. Neither for the onboard storage, transport and processing of suitable fuels for Fuel Cells …

Rules & Regulations

Technology Qualification Process



Rules & Regulations

Classification Guidelines

- The first classification Guideline for Fuel Cell Installation onboard of ships were published by GL in 2002
- In parallel DNV developed classification Guideline for maritime FC applications close together with guidelines for gas as ship fuel (2008)
- At the moment both Guidelines are in a merging process to build DNV GL Guidelines
- The “one set of FC guidelines” will be available beginning 2016
- Up to this publication both above mentioned guidelines are valid

Chapter 2 - Propulsion, power generation and auxiliary systems

Section 3 - Fuel cell installation

Ongoing Developments

Regulatory frame work

- Since 2009 IMO’s Interim Guidelines MSC.285(86) giving construction guidelines for the use of Natural Gas as Fuel (based on combustion engines)
- Since mid of 2015 Draft Internal binding “IGF Code” defining prescriptive requirements for NG as fuel
- Expected end of 2015 Amendments to RVIR Amendments to the Rhine Vessel Inspection Regulations RVIR in work defining prescriptive requirements for NG as fuel for inland vessels
- Further development of IGF Code Second phase of the IGF Code development aims i.a. the implementation of requirements for Fuel Cell Systems; initially for the use of NG as fuel

IMO

CCNR CENTRAL COMMISSION FOR THE NAVIGATION OF THE RHINE

Ongoing Developments

German funded lighthouse project "e4ships"

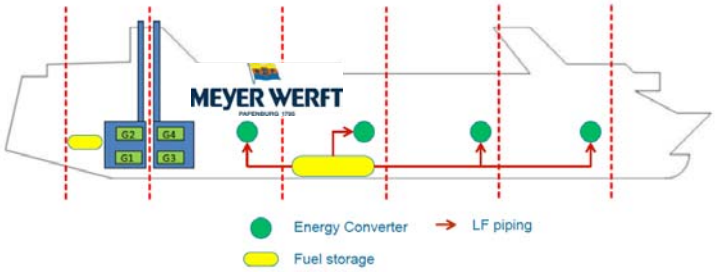
- Framework project "Toplaterne"
  - ► *Focus on safety and rule development*
- Fuel cell systems on board of a Passenger Vessel (Cruise and Yacht)
  - ► *Focus on integration in ship design, ship safety (SOLAS) and overall efficiency*
- High Temperature Fuel Cell systems on board of Passenger and Special Vessels
  - ► *Focus on application of diesel fuel oil and hybrid design (FC – Battery Buffer)*
- Fuel Cell systems on board of an inland navigation Vessels
  - ► *Hybrid system design (just started) (Diesel, Fuel Cell, Energy Buffer)*

Ongoing Developments

e4Ships partner

Ongoing Developments

Pa-X-ell: Distributed Energy Conversion and Integration



- Fuel cells in different fire zones ► SOLAS
- Safe supply of fuel cells ► IGF piping for low-flashpoint fuels
- Thermal integration of Fuel cells ► increased fuel efficiency
- Electrical integration of Fuel cells ► development of control, energy buffer

Ongoing Developments

Pa-X-ell: Actual achievements

- Modularized FC system concept
- 120 kW Fuel Cell Container – Methanol Fuel Cell Rack with auxiliary equipment
- Risk Assessment performed for Fuel Cell and Methanol system
- In operations since May 2014 for long term trials
- Second generation of FC module developed (higher efficiency, reduced invest. Cost)

Ongoing Developments

SchIBZ – application of Solid Oxide Fuel Cells

- 100 kWel high-temperature fuel cell for seagoing vessels has been developed and manufactured
- SOFC is fuelled with diesel oil
- Use of diesel fuel for SOFC system successful tested
- Practical testing planned for end of 2015 / 2016

Ongoing Developments

SchIBZ: Actual achievements

- ***Diesel reforming:***
  proof of concept over more than 3200h with 10ppmS diesel fuel with the result of a clean fuel gas
- ***SOFC Module***:
  construction of a 27kW SOFC module for ship borne use, test with minimal degradation over more than 1000h, electrical efficiency 50+%
- ***System:***
  Risk Assessment performed for SOFC systems and intended onboard integration

Ongoing Developments

Toplaterne - Safety

- Definition of functional safety requirements for Fuel Cell applications
- Assessment of designs by means of risk assessments
- Deduction of IGF Code Requirements for Fuel Cells for submission to the IMO through the German Administration and CESA

Recently from the IMO

- Sub-committee of IMO's MSC "CCC – Carriage of Cargoes and Containers" will meet next week 38 for CCC2
- Topics from the Agenda
  - Requirements for Fuel Cells
  - Requirements for Methanol as fuel

Summary & Outlook

- FC technology is available from land-based applications
- Principal maritime suitability was proven by demonstration projects
- **e4Ships** is currently the most promising project worldwide developing and testing **marketable maritime FC Systems** until end of 2016
- Developments by Pa-X-ell and SchIBZ aiming significant **reductions of investment costs and increase of lifetime** of maritime FC systems
- Resulting from Toplaterne requirements will be implemented in the IGF Code building international **regulatory baselines for FC applications**
- For all projects within e4Ships a second phase is in development for further practical testing of maritime FC technology until 2022
- Developments are strongly supported by the Federal Ministry of Transport and Digital Infrastructure

IMO INTERNATIONAL MARITIME ORGANIZATION **E**

MARITIME SAFETY COMMITTEE
95th session
Agenda item 3

MSC 95/WP.7
10 June 2015
Original: ENGLISH

MSC 95/WP.7
Annex 2, page 2

ANNEX

INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)

CONTENTS

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RULES FOR CLASSIFICATION

Ships

Part 6 Additional class notations

Chapter 2 Propulsion, power generation and auxiliary systems

"water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable"

Jule Verne, the mysterious island, 1874

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