5th CIMAC CASCADES 2014 at Busan

The Development of UE Dual Fuel Engine (UEC-LSGi)

October 23, 2014
Contents

1. Overview

2. Fuel and Regulation Trend

3. UEC-LSGi

4. Test Result

5. Summary
New generation engine: Low speed / long stroke engine ⇒ Improved FOC (ton/day)

LSE series

LSII Type
L/LA/LS Type
H/HA Type
A/B/C/D/E Type

LSH series

50LSH-Eco
40LSE
33LSE
80LSE-Eco
50LSE
45LSE
35LSE
Eco
Eco
Eco
Eco
Eco

Eco: Electronically controlled engine
We are developing longer-stroke UE engine from small/middle bore size.
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Energy-saving technology is essential due to the fuel price rising. (‘‘2,000 USD/ton’’ age will come.)

Reference: GL research
Trend and estimation of natural gas and oil price (USEIA 2011)

LNG price will be stably low
⇒ However, there are differences between areas
**EEDI regulation**

**EEDI (Energy Efficiency Design Index): Theoretical transport efficiency**

\[
\text{EEDI} \ [\text{g/(ton x mile)}] = \frac{\text{specific CO2 content of relevant fuel} \times \text{SFC} \ [\text{g/kWh}] \times \text{Power} \ [\text{kW}]}{\text{DWT} \ [\text{ton}] \times \text{Speed} \ [\text{mile/h}]}
\]

- **CO2 emission [g/h]**
- **Capacity [ton x mile/h]**

**Depends on ship size**

**EEDI reduction rate [%]**

- Phase 0: 0% (present average)
- Phase 1: 10%
- Phase 2: 15% or 20%*1
- Phase 3: 30%

**EEDI limitation will go up gradually after 1/1/2015**

*1 Reduction rate depends on vessel type

**Table**

<table>
<thead>
<tr>
<th>Ship type</th>
<th>Ship size (DWT)</th>
<th>EEDI reduction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase0</td>
<td>Phase1</td>
</tr>
<tr>
<td></td>
<td>2013/1/1 ~</td>
<td>2015/1/1 ~</td>
</tr>
<tr>
<td>Bulk Carrier</td>
<td>20,000(Z) ~</td>
<td>0</td>
</tr>
<tr>
<td>Container ship</td>
<td>15,000(Z) ~</td>
<td>0</td>
</tr>
<tr>
<td>General cargo ship</td>
<td>15,000(Z) ~</td>
<td>0</td>
</tr>
<tr>
<td>LNG carrier</td>
<td>10,000(Z) ~</td>
<td>0</td>
</tr>
<tr>
<td>Ro-ro cargo</td>
<td>10,000(Z) ~</td>
<td>0</td>
</tr>
</tbody>
</table>
EEDI (Energy Efficiency Design Index): Theoretical transport efficiency

\[
\text{EEDI} \ [\text{g/(ton x mile)}] = \frac{\text{Specific CO2 content of relevant fuel} \times \text{SFC [g/kWh]} \times \text{power [kW]}}{\text{DWT [ton]} \times \text{speed [mile/h]}}
\]

\[
\Rightarrow \text{EEDI reduction possibilities:}
\]

- Speed reduction
- Optimizing vessel & propeller
- Air lubricating system

- De-rated engine
- Waste heat recovery
- Gas fueled engine
- Renewable energy etc.
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## Comparison of DF System

<table>
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<tr>
<th></th>
<th>Premixed DF</th>
<th>Gas Injection DF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Merit</strong></td>
<td>- Low gas supply pressure (5-10bar)</td>
<td>- Robust combustion to fuel gas composition ambient condition etc.</td>
</tr>
<tr>
<td></td>
<td>- Lower NOx</td>
<td>- No methane slips</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Same performance as Oil mode (efficiency, gas temp. etc.)</td>
</tr>
</tbody>
</table>
| **Demerit**   | - Sensitive combustion to fuel gas composition ambient condition etc.  
                ⇒ Load restriction (2 cycle)                       | - High gas supply pressure (250 ~ 300bar)          |
|               | - Lower efficiency in Oil mode                        | - Higher NOx than premixed DF but lower than Oil mode |
|               | - Methane slip (1-2% of fuel gas)                     |                                                   |
|               | - More time to switch from Oil to Gas                 |                                                   |
➢ Dual fuel (Gas & Oil) 2cycle diesel engine
  • Multi-fuel operation of Gas (SOx-free) and Oil

➢ Direct injection combustion (GI system)
  • High combustion stability through all load range
    ⇒ Free from knocking
    (No restriction of ambient and operating condition)
    ⇒ No influence of gas composition (methane number)

  • No unburned fuel gas and No methane slip
    ⇒ Lower Greenhouse Effect than other types of gas engines
Outline of UEC-LSGi (Concept)

➢ Flexible and optimum operation both with Gas and Oil supported by full electrically controlled engine based on UEC Eco-engine

➢ Secure designs for high pressure gas
  • advanced combustion diagnosis
  • reliable leak gas detection and inert gas purge system

➢ Simple and high reliability designs

➢ Equivalent engine performance (comparing with Oil)
  ⇒ Retrofit is also available.

➢ NOx Tier-III regulation
  ⇒ with SCR or EGR
Gas combustion technology was already studied and evaluated in 1986 by using the RTA84M-DF, which was designed by MHI’s own technology.
Outline of UEC-LSGi

<System outline of UEC-LSGi>

- Consist of LNG HP supply, HP driver oil line and Ventilation/Safety system

LNG lines (supply, return) are double-wall pipe. The internal of double-wall pipe is ventilated to outside of engine room.
Outline of UEC-LSGi (Design Development)

Plan for 4UE-X3

Blue parts: Diesel origin
Yellow parts: Gas addition

Gas parts overview

Gas Injection Valve
Gas Gate Valve
Gas Accumulator Block
High pressure LNG line
Valve drive oil line
Purge gas line
Development of UEC-LSGi (Gas Injection Valve)

GIV overview

- Gas Injection Valve
- Gas Gate Valve
- Gas Accumulator Block
- Valve drive oil line
- High pressure LNG line
- Purge gas line
Development of UEC-LSGi
(Test bench of Gas Injection Valve)

Gas Accumulator Block (GAB)

Gas Injection Valve (GIV)
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Gas Accumulator Block (GAB)
Gas Gate Valve (GGV)
Gas Injection Valve (GIV)

Combustion test (220h) and valve durability test (6,000h) have already finished!!
<Summary>

- At 75% load, thermal efficiency is almost same, NOx and CO₂ are slightly reduced. (between Diesel mode and Gas mode)
- Adequate response for load variation (60% ~ 80%) considering the rough weather condition

⇒ Now under developing, commercial engine will be marketed in 2017.
We confirmed the ability of Gas mode operation at 1% pilot fuel oil, now durability is under evaluation.
UEC-LSGi High Pressure LNG Supply System

High Pressure LNG Supply System (Test Plant)
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According to rising fuel oil price, there are possibilities that LNG’s competitive advantage will rise up relatively.

We are developing Gas Injection Dual Fuel system utilizing knowledge of fuel oil diesel engine and past test results.

GI system has merits that equivalent engine performance comparing with fuel oil diesel engine and no methane slip. For compliance with Tier Ⅲ, EGR or SCR will be combined.

Mitsubishi’s UEC-LSGi can perform stable combustion, emission decreased and good dynamic characteristic.

⇒ Aiming for higher performance gas injection system, under developing and evaluating further
Thank you for your attention!!