METHANOL – as engine fuel, status Stena Germanica and market overview

Toni Stojcevski
Methanol characteristics compared

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Methanol</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/l)*</td>
<td>0.79</td>
<td>0.85</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>65</td>
<td>150-370</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>11</td>
<td>min. 60</td>
</tr>
<tr>
<td>Auto ignition (°C)</td>
<td>464</td>
<td>240</td>
</tr>
<tr>
<td>Viscosity cSt at 20°C</td>
<td>~ 0.6</td>
<td>~ 13.5</td>
</tr>
<tr>
<td>Octane RON/MON</td>
<td>109/89</td>
<td>-</td>
</tr>
<tr>
<td>Cetane No.</td>
<td>3</td>
<td>45-55</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>20*</td>
<td>42</td>
</tr>
<tr>
<td>Flammability Limits, Vol%</td>
<td>7-36</td>
<td>1-6</td>
</tr>
<tr>
<td>Flame Speed (cm/s)</td>
<td>52</td>
<td>37</td>
</tr>
<tr>
<td>Heat of Evaporation (kJ/kg)</td>
<td>1178</td>
<td>233</td>
</tr>
<tr>
<td>Stoichiometric Air-Fuel Ratio</td>
<td>6.45</td>
<td>14.7</td>
</tr>
<tr>
<td>Adiabatic flame temp. (°C)</td>
<td>1910</td>
<td>2100</td>
</tr>
</tbody>
</table>

* 2,17:1 Methanol:Diesel
Possible Methanol Concepts for Marine Engines

- Surface Ignition
- Fumigation
- Mixing Concept (Emulsion)
- Ignition Improvers
- Pilot fuel assisted Diesel Combustion
- Premixed Combustion with Spark Plug or Pilot Fuel Ignition
Conclusions from using methanol in the diesel process

- Engine output and efficiency equal to the diesel engine
- Significant reduced NOx and PM compared to diesel
- Life time of major components will be similar or better than the diesel engine
- No change in oil change intervals are expected

Sources: SAE 902160 paper, EPA-460/3-023 August 1981
Wärtsilä Methanol-Diesel retrofit solution

- Methanol is combusted according to the diesel process. The methanol is injected close to TDC and ignited by a small amount of diesel pilot fuel.

- The methanol injection pressure is limited to below 650 bar.
Wärtsilä Methanol-Diesel retrofit kit

- On-engine scope is limited to exchange of cylinder heads, fuel injectors and fuel plungers in existing fuel pumps
- A common rail system for methanol injection will be added on the engine
- In addition to the on-engine conversion parts, the conversion kit includes: stand-alone methanol pump, standalone oil unit for supply of sealing and control oil to the fuel injectors, and an update of the automation system.
Wärtsilä Methanol-Diesel retrofit solution on-engine piping
Recent testing of Wärtsilä Sulzer ZA40S-MD

* Preliminary tests - Engine consumption
- Further investigation on engine efficiency to be performed
- (Heat Balance and heat release to be calculated)
Technology – Test results

- NOx 3-5 g/kWh (Low Tier II, no major conversion)
- CO (< 1 g/kWh)
- THC (< 1 g/kWh)
- PM only from MGO pilot (FSN ~ 0.1)
- SOx only from MGO pilot (99% reduction)
- Formaldehyde emissions (~ below TA-luft)
- No Formic acid detected in exhaust gases
- No reduction in output and load response unchanged, full fuel redundancy
- Same or better efficiency

Methanol or MGO can be selected (or re-selected) as source of energy in a fast, simple and reliable way without stopping the engines and without losses in engine speed and output.
Stena Germanica - Conversion Scope

- Engines converted for methanol combustion
- Double walled fuel pipes
- Ballast tank converted to methanol fuel tank
- Transfer pump room
- Pump room
Methanol Project – Stena Germanica Status

- ZAL40S test engine have been running 100 hours on methanol, results **positive**
- Type Approval Test of the conversion package – **approved by LR**
- Stena Germanica going to shipyard 28.01.2015: bunkering line, tanks, pump room, pumps, piping, automation upgrade and one engine conversion to be done during in shipyard
- **First ever** ship operating on methanol – 15.03.2015
Engine conversion kit - features

- Adaptation of proven engine technology (GD), minor modification to the engine
- No reduction in efficiency or output running on methanol, load response unchanged, fuel redundancy
- Existing fuel / ballast tanks can be converted to methanol tanks
- Short off-hire time, can be done engine by engine
- Lower thermic load on the engine
- Much lower NOx, SOx, GHG and PM (particulates), safe for future ECA regulations
- Available fuel infrastructure
MARKET OVERVIEW

Toni Stojcevski
Increasing environmental regulation and alternatives for decreasing emissions

<table>
<thead>
<tr>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{x}</th>
<th>Particulate matter</th>
<th>Greenhouse gas</th>
<th>Ballast water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid rains</td>
<td>Acid rains</td>
<td>Impact on air quality</td>
<td>Global warming</td>
<td>Damage to local eco-systems</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td></td>
<td>Along with SO\textsubscript{x} reduction</td>
<td>Under evaluation by IMO</td>
<td>Global ballast water convention</td>
</tr>
<tr>
<td>Tier II (2011)</td>
<td>3.5% (2012)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tier III in ECA\textsuperscript{*} (2016)</td>
<td>ECA 0.1% (2015) Global 0.5% (2020)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wärtsilä offers a multi-solution approach to meet requirements for different owner needs, ship types and operating profiles.

**LNG**
- Simultaneous reduction of GHG / SO\textsubscript{x} / NO\textsubscript{x} / PM
- Market: mainly ships with regular routes and limited autonomy requirements operating in ECAs
- Infrastructure development is needed for larger uptake
- Conversion solution available

**HFO**
- NO\textsubscript{x}: SCR or wet methods
- SO\textsubscript{x}: Scrubbers
- Market: mostly merchant ships operating a significant time in ECAs

**MGO**
- NO\textsubscript{x}: SCR or primary methods
- Market: ships operating a limited time in ECAs, small ships
Future market dynamics – Ship Owners perspective

Regulations
- Emissions
- Flag State
- Class compliance

Cost
- Capex
- Opex

Availability
- Fuel
- Technology
**Methanol overview – Availability, Cost and Market**

### Availability
Fuel availability: Liquid, widely used in chemical industry, utilizes existing transport and terminal infrastructure

**Technology:**
- Test results show simultaneous reduction of SOx / NOx / PM
- Same or better efficiency, No reduction in output and load response unchanged, full fuel redundancy
- Pilot Installation Q1 2015

### Cost
**Capex:**
- Relatively simple conversion ~350€/kW
- Methanol Common rail system and MD-injector
- New engine control system (UNIC C3)
- Existing fuel/ballast tanks can be converted to methanol tanks (No loss of commercial space)

**Opex:**
- Several methanol suppliers have showed interest in supplying methanol with attractive contract pricing
- Same or better efficiency and life-time of components

### Market
**Ships operating in ECA’s**

With a liquid fuel that is widely available global traded commodity and with existing infrastructure there is a potential market in every ECA
Legislation: Current and potential emission control areas
Fuel availability: Methanol Infrastructure Advantage

- Extensive existing terminal infrastructure + modest cost to build new terminal capacity; ability to use existing fuel infrastructure

- Terminal locations are representative based on available information and is not a complete list

Source: Methanex
Infrastructure and pricing

<table>
<thead>
<tr>
<th>Description</th>
<th>Price 1</th>
<th>Price 2</th>
<th>Unit</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas well head price</td>
<td>0.010</td>
<td>€/KWh</td>
<td>183</td>
<td>Crude eqv.</td>
</tr>
<tr>
<td>Methanol cost ex works</td>
<td>0.025</td>
<td>€/KWh</td>
<td>432</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>Methanol produced from forest products</td>
<td>0.072</td>
<td>€/KWh</td>
<td>1244</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>Methanol along side Göteborg</td>
<td>0.044</td>
<td>€/KWh</td>
<td>805</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>Natural gas well head price</td>
<td>0.010</td>
<td>€/KWh</td>
<td>183</td>
<td>Crude eqv.</td>
</tr>
<tr>
<td>LNG cost ex works</td>
<td>0.02</td>
<td>€/KWh</td>
<td>345</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>LNG FOB Zeebrugge</td>
<td>0.03</td>
<td>€/KWh</td>
<td>518</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>LNG along side Göteborg</td>
<td>0.046</td>
<td>€/KWh</td>
<td>845</td>
<td>MGO eqv.</td>
</tr>
<tr>
<td>Crude oil well head price</td>
<td>115</td>
<td>$/bbl</td>
<td>843</td>
<td>$/ton</td>
</tr>
<tr>
<td>Crude landed (WTI/Brent approx)</td>
<td>119</td>
<td>$/bbl</td>
<td>872</td>
<td>$/ton</td>
</tr>
<tr>
<td>MGO port price</td>
<td>0.062</td>
<td>€/KWh</td>
<td>1070</td>
<td>$/ton</td>
</tr>
<tr>
<td>HFO port price</td>
<td>0.042</td>
<td>€/KWh</td>
<td>716</td>
<td>$/ton</td>
</tr>
</tbody>
</table>

Co-financed by the European Union
Trans-European Transport Network (TEN-T)
Financial conversion feasibility simulation

Methanol MD engine allows to switch between cheapest fuel (MGO/MDO or Methanol)
Example: US$21 million savings 2009-2013
Reflections on fuel prices and attractiveness of solutions

- Global demand for distillates is likely to increase → Price of MGO is expected to increase while price of HFO expected to stay the same
- Methanol price driven by market demand, stable feedstock (NG) price
- Methanol long-term contract pricing lower than spot pricing
- More ECAs can be expected for the future
- IMO – IGF code includes methanol as alternative fuel (next phase)
- Several retrofit solutions for ECA compliance available
Can we tick all the boxes with Methanol?

**Legislation**
- ✔ Emissions
- ✔ Flag State (preliminary)
- ✔ Class Compliance

**Availability**
- ✔ Fuel availability (not used as marine fuel)
- ✔ Technology (pilot project Q1 2015)

**Cost**
- ✔ Capex (calculations, to be confirmed)
- ✔ Opex (calculations, to be confirmed)

✔ Fulfilled
✔ To a great extent
Methanol – the bridge to a GHG free society

The same infrastructure for Shipping and Land transport

BIO-Methanol

* NG-Methanol

CO2-Electrofuel
Carbon Capture and Recycling, CCR

Methanol bunkering NG-Methanol + NG-Methanol is ultimate transition fuel to Production of DME for trucks GHG-neutral Renewable Methanol

Volvo DME trucks

Wärtsilä Methanol Engines

Methanol fuel blending M-15, M-85 or M-100

* “Methanol provides natural gas an entry point to markets where it is currently underutilized ... By any yardstick, methanol is the most attractive carrier for natural gas.”

* Source: Gal Luft - IAGS

NG-Methanol +
Thank you!

• Toni Stojcevski
• +46 706 656115
  toni.stojcevski@wartsila.com
• www.wartsila.com