Mitsubishi UE Engine Updates
New UEC LSH-Eco Series and Service Results

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MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.
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New UE Engine Line-Up

e.g. 6 UEC 50 LSH - Eco - C 2 - EGR

- Tier III technology:
  (blank) Tier II
  EGR: Low Pressure EGR
  SCR: Low Pressure SCR

- Version number:
  1: Standard version
  2: Low-SFOC version

- BMEP number:
  A: 20bar
  B: 21bar
  C: 22bar or more
  (blank): less than 20bar

- Eco: Electronically controlled engine
  (blank): Camshaft controlled engine

- Development code: LSII, LSE or LSH

- Bore size in cm

- Brand name: Uniform scavenging
  Exhaust gas turbocharged
  Crosshead type

- Number of cylinders:
Production Records latest LSE & LSH series

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Ordered</th>
<th>Delivered</th>
<th>1st set in service</th>
</tr>
</thead>
<tbody>
<tr>
<td>UEC60LSE</td>
<td>28</td>
<td>18</td>
<td>2008. 6 (2014.10 Upgrade)</td>
</tr>
<tr>
<td>UEC45LSE</td>
<td>234</td>
<td>195</td>
<td>2008.12 (2014.3 Upgrade)</td>
</tr>
<tr>
<td>UEC35LSE</td>
<td>4</td>
<td>1</td>
<td>2014. 6</td>
</tr>
<tr>
<td>UEC33LSE</td>
<td>13</td>
<td>3</td>
<td>2014.12</td>
</tr>
<tr>
<td>UEC50LSH</td>
<td>21</td>
<td>1</td>
<td>2015. 9</td>
</tr>
</tbody>
</table>

Number of order and manufacturing of latest series are increasing steadily.
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Development concept of UEC50LSH-Eco-C2

- Researched and analyzed thorough market needs.
- The UEC50LSH-Eco-C2 is one of the best engine satisfying worldwide needs.
Development concept of UEC50LSH-Eco-C2

1. Lower daily fuel oil & cylinder lubricating oil consumption
2. Wide rating field
3. Compact engine size
4. Reliable structure

6UEC50LSH-Eco-C2
Lower SFOC and high performance

- Improved trade-off relationship between SFOC and NOx by optimized fuel injection rate
- Reduced mechanical loss by optimized configuration of running parts

<table>
<thead>
<tr>
<th>Engine type</th>
<th>6UEC50 LSE -Eco-B1</th>
<th>6UEC50 LSH -Eco-C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore</td>
<td>mm</td>
<td>500</td>
</tr>
<tr>
<td>Stroke</td>
<td>mm</td>
<td>2,050</td>
</tr>
<tr>
<td>Stroke / Bore</td>
<td>-</td>
<td>4.1</td>
</tr>
<tr>
<td>Rated output</td>
<td>kW</td>
<td>10,500</td>
</tr>
<tr>
<td>Engine speed</td>
<td>min⁻¹</td>
<td>124</td>
</tr>
<tr>
<td>BMEP</td>
<td>bar</td>
<td>20.0</td>
</tr>
<tr>
<td>Piston speed</td>
<td>m/s</td>
<td>8.50</td>
</tr>
<tr>
<td>SFOC</td>
<td>g/kWh</td>
<td>167</td>
</tr>
<tr>
<td>under IMO-NOx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>regulation Tier2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With 5% tolerance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Improved trade-off relationship between SFOC and NOx by optimized fuel injection rate
- Reduced mechanical loss by optimized configuration of running parts
Wide rating field

- Cover various ships by its wide rating field
- Contribute to flexible planning for shipyards
Comparison of SFOC Curve

SFOC of UEC50LSH-Eco-C2 is lower than competitor’s engines at all load.

MR: 8,1000kW × 89 min⁻¹
Various analysis and past technical know-how are used to achieve compact and light design against longer piston stroke.

UEC50LSH-Eco engine was designed so as to be replaced easily by same footprint and compact outline.
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Principle Structure

- **New concept Eco system**
  - SFOC reduction by new ECO system

- **3 FOVs per cylinder**
  - More uniform combustion
  - Zero-sac FOV
  - Higher reliability by reduction of HC

- **Bedplate & Column**
  - High stiffness and light weight

- **Proven design by existing LSE-series**

- **New design for 50LSH**

- **Higher reliability**
  - For
    - Exhaust valve
    - Piston
    - Piston ring
    - Cylinder liner

- **A-ECL system**
  - Reduction of running cost by lower cylinder oil consumption

- **Main bearing & Crankpin bearing**
  - Improved fatigue strength by aluminum metal
Main structure

- Stiffness and weight of these structures were optimized by FEM and EHD analysis.

- Cylinder jacket is highly stiff and light weight by optimized shape

- Highly stiff single wall structures are applied to bedplate and column

- Less deformation of bedplate thanks to twin stay tie bolt on top of bearing girder

FEM model

EHD* result of main bearing

*EHD : Elastohydrodynamic Lubrication
The strength and heat condition of combustion chamber were analyzed by FEM and Heat analysis.

- Nimonic exhaust valve (Standard)
- New heat-resistant material type is available.
- Piston is bore cooling type with high top land
- Temperature is controlled by bypass line of jacket cooling water
- Cylinder liner is non bore cooling type
- Well-proven A-ECL* system
  *A-ECL: Advanced Electronically Controlled Lubricating system
Latest design concept against low temperature corrosion

- Optimized cylinder liner temperature by adjustable cooling system and insulation bandage depends on engine rating.
- Optimized position and number of lubricating point on cylinder liner.
- Improved lubricating efficiency by applying Cr-Ce piston ring and plateau honing cylinder liner.
- New recommendation for operation
  - To increase JCW outlet temperature from 85 deg C to 90 deg C.
  - To use BN100 for cyl. lub. oil for S>1.5%
Cylinder liner

- Insulation bandage is applied at upper part to keep appropriate temperature against slow steaming operation.
Loop cooling can control liner temperature to avoid low temperature corrosion.

Optimum specification can be applied for every engine in the rating map.
Fuel injection rate control

Fuel injection rate is controlled by differences of main valve’s opening timing

Fuel injection rate control improves trade-off relationship of NOx emission and FOC.
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World-first 6UEC50LSH-Eco-C2 engine

- Engine builder: Kobe Diesel CO., LTD.
- Shop test: March 3rd, 2015
- Sea trial: July 27th - 28th, 2015
- In-service: Sept. 8th, 2015
- Total running hour: Approx. 4,000h (As of May, 2016)
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Performance result

- Confirmed to meet expected performance.
- NOx emission is within Tier2 regulation

Corrected to ISO condition
Sufficient reliability was confirmed due to lower mean & fluctuating stress for every points.

<table>
<thead>
<tr>
<th></th>
<th>Mean stress [MPa]</th>
<th>Fluctuating stress[MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 100% load</td>
<td></td>
</tr>
<tr>
<td><strong>Column</strong></td>
<td>3.92 ± 2.94</td>
<td>6.86 ± 3.92</td>
</tr>
<tr>
<td><strong>Bed plate</strong></td>
<td>-58.8 ± 16.7</td>
<td>4.90 ± 13.7</td>
</tr>
<tr>
<td></td>
<td>4.90 ± 13.7</td>
<td>30.4 ± 43.1</td>
</tr>
<tr>
<td></td>
<td>-71.6 ± 18.6</td>
<td>-64.7 ± 17.7</td>
</tr>
</tbody>
</table>

- Sufficient reliability was confirmed due to lower mean & fluctuating stress for every points.
Temperature measurement result of combustion chamber

At 100% Load
(6,870kW x 94 min⁻¹)

- Temperatures are within design limit for every point.
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The cylinder lubricating oil feed rate has been reduced successfully according to the guideline of UE engine.

Sulfur content of using fuel: 2.06 ~ 3.38%

- Cylinder lubricating oil feed rate
- Sulfur content of using fuel: 2.06 ~ 3.38%
Inspection Result of Piston, Ring, & Liner (TRH: 3,091hrs)

- Running surface of all cylinder liners are in good condition.
- No low temperature corrosion was observed because honing mesh is still left around TDC position.
- Wear rate of all piston rings is significantly low.
- Iron content in cylinder drain oil is also stably low.
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Compliance with IMO-NOx Tier III regulation

- Mitsubishi UE engines can comply with IMO-NOx Tier III regulation with EGR or SCR.

- UEC50LSH-Eco is completed application design of LP-EGR system.
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Conclusion of New UEC50LSH-Eco

- Developed to meet worldwide needs and will contribute to ship owners, ship operators and shipyards to cut operating costs and installation cost.

- Performance and reliability are already proven.

- Experience of excellent operating condition of in-service engine will be fed back to new buildings.

- Ready for complying with IMO-NOx Tier III regulation.
Thanks for your attention.
Your confidence is our goal!