(Fuel) Efficiency versus Safety in Ship Design

STG´s Ship Efficiency Conference 2009

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Definition of Ship Efficiency/Performance

Efficiency/Performance can be defined based on:
- Cargo capacity
- (Hydrodynamic) Performance on the anticipated route
- Harbour performance
- Investment & Maintenance costs
- Comfort ?!
- Ship & Cargo safety ?!

Boundary conditions which can NOT be influenced include
- Characteristics of the anticipated route (e.g. water depth)
- Restrictions in main dimensions (e.g. harbour restrictions)

Thus there is no universal “Ship Efficiency Index”
Ship performance needs to be compared based on the task!
Sometimes a comparison is easy

The FSG design has the same main dimensions & slightly more cargo capacity

Competitor at 19 knots

ConRo200 at 19 knots

11000 kW

8400 kW
**Design challenge**

**Target:**
RoRo for the Irish sea
2150 lane meters
21 knots
2x 8MW MCR

**Problem**
Main dimension restrictions:
- $L < 142\text{m (Fn = 0.29)}$
- $B < 25 \text{m}$
- $T < 5.2 \text{m}$
- High block coefficient

4 weeks for design work before contract!

**Solution**
Four decks
Extensive wave resistance-and wake field optimization
General Arrangement
Resistance Optimisation

Competitor Design
3-Decks at 21 knots

FSG Design
4-Decks at 21 knots
A better wakefield enables more degrees of freedom in propeller design for

• reduced pressure pulse
• cavitation control
• better efficiency

More details were presented in TUHH/FSG paper by Haack & Vorhölter at IMDC 2009
Reasons for an „extra“ Design-Loop

At this stage the design (over) fulfils all requirements and standards from:

- The specification and contract
- Classification
- IMO (e.g. Intact and Damage stability requirements)

BUT:
The vessel does not pass FSG´s dynamic stability standard and
- Generally „likes to roll“
- The wakefield is still challenging
The current intact stability rules are not sufficient:

- Dynamic Effects are not taken into account
- IMO A.749 based on statistics including vessels mostly <100m; dates back to early 20th century
- Limiting values un-scaled
Evaluation Concept
(Joint development with TUHH-SSI within BMWI research projects SinSee and LaSSe)

Ship Response (Time Series)

Evaluation
safe (0) / unsafe (1)

Statistics
- Course
- Speed
- Environmental Conditions

Evaluation-Index

Threshold Value

For more information:
www.ssi.tu-harburg.de
Assessing the Seakeeping Behaviour by Numerical Simulations

- E4-Rolls: Non-linear sea-keeping simulation
- Delivers the ship response in waves 6 Degrees of Freedom
- Natural Seaway (irregular, short crested waves) modelled by wave spectra (e.g. JONSWAP)
- Flume tanks, stabilizer fins, cargo shift can be considered
- Validated by model tests in various research projects

Model tests on intact stability
BMBF funded project "SinSee"

Test no 141
Capsizing in following seas

Hamburgische Schiffbau-Versuchsanstalt
Technische Universität Berlin
Consideration of operating conditions

Operating Condition:

- Speed
- Wave lengths
- Relative course

$H_{\text{lim}}$
Statistical Analysis

- Area of reference: North-Atlantic
- Assumption course probability: Equal distributed
- Assumption for speed: Linear distribution
- $V_{\text{max}}$ takes into account added resistance

$$\text{ISEI} = \sum \text{Pseaway} \times \text{Pspeed} \times \text{Pcourse}$$

All unsafe operating conditions

Data: DNV
Evaluation Concept
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Ship Response (Time Series) → Evaluation
safe (0) / unsafe (1) → Evaluation-Index → Threshold Value

Statistics
- Course
- Speed
- Environmental Conditions

For more information:
www.ssi.tu-harburg.de
Accident investigation

- ISEI
- IMO GM req.
- Accident

Displacement in t
GM in m

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• ISEI curve represents dynamic stability limit
• More conservative than intact stability rules
• In some situations even stricter than damage stability limit
• Allows for a better representation of roll damping devices
• Included in all FSG stability booklets
Design Goals & Options

Goals:
• Keep Cargo Capacity
• Improve Seakeeping / Dynamic stability
• Improve Wakefield
• Minimize influence on Speed-Power performance

Options:
• Keep hullform and increase roll damping via larger bilge keels and/or fins
• Design new hullform (and GAP!) with better seakeeping and wake characteristics and include a FLUME tank
CFD Analysis

Old

New
Wake Field Comparison

Old

New
Maximum Roll Angle of 30°
For the Initial and the New Design

Wave length = 141m
Wave length = 172m
Maximum Roll Angle of 30°
With and Without Flume Tank

Wave length = 141m
- Flume + Flume

Wave length = 172m
- Flume + Flume

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ISEI-Index Comparison

- Design Load Case
- Riverdance, accident
- Difference in safety due to hull form only
- 746 old
- New hull form Design Load Case
- New hull form + Flume tank

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Design Goal Check

Goals achieved:
- Keep Cargo Capacity
- Improve Seakeeping / Dynamic stability
  - Hullform has better seakeeping characteristics
  - FLUME tank for enhanced cargo safety
- Improve Wakefield
  - Better propeller efficiency
  - Less pressure pulses
- Minimize influence on Speed-Power performance
  (additional 150 kW are necessary)

New Hullform delivers an improved overall hydrodynamic performance!