Operational experience of the 51/60DF from MAN Diesel & Turbo

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EETG
Disclaimer

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1. Introduction
2. Performance and behaviour
3. Next steps
4. References
5. Conclusion
### Main Technical Data

<table>
<thead>
<tr>
<th>Number of Cylinders</th>
<th>L:</th>
<th>6, 7, 8, 9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V:</td>
<td>12, 14, 16,18</td>
</tr>
<tr>
<td>Speed</td>
<td>rpm</td>
<td>500</td>
</tr>
<tr>
<td>Cylinder Output</td>
<td>kW/cyl.</td>
<td>975</td>
</tr>
<tr>
<td>Bore / Stroke</td>
<td>mm</td>
<td>510 / 600</td>
</tr>
<tr>
<td>Power Range (at 514 rpm)</td>
<td>kW</td>
<td>6.000 – 18.000</td>
</tr>
</tbody>
</table>
Overview of 51/60DF components

The 51/60DF is based on the approved 48/60 engine with additional components:

- Turbo charger
- Intercooler
- Double wall gas piping
- Rocker arm
- Rocker arm casing modified
- Main fuel injection system
- Piston & line
- Connecting rod
- Crankcase
- Crankshaft
- Exhaust gas manifold
- CR Pilot fuel injection system
- Cylinder head
- Water jacked minor modification
- Camshaft
- Pressure relieve valve
- Main & connecting rod bearing
- Oil pan
Cross Section

- Double wall gas pipe
- Gas valve arrangement
- Rocker arms
- Charge air manifold
- Gas flow control pipe
- Main fuel injection nozzle
- Pilot fuel injection nozzle
- Main fuel injection pump

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Further additional components

- Pilot fuel injector for Common-Rail
- Air / fuel ratio control flap
- Elec. Common-Rail Pump
- Pressure Relief valve
- Elec. Gas valve
- Knocking Sensor/Control
- Elec. actuator
- L51/60DF
- Phase Pick Up
Diesel mode

99% Main fuel nozzle

MDO (DMA, DMB)
HFO

< 1% Pilot fuel nozzle

MDO (DMA, DMB)
Gas mode

99% Gas admission valve
Natural gas (vaporized LNG)

< 1% Pilot fuel nozzle
MDO (DMA, DMB)
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**Validation Field test**

<table>
<thead>
<tr>
<th>engine type</th>
<th>12V51/60DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant output</td>
<td>11.4 MW</td>
</tr>
<tr>
<td>Location</td>
<td>Portugal</td>
</tr>
<tr>
<td>Dual Fuel start up</td>
<td>May 2008</td>
</tr>
<tr>
<td>Gas operating hours</td>
<td>14000</td>
</tr>
<tr>
<td>Availability</td>
<td>97%</td>
</tr>
</tbody>
</table>

**Solved items:**
- inlet and outlet valve ware
- untight pressure relief valves

**Positive items:**
- 15000 op. hours with the first pilot fuel equipment
Validation Field test
174,000 m³ LNG Carrier

<table>
<thead>
<tr>
<th>No. and engine type</th>
<th>5 x 8L51/60DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant output</td>
<td>40 MW</td>
</tr>
<tr>
<td>Fuel</td>
<td>Gas (NBOG, FBOG), MDO, HFO</td>
</tr>
<tr>
<td>Commercial operation</td>
<td>2010</td>
</tr>
<tr>
<td>MAN's work scope</td>
<td>engines and auxiliary equipment</td>
</tr>
<tr>
<td>Operating hours</td>
<td>9000/engine on gas and HFO</td>
</tr>
</tbody>
</table>

Solved items:
- Contamination Gas pipes
- Filtration Pilot fuel
- Operation MN70-MN100

Open item:
- Gas valve wear

Positive items:
- >8000 op. hours with the first pilot fuel equipment
Gas / Liquid mode transfer

- **Load**
  - 110% / 1100kW/cyl.
  - 100% / 1000kW/cyl.
  - 15% / < 24 hrs
  - 7% / < 30 min.
  - 0% /< 30 min.

- **Transfer**

- **Graphs**
  - Engine speed
  - Gas duration
  - Diesel index
  - 100% Diesel
  - Change over
  - 100% Gas

- **Trip**

- **Legend**
  - % Gas
  - Gas mode
Operating profile

- Round Trip app. 40-48 days
- Main target: to operate the engines on gas (NBOG and FBOG)
- Average operating hours:
  - Total: 9900 / engine
  - Gas operation: 7700 / engine
  - HFO operation: 2200 / engine
- Engine load in normal operation 75% up to 90%
- Manoeuvring and port operation in Gas mode
Boundary condition Gas

Change of gas composition during a round trip:

Cargo gas: Methane No. 76

- Methane No. Up to >100 during Laden voyage and down to 65 during Ballast voyage
- Heat value 32000kJ/km³ @ MN100 up to 41600 kJ/m³@ MN65

Target: Run the engine at 100% load on gas with MN 70 up to 100

=> new TC matching necessary

=> impact in efficiency of 0.2% points
Gas Quality Laden voyage

20 Days

10,95% N2
86,83% CH4
0,22% C2H6
-> MZ 102

4,96% N2
95% CH4
0,03% C2H6
-> MZ 101

N2, MethaneConc, EthaneConc
Gas quality Balast voyage

20 Days

1.53% N2
97.52% CH4
0.85% C2H6
MZ 96

1.16% N2
88.61% CH4
10.24% C2H6
MZ 79

Worst case:
1.43% N2
83.21% CH4
15.36% C2H6
MZ 73.2
Transfer HFO / Gas operation

- Transfer HFO operation to Gas operation in the range of 15% up to 100% Load with out cleaning with MDO always possible.
- SaCoS one with integrated cleaning algorithms to clean up the combustion chamber.
Performance and behaviour

- Challenge for Gas supply system: QCO of one or more engines. Gas pressure fluctuation in the range of 0.5 bar due to the volume of gas pipe between compressor and GVU. No impact on the other engines.
- No indication of load hunting (swinging), stable load on each engine.
- Cleaning of combustion chamber after HFO operation takes 10 min up to 60 min depending on duration of HFO operation.

- Instant load application in the range of the released data’s for Gas and Diesel operation.

[Graph showing load application vs base load.
Main outstanding targets

- Contamination and plugged Pilot fuel filter with DMB fuel
- TBO of Gas valves
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Controllable-Pitch Propeller Curve

- Load limit
- Recommended combinator curve
- Zero thrust

Range I

Range II

Gas mode

Liquid fuel mode
Fuel sharing capability

- Overload operation
- Continuous operation

Engine Load [%] vs Amount of liquid fuel [%]

Gas + Liquid Fuel

Fuel sharing blocked
Influence of Fuel sharing

\[ \eta_e [\%] \]

\[ \Delta = 1 \% \eta_e \]

\[ \text{Liquid fuel rate [% total energy]} \]

\[ \text{NO}_x [\text{g/kWh}] \]

\[ \Delta = 2 \text{ g/kWh} \]

\[ \text{Liquid fuel rate [% total energy]} \]
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# References 51/60DF

<table>
<thead>
<tr>
<th>Customer</th>
<th>Engine type</th>
<th>Operating hours</th>
<th>Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empresa Naviera Elcano / Spain</td>
<td>5 x 8L51/60DF</td>
<td>9900/engine</td>
<td></td>
</tr>
<tr>
<td>Wykes /England</td>
<td>1 x 7L51/60DF</td>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>T M G / Portugal</td>
<td>1 x 12V51/60DF, retrofit 12V 48/60</td>
<td>15000</td>
<td></td>
</tr>
<tr>
<td>Ibiza / Spain</td>
<td>2 x 18V51/60DF, retrofit 18V 48/60</td>
<td></td>
<td>2011-2012</td>
</tr>
<tr>
<td>Breitener / Brazil</td>
<td>1 x 18V51/60DF</td>
<td>10000</td>
<td></td>
</tr>
<tr>
<td>Sovcomflot / Russia</td>
<td>2 Ships 8L+2x 9L 51/60DF</td>
<td></td>
<td>2013</td>
</tr>
<tr>
<td>EDF / France</td>
<td>7 x 18V51/60DF</td>
<td></td>
<td>2013</td>
</tr>
<tr>
<td>Karadeniz / Turkey</td>
<td>24 x 18V51/60DF</td>
<td></td>
<td>2011-2013</td>
</tr>
<tr>
<td>Gabun</td>
<td>2+2 x 18V51/60DF</td>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>Power and Water / Australia</td>
<td>3 x 12V51/60DF</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>
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100% Load operating with a Fuel gas in the range of MN100 down to MN70 is possible

An additional functionality has been applied to SaCoS one with realise a direct transfer from HFO to gas operation

Cleaning of combustion chamber after HFO operation takes 10 min up to 60 min

No indication of load hunting (swinging),

Instant load application in the range of the released data’s for Gas and Diesel operation
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