RoRo Ship Optimization

A  Definitions
B  General Information and Optimization Targets
C  Economy of Scale and Speed
D  Optimization of Hull and Propulsion
E  Optimization of Machinery and Components
F  Trim Optimization
G  New Rules
H  Conclusion
Definition >> Optimization <<

Optimization is „the process of finding function extrema to solve problems“

To optimize a structural design, you would want a design that is both light and rigid.

Because these two objectives conflict, a trade-off exists. There will be one lightest design, one stiffest design, and an infinite number of designs that are some compromise of weight and stiffness.
Definition >> RoRo <<

RoRo “Roll on – Roll off” will here be used for trailer vessels.

StoRo “Rolled Cargo to be stowed” will here be used for vessels where the cargo rolls on board and needs to be stowed and secured.

RoPax “RoRo with Passengers” will here be used for vessels with more than 12 Passengers like ferries.

All these types of RoRo vessels have different optimization targets!

This presentation will focus on the “RoRo” vessels for trailers.
RoRo Ship Optimization

Topics

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H Conclusion
Speed – Power and Speed – Fuel Curves

Speed – Power - Curve  ➔  SFOC - Curve  ➔  Speed – Fuel - Curve
Cost derivation in shipping

Percent of annual costs for RoRo – Vessels of abt. 2000lm in 2010

- Total ship costs: 100%
  - Fixed operating: 21.9%
  - Voyage related: 46.3%
  - Capital cost: 31.8%

- Fuel: 44.5%
- Lubricants/consumables: 1.8%
- Cost of passage: Tbd
- Cost in port: Tbd
- Other: Tbd

- Crew: 13.0%
- Maintenance & Repair: 3.3%
- On-shore admin: 2.6%
- Insurance: 2.2%
- Classification: 0.8%
- Other: Tbd
RoRo is Short Sea Shipping

General Voyage Examples

Voyage A: 160nm
8h at sea
6h at port = 43%

Voyage B: 590nm
29.5h at sea
6h at port = 17%

Voyage C: 1560nm
78h at sea
6h at port = 7%

@ harbour time = constant
@ speed = constant 20kn

Where optimization makes sense
RoRo is Short Sea Shipping

General Voyage Examples

Voyage A (short):
A Port-Time-Optimization of 10% leads to a speed reduction 1.4kn and a fuel reduction of 25%

Voyage B (medium):
A Port-Time-Optimization of 10% leads to a speed reduction 0.4kn and a fuel reduction of 9%

Voyage C (long):
A Consumption-Optimization for main engine and auxiliaries creates a possible benefit
Ramp Arrangement Alternatives

Variant of lowest installation, maintenance and building costs.

Best variant for long voyages.
Ramp Arrangement Alternatives

By upgrading the internal ramps by a hoistable double ramp to weather deck the port time could be reduced.

Extra costs about 5-10% of newbuilding price.

Possible savings due to shorter port time up to 25%.

Total savings up to 7%
Ramp Arrangement Alternatives

By upgrading the shore arrangement with a second level the port time can be reduced significantly!

Savings on board about 2% of newbuilding price for deleting the internal ramp.

Additional possible savings due to shorter port time up to 25%.

Total savings up to 12%
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Economy of Scale and Speed

What is slow steaming?

What is optimized speed?

Cost per 1000 lane-meter-miles incl. fuel, lub, running expenses, manning, financial. (excl. port and harbor costs)

Savings of about 1/3 appear defining an optimal speed for a liner service.
Optimization Hull
Same Purpose – same Speed – same “optimized” hull ???

FutureShip Consulting | 20/05/2011 | No. 16
Optimization Hull

Traditional lines development
- Open drawer
- Select similar ship
- Adjust dimensions
- Some selected CFD
- Model testing
  - Bossing
  - Rudder configuration
  - Propeller position
- Done!

Variations looked at < 10
Optimization Hull

\[ a^2 + b^2 = c^2 \]

\[ E = m \cdot c^2 \]

Equation of kinetic energy
and
gravity
+ friction of water and shell

Navier-Stokes-Equation

\[- \nabla p + \mu \left( \nabla^2 \vec{u} + \frac{1}{3} \nabla (\nabla \cdot \vec{u}) \right) + \rho \vec{F} = \rho \left( \frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} \right)\]

STILL IMPOSSIBLE TO CALCULATE!  \( \rightarrow \) Simplifications: Potential Method or RANSE
Optimization Hull - Systematic / Formal optimization

Parametric hull model definition
CFD Analysis and variants generation
Exploration/Exploitation (>> 10,000 Variants)
Optimization Hull - Systematic / Formal optimization
Optimization Hull - Exploration of design space

Each single red cross represents a full hull design and analysis approx. 20,000 valid designs.

Point of Contract

Lower Resistance - >>10%

Database: Pareto-Optimization (NSGA II) @ draft = 14.5 m, ship speed = 22.2 kn

CV 9000 TEU
Optimization Hull – Comparing Speed Curves

The graph illustrates the comparison between the Basicline and Postmodel in terms of speed versus power. The Basicline operation point is at 8,200 kW with a speed of 0.92 kts, while the Postmodel operation point is at 54,000 kW with a speed of 22.3 kts. The graph shows the relationship between power (PD, PE [kW]) and speed (V [kts]) for the two models.
Optimization Hull - Dynamic hull pressure

What do coloured pictures show you / us?

Some dozen / hundred calculations to compare.
Optimization Hull – Stream Lines

Paint streamline test from model basin and from computation.
Prediction of ship motions and sloshing induced loads in tanks of LNG-Tanker.

Slamming induced loads acting on structures including fluid-structure interaction (springing and whipping effects).
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Engine System Performance Optimisation

Considerations in Conceiving Engine Plant Concepts

- Efficiency of Propulsion Train
- Flexibility of ME and AE Setup
- Optimized utilization levels for ME and AE
- Minimised Fuel Oil Consumption
- Minimised Installation Costs

Engine Plant Concept
Engine System Performance Optimisation

Voyage Example

Could you imaging the savings in the baltic??

Air /Sea [ C]

Design 45/32 C

Cargo Hold Ventilation [kg/Voyage]

<table>
<thead>
<tr>
<th></th>
<th>Real</th>
<th>Delta</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec</td>
<td>3.781</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>192</td>
<td>346</td>
<td>538</td>
</tr>
</tbody>
</table>

Cooling Water Pumps [kg/Voyage]

<table>
<thead>
<tr>
<th></th>
<th>Real</th>
<th>Delta</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec</td>
<td>4.088</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>3.704</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Engine Room Ventilation [kg/Voyage]

<table>
<thead>
<tr>
<th></th>
<th>Real</th>
<th>Delta</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec</td>
<td>9.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>3.920</td>
<td></td>
<td></td>
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</tbody>
</table>
Engine System Performance Optimisation

Examples to make Use of Energy Saving Potentials 1

Flexibilisation of Auxiliary System Structure

Cooling Water Pumps: 3 x 50% instead of 2 x 100%

Automatic Adjustment of Pump Speed

*1) MSB...Main Switch Board, Ctrl...Controller, FC...Frequency Controller
Engine System Performance Optimisation

Examples to make Use of Energy Saving Potentials 2

Flexibilisation of Auxiliary System Structure

ER Vent: 2x50 instead of 1x100%

Automatic Reduction of Fan Speed
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A ship’s trim impacts on overall resistance, thus fuel consumption

Even keel is for operation in design draft at design speed

3 principal trim modes

“Even keel”

“To bow”

“To stern”

Implications

- *Even keel* if minimal draft is required (e.g., rivers)
- *To bow* enhances effectiveness of bulbous bow
- *To stern* enhances propulsion effectiveness

⇒ Optimal trim difficult to assess

- Existing tables often refer to design draft and design speed
- Normally, crews apply stiff rules as learned in nautical studies, e.g. “2-3 feet to the stern”
- Company specific habit established, load planners by adhere to such commonly accepted, traditional rules
ECO-Assistant optimizes the required propulsion power

Trim adjustment proposals for given displacement and at given speed
Extensive simulations to find best trim in various operational conditions

- Individual ship body is transferred into electronic model
- Computational Fluid Dynamics (CFD) is used to assess thousands of conditions in terms of overall resistance in water
- Complex calculations that take several days of grid computing

User Interface for ship personnel

- Data for speed, draft and water depth are entered
- Optimal trim and daily savings are indicated by tool
- Preview impact of ballast water operations

Normal trim: intense colors indicate high resistance

Optimized trim: less intense colors, i.e. less fuel

MV ECO Multi Purpose Vessel

- With extra ballast
- No extra ballast

The ECO-Assistant – leading-edge hydrodynamic simulations
The ECO-Assistant provides ship crews with readily implementable trim-rules
## ECO-Assistant Quick Reference Guide

### How to ensure optimal trim

#### Standard procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ensure that the dongle is placed in the PC before starting ECO-Assistant</td>
</tr>
<tr>
<td>1</td>
<td>Select the target speed for the voyage ahead</td>
</tr>
<tr>
<td>2</td>
<td>Enter departure drafts (direct reading, data from stowage calculator)</td>
</tr>
<tr>
<td>3</td>
<td>Select the appropriate water to sail in</td>
</tr>
<tr>
<td>4</td>
<td>ECO-Assistant indicates the optimum trim, (assuming no additional ballast water needed) and the approximate daily fuel/CO\textsubscript{2} savings</td>
</tr>
</tbody>
</table>

#### If extra ballast water is needed to achieve recommended trim ...

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Enter ballast water (in tons) needed to achieve recommended trim</td>
</tr>
<tr>
<td>B</td>
<td>Tool indicates fuel/CO\textsubscript{2} savings with optimized trim (solid line). If fuel savings from new trim are off-set by additional displacement, the box will turn to red: then re-trimming does not make sense.</td>
</tr>
</tbody>
</table>
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Overview and timeline of maritime environmental regulations

- **0.1% S, SECA**
- **0.1% S, EU ports**
- **1% S, SECA**
- **3.5% S, global**
- **US+CAN ECA active**
- **NOx Tier I, global** (for existing ships)
- **NOx Tier II, global** (for newbuildings)
- **NOx Tier III, ECA**
- **CO2 market measures**
- **CO2 technical measures**
- **Ship Recycling**
- **Ballast water**
- **NOx Tier I** → 17g NOx /kWh
- **NOx Tier II** → -20%
- **NOx Tier III** → -80%
- **review**
- **0.5% S, global**

*) estimated entry into force

Source: GL Strategic Research & Development
Gas as Fuel

For a round trip of 3000nm:

- 590m³ LNG tanks would be required
- Cylindrical tanks with up to -162 °C and 10 bar pressure
- A loss of 70 lane meter
- Due to low LNG prices the running costs decrease by about 40% compared to gas oil prices
- CO₂ and NOₓ emissions are reduced as well.
Gas as Fuel
Scruber Technology

**SOx can also be reduced by means of Scrubber Technology:**

- The installation costs are less that 50% compared with LNG
- The normal HFO can be used
- Additional supply NaOH of about 5% fuel costs
- CO2 and NOx are not reduced.
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Conclusion

Following items could be optimized
(not all to the same time)

- Port times → to reduce ship’s necessary speed and resulting fuel consumption
- Economy of Speed and Scale → to provide the right cargo capacity at minimum fuel.
- Resistance → to reduce necessary power at demanded speed
- Propulsion → to prove the right efficiency factor within the wake field
- Machinery and Systems → to provide flexibility where necessary
- Trim → by using modest simulation methods
- New Fuel / Exhaust Systems → to proof ourselves for future regulation

Savings
(up to)

~25%
~37%
~ 8%
~ 4%
~ 4%
~ 3%
???

Remark:
It is clear understood that several circumstances might reduce possible savings in real voyage conditions as there are:

- Ice conditions
- time schedule of cargo connections
- Investments and port restrictions
Thank you for your participation and attention

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