PURE: APU FOR RECREATIONAL YACHTS

pure

DICK LIEFTINK - JUNE 14, 2013

New Energy World JU
fuel cells & hydrogen for sustainability

HYGEAR

ABOUT HYGEAR

- Established in The Netherlands, 2002
- 60 people
- EBITDA 2 M€ (2012)
- Revenue 9 M€ (2012)
- Investors:

ABENGOA

ppm oost

HYGEAR'S PRODUCTS

- **Hydrogen Generation Systems** (lead product)
- Gas Upgrading Systems
- Gas to Liquid
- Fuel Cell Systems

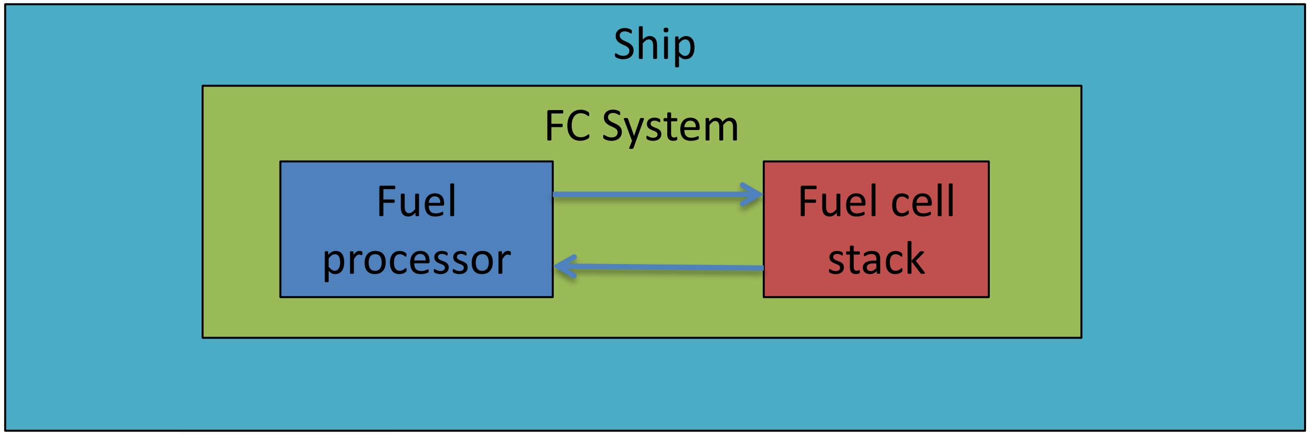
- Key technologies:
  - Small-scale gas processing
  - Highly efficient reforming (SMR)
  - (Vacuum) Pressure Swing Adsorption (PSA)
  - Catalysis

HYGEAR AND MARITIME

- PURE (FCH-JU, GA 303457)
  - APU for recreational yachts
  - Target power: 500 We
  - Start January 1, 2013
- HySeas (Dutch national funding)
  - On board power for coasters
  - Target power: 200- 300 kWe
  - 2010- 2013
- Joules (FP7, GA 605190)
  - Ultralow emission shipping
  - Start June 1, 2013
- Commercial Engineering projects

SYSTEM REQUIREMENTS

- Function of Fuel cell system:
  - Propulsion
  - Hotel function
  - Auxiliary Power Unit
- Each application has its own set of requirements:
  - Power level
  - Start/stop behavior: number and start up time
  - Integration in ship, size, specific maritime conditions



TECHNOLOGY DECISIONS

- Stack type
  - LT PEM: T = 60 – 70ºC, CO < 10 ppm, quick start up, polymeric
  - HT PEM: T = 170 – 180ºC, CO < 1-5%, medium start up, polymeric
  - SOFC: T = 650 - 800ºC, CO can be fuel, long start up, Ceramic
- Fuel type
  - Hydrogen: storage required
  - Hydrocarbons fuels: fuel processor system required
    - LPG
    - CNG
    - Diesel
    - Ethanol/ methanol

HYDROGEN PRODUCTION

- Hydrogen production technologies for Fuel cells
  - Steam reforming
    - $CH_4 + H_2O \rightarrow CO + 3H_2$ (endothermic)
  - Catalytic partial oxidation
    - $CH_4 + ½\ O_2 \rightarrow CO + 2H_2$ (exothermic)
  - Autothermal reforming
    - Combination of the reactions above in one reactor

- CO removal technologies
  - Water gas shift (> 1000ppm)
    - $CO + H_2O \rightarrow CO_2 + H_2$
  - Preferential oxidation (<10ppm)
    - $2CO + O_2 \rightarrow 2CO_2$
  - Methanation (<10 pmm)
    - $3H_2 + CO \rightarrow CH_4 + H_2O$
  - Pressure Swing Adsorption/ membranes → pure hydrogen

PURE

- Development of Auxiliary Power Unit for Recreational yachts

- SP1-JTI-FCH.2011.4.4 Research, development and demonstration of new portable Fuel Cell systems
- Duration 36 month, start date January 1, 2013
- Partners:
  - HyGear Fuel Cell Systems (NL),
  - Danmarks Tekniske Universitet (DK),
  - Centre for Research and Technology Hellas /APTL (GR)
  - Joint Research Centre, Petten, NL (B)
  - Damen Shipyards (NL)

PURE TARGETS

Targets set by the FCH-JU (AIP 2011):

• Electrical power output should be between 50 W and 500 W_e

• Proof of concept systems containing stacks, all balance of plant components and fuel supply meeting application specifications

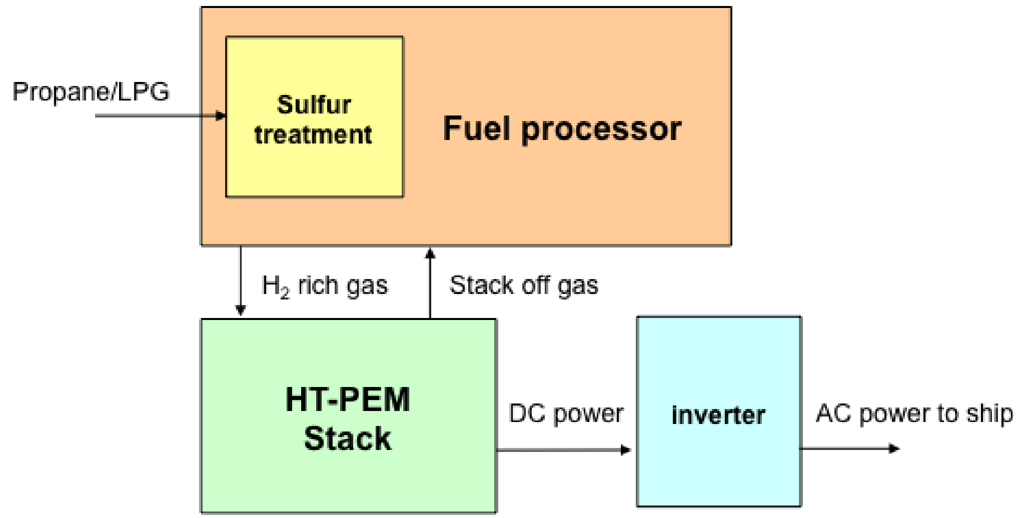
• Demonstrate system operation with electrical efficiencies of 30%+ (based on a logistic fuel input)

• 1,000 h lifetime including 100 start-stop cycles and specific size and weight of less than 35 kg/kW and 50 l/kW (fuel amount excluded)

• System validation through systematic and widely agreed testing protocols/activities, demonstrating a cost prediction for mass production of less than 5,000 €/kW

PURE IN NUTSHELL

- System requirement definition: (DAM, HFCS)
- Certification, codes and Standards (DAM)
- MEA development (DTU)
- System development (HFCS)
  - Sulfur management (APTL)
  - Stack procurement (HFCS)
- System Construction (HFCS)
- Environmental tests (JRC)
- On board tests (DAM)

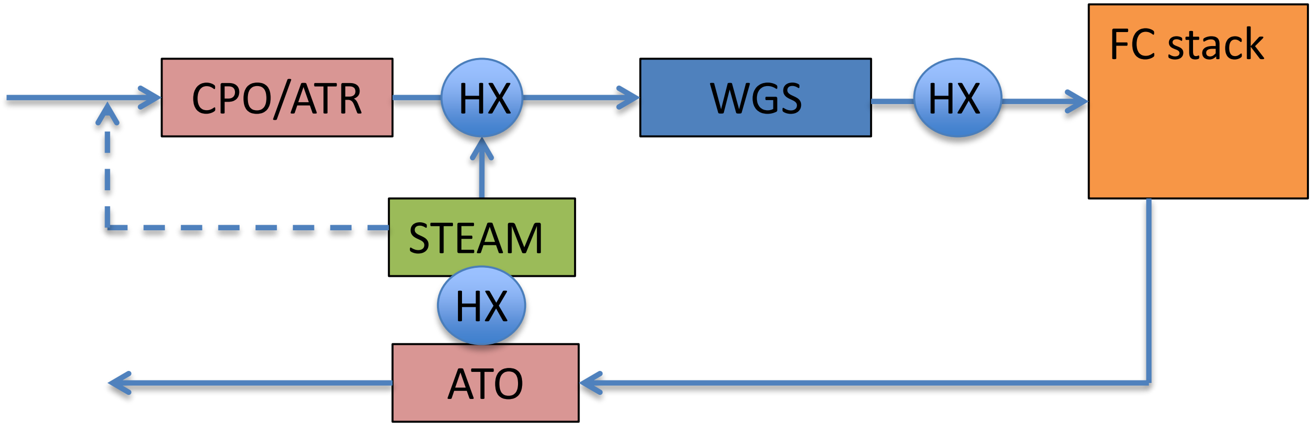


THE PURE SYSTEM

- LPG/propane is widely used in recreational yachts: Campinggaz©)
  - Propane, butane, ethyl-mercaptan as odorant
- HT PEM technology fits best
  - Limited CO clean up required → Small reformer
  - No steam generator system required for stack, however 1-5% CO at inlet requires some water gas shift reaction in FP, therefore some steam
  - Suppliers available
- Small size, both power (500We) and volume (25 L)/weight (17.5 kg)
  - Experience from other FCH-JU projects using small fuel processors
    - LOTUS (1kWe SOFC micro CHP system)
    - SUAV (250W FC system for drones)

PURE FUEL PROCESSING

- Quick start up: CPO or ATR
- Lifetime: ATR (steam), but 1000hr is not very long.
- CO: 1-5% in reformate to Stack: Water gas shift
  - Steam production from waste heat
- Low emissions CH_4, CO, H_2: Anode tail gas oxidiser
  - Catalyst of burner flame, also used as start up burner



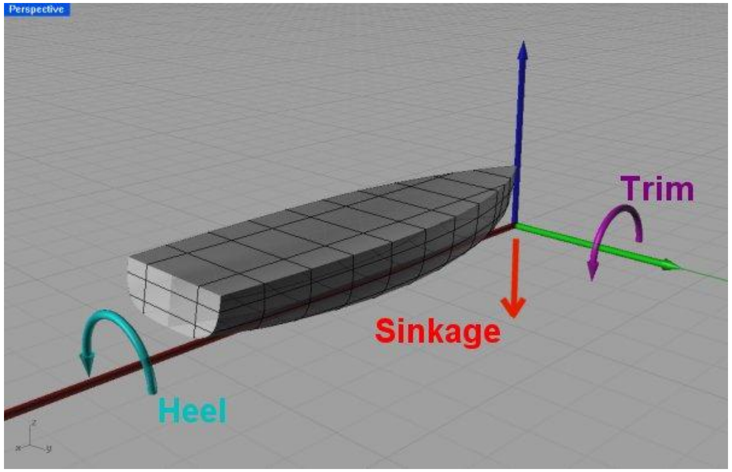
SULFUR MANAGEMENT

- Sulfur deactivates fuel processing catalysts and Fuel cell stack. The catalysts define where it should be removed from the gas stream.
  - Upstream of all catalysts in the fuel by adsorption processes
    - Active carbons, zeolites, base metals
  - Downstream of reformer catalyst
    - Converted into H_2S/ COS
    - Adsorption between 250-350ºC in ZnO/ CuO type materials

- Ideally, all materials are S tolerant and no De-sulfurization is required.

MARITIME REQUIREMENTS

- Salt laden air and waves (however small) should be taken into account as external factors)
- The air must be assumed as salt laden with a relative humidity of 100% at a reference temperature of 45° C
- Machinery should be able to cope with a static heel angle of 15º, a dynamic heel of 30º and a dynamic trim of 20º.



CONCLUSIONS

- Design according to specific requirements of the application:
  - Fuel processing
  - Stack technology
- Size requirements are challenging
  - Reduce number of parts, combine functionality
  - Choice for HT PEM stack
  - Avoid steam generation where possible
- Design for maximum 30º tilting
  - Water levels,
  - Connections between reactors and heat exchangers
- Design for salt air environments
  - Proper air filters

Damen FCS 1605

ENGINEERING FOR SUSTAINABLE GROWTH

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IEA Hydrogen Implementing Agreement
New task on Hydrogen in Marine Applications

- Overall goal
  - Investigate possibilities for use of hydrogen and bio-fuels in marine systems (surface and underwater)
  - Generate an overview of existing projects and initiatives
  - Identify and contribute to research within the area
  - Technology monitor
  - Meeting platform for academia, industry and end-users

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