Kappel Propellers and Other Efficiency Improving Devices

Presentation by MAN Diesel & Turbo
Agenda

- EEDI aspects in general
- Various efficiency improving devices
- The Kappel propeller concept
- Customised rudder bulbs
The Environmental Focus

Propeller efficiency: 50-70%

Mechanical output: 48.5%

Energy in fuel: 100%

Exh. gas: 25.1%

Charge air cooling: 17.8%

Jacket water cooling: 4.8%

Lub. oil cooling: 3.2%

Radiation: 0.6%

IMO Tier I – III regulations

EEDI
\[
\frac{\text{CO}_2 \text{ emission}}{\text{Benefit of the ship}}
\]

\[
\frac{\sum P \times C_F \times SFC}{\text{Capacity } \times \text{Speed}}
\]
EEDI - Calculation

\[
\text{EEDI} = \frac{\sum_{j} (\Sigma P_{ME} \times C_{FME} \times SFC_{ME}) + P_{AE} \times C_{FAE} \times SFC_{AE} + (\prod_{j} (\Sigma P_{PTI} - \Sigma f_{eff} \times P_{AEeff}) \times C_{FAE} \times SFC_{AE} - \Sigma f_{eff} \times P_{eff} \times C_{FME} \times SFC_{ME})}{f_i \times \text{Capacity} \times V_{ref} \times f_w}
\]

- **CO}_2 emission**
  - Main engine - PTO
    - Ref: 75% \(\times (P_{SMCR} - P_{PTO})\)
  - Auxillary engine
    - Ref: 2.5\% \times P_{MCR} + 250 kW
  - Power Take In
    - Ref: 75% PTI
- **CO}_2 reduction**
  - WHR or similar
    - Electrical
  - Wind, Solar …
    - Mechanical

\(P_{MCR}\) and \(P_{PTO}\)
Plant Optimisation Considering EEDI

**Today**
- Yard focus: Keep the guaranteed **trial speed** / bollard pull
  At lowest possible initial costs
  Engine power/type is typically **preselected**
- Owner focus: Low operational costs.
  Performance at **design speed**
- General improvement in propulsive eff. = lower OPEX

**Tomorrow?**
- Design focus: Achieve required EEDI index
  Optimise on the basis of the rules
  More complex propulsion systems
  Involve suppliers more in the design/solutions
- Improvement in propulsive eff. = **lower engine power** installed
Efficiency Improving Solutions

- Propeller inflow
- Improved lines
- Pre swirl fins
- Propeller
- Smaller hubs
- Mewis ducts
- Larger diameters
- Schneekluth nozzle
- Pre swirl fins
- Kappel blades
- Integrated bulb/rudder
- Integrated bulb/rudder caps (PBCF)
- Post swirl fins
- High lift nozzles
- Counter rotating propellers
- Vortex generators
### Efficiency Improving Solutions (EIS)

#### Table showing effects from combinations of EIS

<table>
<thead>
<tr>
<th>SOLUTIONS</th>
<th>Post swirl fins</th>
<th>Rudder bulb</th>
<th>Kappel</th>
<th>PBCF</th>
<th>AHT Nozzle</th>
<th>Mewis Duct</th>
<th>Pre Swirl Fins</th>
<th>Eff. rudders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post swirl fin</td>
<td>2-3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rudder bulb</td>
<td>2-5%</td>
<td>3-5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kappel propeller</td>
<td></td>
<td></td>
<td>2-5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PBCF</td>
<td></td>
<td></td>
<td></td>
<td>2-5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHT Nozzle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6-8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mewis Duct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre swirl fins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3-5%</td>
<td></td>
</tr>
<tr>
<td>Efficiency rudders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2-4%</td>
</tr>
</tbody>
</table>

**Note:** Claimed efficiency gains vary much from source to source and also from project to project.
Customisation & Verification

There are no off-the-shelf products.

Efficiency Improving Devices must all be designed for the specific vessel and its operating profile.

Verification by CFD and model tests.
Tip Fin and Winglet Applications

Tip vortices are formed due to the difference in pressure between the pressure and suction side of the profile as the flow will move from the region of high pressure to the region of low pressure.
The Kappel Concept

Prof. J.J. Kappel was the first to develop a method to calculate "winglets" on ship propellers – together with the Technical University of Denmark.

MAN Diesel & Turbo has now acquired the rights and knowhow for the concept.
Kappel Propeller Tip Fin Efficiency

- The pressure on both sides near the tip will therefore equalise and the efficiency of the tip region will decrease.

- The Kappel propeller minimises the flow over the tip, and the outer region of the Kappel propeller therefore retains a high efficiency increasing the total efficiency of the Kappel propeller compared to conventional propellers.
Winglets / Kappel Principle
M/S Nordamerika
Comparative Full-Scale Results
Fuel Savings and Low Noise
Innovative Kappel propeller designs

Nature of optimisation parameters:

• Lower speed and larger propeller diameter
• Larger diameter and fewer propeller blades
• Lower pressure impulses and smaller clearance to the ship's hull – offer the deployment of a larger propeller.
FP Propeller and Low-speed Engines
Layout and Load Diagram

- M: Specified engine MCR
- Line 1: Heavy propeller curve, fouled hull and heavy seas
- Line 2: Propeller curve with 5% light running
- Line 3: Engine speed limit
- Line 4: Extended speed limit, provided torsionals permit
- Line 5: Engine load limit diagram

Engine shaft power, % of M
Engine speed, % of M

Improved propeller efficiency
Reduced engine SFOC
Reference Case
Model testing: Kappel vs Conventional FPP

<table>
<thead>
<tr>
<th>Project: Container vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel service speed</td>
</tr>
<tr>
<td>Design draft</td>
</tr>
<tr>
<td>Engine type</td>
</tr>
<tr>
<td>Engine power</td>
</tr>
<tr>
<td>Engine speed</td>
</tr>
<tr>
<td>Max. propeller diameter</td>
</tr>
<tr>
<td>Number of blades</td>
</tr>
</tbody>
</table>

*) Above conditions were fixed when MAN Alpha entered the project
Reference Case

Results from model testing

Self propulsion tests carried out at SVA Potsdam in October 2011

<table>
<thead>
<tr>
<th>Project: Container vessel</th>
<th>MAN Alpha</th>
<th>Competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propeller design (FPP)</td>
<td>Kappel</td>
<td>Conventional</td>
</tr>
<tr>
<td>Propeller diameter</td>
<td>6,4 m</td>
<td>6,59 m</td>
</tr>
<tr>
<td>P/D ratio</td>
<td>1,099</td>
<td>?</td>
</tr>
<tr>
<td>Blade area ratio</td>
<td>0,5875</td>
<td>?</td>
</tr>
<tr>
<td>Improvement at design draft</td>
<td>1,2-3,5% *</td>
<td>-</td>
</tr>
<tr>
<td>Improvement in ballast draft</td>
<td>1,4-4,0% *</td>
<td>-</td>
</tr>
</tbody>
</table>
Reference Case

Results from model testing

Cavitation tests carried out at SVA Potsdam in October 2011

<table>
<thead>
<tr>
<th>Pressure impulses</th>
<th>MAN Alpha</th>
<th>Competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; order</td>
<td>0.6 kPa</td>
<td>1.6 kPa</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; order</td>
<td>0.1 kPa</td>
<td>1.0 kPa</td>
</tr>
</tbody>
</table>
Reference Case
Further potential with Kappel propeller

Further improvement potential exists with the Kappel propeller compared to conventional propellers as the diameter can be increased. 2 scenarios can be calculated.

<table>
<thead>
<tr>
<th>Scenario 1: Reduce number of blades from 5 to 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappel propeller diameter increase app. 300 mm</td>
</tr>
<tr>
<td>Propeller efficiency increase by further</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2: Select engine which offers lower rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum rpm of a 6,6 m Kappel propeller is</td>
</tr>
<tr>
<td>Propeller efficiency increase by further</td>
</tr>
</tbody>
</table>
Kappel Propeller Optimisation

Optimum RPM for a given power and propeller diameter

- Conventional propeller
- Kappel Propeller
- Kappel propeller – lower blade no

Relative diff. 3-5%

Optimum Kappel rpm 5-15% lower
The reduction in propeller rpm for the Kappel propellers (compared to conventional propellers), depends on the thrust loading coefficient ($C_{th}$).
Optimising Propeller Diameter

Clearance depends on:
- Wakefield
- Propeller load
- Amount of skew
- Nos of blades
- Type of propeller

Clearance can be related to a pressure impulse level measured in [kPa]
Fuel Savings from Kappel Efficiency Improvement examples

- Engine output, specified MCR: 10 000 kW
- Average engine load: 80%
- Operating hours per year: 6 000
- Fuel price (USD/ton): 650
Rudder bulbs

Optimisation in the past

- Optimised in model basins on a “trial and error” basis
- Often handled by the yard with little interaction to propeller maker
- Limited improvements
New Approach with CFD Optimization

- **MAN Alpha** have developed a CFD optimisation routine
- The rudder bulb solution is customized to each individual project
- We optimize bulb shape, rudder maker optimize rudder aspects
- Can be verified at model tests—both in self-propulsion and cavitation tests
- **MAN Alpha** scope of supply:
  - CFD optimization of bulb
  - Fairing cone mounted on the propeller hub
The DFDS RoRo Project

2 x 3000 LM RoRo Vessels

Owner: DFDS, Denmark
Yard: P+S Werften, Germany

NB500 / 501

M.E.: 2x8S40ME-B9.2
2 x 9.080 kW @ 146 rpm

CPP: 2 x VBS1350 / AT2000

Aux.: 3 x L16/24

Special features

- 2 x VBS1350 with full feathering capabilities
- 2 x Becker Marine System twisted rudders
- Investigations on optimised rudder bulbs
Self-propulsion Test at HSVA
Result from Self-propulsion Test

Annual fuel oil savings > 250,000 €
Pay back time < 4 months
Propeller Cavitation Test

Propeller induced pressure impulses as low as 1,58 kPa
Full Feathering CPP with Fairing Cone for Rudder Bulb
Thank you for your attention

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