Future Fuels

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EffShip WP 2 – Objectives

The purpose of Work Package 2 was to identify and present possible future fuels for maritime use. An overview level investigation with a focus on a wide picture of maritime fuel over short term, medium term and long term perspectives was to be conducted. Logistic and risk aspects of the supply and storage of the fuels were also to be assessed.
Future Marine Fuels - Criteria

Technical Criteria
- Fuel properties
- Propulsion system
- Fuel pre-treatment requirements

Economic criteria
- Investment cost
- Fuel price
- Operational cost

Environmental criteria
- Consequences of fuel spills and accidents
- Exhaust emissions
- Life cycle environmental performance

Other criteria
- Safety and safe handling criteria
- Logistical criteria
- Public opinion
- Political and strategy aspects
- Security
- Ethics

Future Marine Fuels
Drivers for alternative fuels – Customer Perspective

Legislation
- SOx
- NOx
- Particulates
- Green house gases
- Safety regulations and class compliance

Cost
- Operating cost
- Investment cost
- Service cost

Availability
- Fuel availability
- Technology
Fuels for Shipping – Alternatives

- MGO Marine Gas Oil
- LNG Liquefied Natural Gas
- Methanol
- Ethanol
- LPG
- DME
- Synthetic Diesel (Gas To Liquid, Coal To Liquid)
- RME Raps-Methyl-Ester (Biodiesel)
- Bio oils
- Hydrogen
Fuels for Shipping – Alternatives

- MGO Marine Gas Oil – Expensive!
- LNG Liquefied Natural Gas – Infrastructure?
- Methanol – Technical solutions?
- Ethanol – Food restrictions!
- LPG – Safety/Expensive!
- DME – Infrastructure?
- Synthetic Diesel (Gas To Liquid, Coal To Liquid) – Expensive!
- RME Raps-Methyl-Ester (Biodiesel) – Expensive/Not available!
- Bio oils – Expensive/Not available!
- Hydrogen – Storage?
Alternatives Fuels – Time Perspective

Short term – Fuel Alternatives 2015
(Upcoming SOx regulation for 2015 sets the agenda)

- Use of MGO will be the most used SECA solution (>95%)

- 0,1% S HFO will not exist, but high S HFO with aftertreatment will meet the regulation within SECA

- LNG will be limited by not developed infrastructure and expensive conversions, but vessel solutions are mature

- First pilot project with methanol will start
Alternatives Fuels – Time Perspective

Medium term – Fuel Alternatives 2020/2030:

- High S HFO with aftertreatment will be a more frequent used solution
- 0,5% S HFO will be an alternative outside SECA
- LNG infrastructure will be developed, which will boost LNG
- Methanol can be a competitive alternative. GHG targets for 2030 can be fulfilled by lower CO2 fuels such as methanol (conventional production combined with renewable production such as from forest industry residuals)
- Raw methanol might be considered as a marine methanol quality
Alternatives Fuels – Time Perspective

Long term – Fuel Alternatives 2050:

- LNG frequent used – infrastructure in place
- HFO solutions will still exist, but with steadily declining share
- Methanol can be a competitive alternative. From the perspective of fuels, GHG targets can be fulfilled by gradually increasing the amount of GHG neutral methanol produced from captured CO2 and hydrogen produced with wind, water, sun and geothermal energy
Methanol Basics

- A multi source and multi purpose fuel
- Infrastructure and safety similar to Ethanol
- Liquid – no pressure tanks
- Estimated engine performance acceptable

However:

- Toxic
- Safety
- Dubble volume versus Diesel
- Corrosive
Methanol Characteristics

**Methanol**
- Density 0.79 kg/l
- Boiling point 65°C
- Flash point 11-12°C
- Auto ignition 464 °C
- Viscosity ~0.6 cSt at 20°C
- Octane 108 RON
- LHV 20 MJ/kg

**Diesel**
- Density 0.85 kg/l
- Boiling point 150-370°C
- Flash point 60°C
- Auto ignition 240°C
- Viscosity ~13.5 cSt at 20°C
- Cetane No. 45-55
- LHV 42.9 MJ/kg
Methanol - Sources

Natural Gas

Coal

Biomass

Municipal waste

Carbon Dioxide

Synthesis Gas

\((H_2 + CO)\)
Methanol and LNG, two sides of the same coin

Natural Gas (Methane)

\[ \eta = 70\% \]

Methanol

\[ \eta = 90\% \]

LNG

Cheap Distribution

Expensive Distribution

Renewable Methanol possible - but expensive

$ ?$
Well-to-propeller Analysis (LCA)

Summary of the life cycle environmental performance for a number of areas for marine gas oil (MGO), liquefied natural gas (LNG), methanol produced from natural gas (MeOH), dimethyl ether produced from natural gas (DME), liquefied biogas (LBG), methanol produced from biomass (BioMeOH) and dimethyl ether produced from biogas (BioDME) compared with heavy fuel oil (HFO) as shipping fuel (represented by the dashed line).
Methanol usage

- Is primarily produced from natural gas
- Has diversified end uses
  - **Traditional Uses (Mature Markets)**
    - Formaldehyde: Pharmaceuticals, Wood Industry, Automotive
    - Acetic Acid: Fleece, Adhesives, Paints
    - Dimethyl Terephthalate: Recyclable plastic bottles
    - Methyl Chloride: Silicones
  - **Energy & MTO (High Growth Potential Markets)**
    - DME (dimethyl-ether)
    - Fuel Blending
    - MTO (Methanol-To-Olefins)
    - Biodiesel
Availability

World Methanol Supply & Demand

Million Metric Tons

Operating Rate

Forecast

% AAGR = 06-11/11-16

Demand (7.7/10.8) • Total Capacity (14.8/5.2) • Operating Rate


0.0 20.0 40.0 60.0 80.0 100.0 120.0
Methanol production by feedstock

World Methanol Production by Feedstock Forecast

Million Metric Tons

Forecast


Natural Gas (3.2/5.6)
Heavy Liquids (-5.7/3.9)
Coal/Other (27.1/21.1)
Total Capacity (14.8/5.2)

(% AAGR = 06-11/11-16)
Methanol Price vs. HFO, MGO

"Methanol spot prices remain under pressure due to tight supply"

Spot prices of IF380 vs. Methanol in Rotterdam.

Source: www.bunkerworld.com & JJ&A Jim Jordan & Associates weekly methanol reports
Production Cost Of Methanol

Industry Environment

“Expensive” methanol produced from coal in China settles the global price of methanol on the spot markets, which means that methanol produced from natural gas will be produced with good profit.
Use of Methanol in Internal Combustion Engines

**Diesel Engine Concept for OBATE-DME** *

The traditional HFO, or LFO, is replaced with OBATE-DME in a diesel engine. Since OBATE-DME is a gas at atmospheric pressure you need to pressurize the fuel supply and return system. The challenge is the major modifications of the fuel injection system to handle fuel characteristics: low viscosity, low heat value, low cetane number and high compressibility. Full output achievable.

**Duel Fuel concept for Methanol**

In this concept you replace the gas valve on a DF-engine, or complete the engine, with a methanol injector. You ignite the compressed premixed methanol-air mixture with a small pilot fuel diesel spray when the piston is close to TDC. Performance corresponding to the DF concept.

**Methanol-Diesel concept for Methanol**

You inject the methanol at high pressure close to TDC and ignite with pilot diesel. By using the diesel principle you avoid knocking problems, which you might face using the methanol in a Duel Fuel engine. Area for adaption is the fuel injection system for the methanol. Full output achievable.

* On-line conversion of MeOH to DME/MeOH/water mix
Methanol-Diesel Concept

+ no knocking (diesel combustion)
+ no power reduction
+ good load acceptance
+ cost effective adaption
+ low THC, CO and formaldehyde levels
+ good back-up fuel performance
+ HFO pilot fuel possible

- NOx higher than for DF concept
- depending on pilot fuel for ignition
Methanol Fuel Injector

- Sealing oil pressure 20bar over gas pressure.
- Sealing oil ensures that use of low viscosity fuel is possible.
- Sealing oil pressure limits the injection pressure level.

Sealing oil around needle
Test – Methanol-Diesel Concept

- Output 410kW/cyl. at 750 rpm
- Compression ratio: 13.8
- Inlet valve:
  - Open 52° BTDC
  - Close 28° ABDC
- Exhaust valve:
  - Open 56° BBDC
  - Close 44° ATDC
Tests on Methanol - NOx

Reference run HFO: NOx 11.8 g/kWh

Specific emission of NOx, g/kWh

Main injection timing, ° BTDC

FS: 50 - 51 %
FS: 75 - 76 %
FS: 91 %
FS: 90-91 %, advanced pilot
Test Results

- NOx acceptable (Low Tier II values)
- CO acceptable (< 1 g/kWh)
- THC acceptable (< 1 g/kWh) and no “methane slip”
- Very low PM (FSN ~ 0.1 with HFO as pilot)
- Formaldehyde emissions low 15-20 ppm (below TA-luft limit)
- Efficiency with methanol comparable to diesel
- No Formic acid detected in exhaust gases
Tests at Methanol

O-ring failures at tests - Connection pipe Methanol leakage to lube oil and clean fuel
Potential – thoughts for the future....

Go for raw methanol (10% water) instead of chemical methanol

→ OK for engine (even lower NOx)

→ price structure disconnected from ordinary methanol

→ 10% lower refinery cost (on energy basis)

→ 10% higher production efficiency means reduced carbon footprint
Methanol test results

![Graph showing NOx emissions vs. main fuel injection advance for different fuel types and loads.]

- Green line: Neat methanol, 90% load, FS=75%
- Blue line: Methanol+10% water, 75% load, FS=90%
- Red line: LFO 75% load
- Black line: Methanol, 75% load, FS=90%
Thank You

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