Deliverable D7.3

*Proceedings of 3rd workshop*

Due date of deliverable: 31-03-2016
Actual Submission date: 05-05-2016

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Dissemination level:

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Status of Deliverable: Draft/Final

Document Reference Number: SHOPERA-D7.3-rev01
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Document History

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<td>28-04-2016</td>
<td>Description and basis of changes</td>
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The third public SHOPERA workshop was hosted by LR and jointly organised by LR, NTUA and ITTC Manoeuvring Committee on April 14, 2016 in London with representatives from the ITTC Seakeeping, Stability and Performance Committees. The aim of this workshop was to communicate the findings from the elaboration of the project to the wider scientific and technical community, to enhance collaboration of the SHOPERA partners with other research teams working on the same or similar research topics in Japan, Korea, The Netherlands as well as with the ITTC Manoeuvring Committee and Seakeeping Committee and to obtain valuable feedback from the external participants regarding the set objectives and the procedures adopted in order to meet these objectives.

State of the Art
The State of the Art was presented by external speakers and by project partners presenting the progress of work during the elaboration of the project, including research on numerical tools, experimental studies, validation of tools and development of criteria.

Value added to SHOPERA
The main added value of the workshop is the communication of the outcome of the project to the wider community of experts and the feedback from external experts regarding the set objectives and the procedures adopted in order to meet these objectives.

Achievements
One-day workshop with 6 presentations by external experts and SHOPERA partners. The workshop was attended by 29 SHOPERA partners, 4 Advisory Committee members and 36 external experts.

Not achieved
N/A

Input from other Deliverables
During the workshop, the outcome of WP1, 2, 3 and 4 was presented.

Exploitation of results
The proceedings of the workshop will be publically available and widely distributed through the project’s web site. The input from the external experts will be exploited during the final phase of the elaboration of the project.
This executive summary may be published outside the SHOPERA consortium. **YES/NO**

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1 Introduction

1.1 Background

The introduction of the Energy Efficiency Design Index (EEDI) was a major step towards improving energy efficiency of shipping and reducing GHG emissions. At the same time, it has raised concerns that ship designers and ship builders might choose to lower the installed power and ship’s speed to achieve the EEDI requirements, instead of optimizing ship’s speed-powering performance. This may lead to insufficient propulsion power to maintain manoeuvrability of ships under adverse weather conditions. The above concerns refer especially to Phase 3 of the EEDI implementation, from 2025-01-01, when the required EEDI is to be reduced by up to 30% compared to present base level (2013). Following a proposal from the International Association of Classification Societies (IACS), the following requirement was added to the Reg. 21, Ch. 4 of MARPOL Annex VI: “For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization.” Work carried out by IACS to develop such guidelines, see MEPC 64/4/13 and MEPC 64/INF.7, served as basis for the Interim Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ship in Adverse Weather Conditions, MSC-MEPC.2/Circ.1 (2012) referring at first to bulk carriers, tankers and combination carriers. Discussions within IMO led to 2013 Interim Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ship in Adverse Weather Conditions, ref. MEPC 65/4/3, Annex 1 (2013), see IMO Resolution MEPC 232(65), valid for Phase 0 and Phase 1 of EEDI implementation (until 2020-01-01).

1.2 Project SHOPERA

To address the challenges of the problem of norming manoeuvrability of ships in adverse conditions, an European research project called SHOPERA (Energy Efficient Safe SHIP OPERAtion, see www.shopera.org), funded by the European Commission in the frame of FP7, was launched in October 2013, aiming at developing suitable methods and tools and systematic case studies which will enable the development of improved Guidelines and their submission for consideration to IMO-MEPC in 2016. A strong European RTD consortium was formed\(^\text{1}\), representing the whole spectrum of the European maritime industry, including classification societies, universities, research organisations and model basins, ship designers, shipyards and ship operators. The project will:

- Validate the proposed adverse weather conditions using data from deep water and coastal areas as well as ship accident databases.

\(^1\)National Technical University of Athens (NTUA, coordinator), DNV-GL, Lloyds Register (LR), Marintek (MRTK), Instituto Superior Tecnico (IST), Univ. Duisburg-Essen (UDE), Registro Italiano (RINA), Flensburg Schiffbau Gesellschaft (FSG), Uljanik Shipyard (ULJ), VTT, Flanders Hydraulics Research (EVFH), CEHIPAR, Strathclyde University (SU), Denmark Technical University (DTU), Tech. Univ. Berlin (TUB), Delft University of Technology (DUT), Naval Architecture Progress (NAP), Danaos Shipping Company Ltd. (DANAOS), FOINIKAS Shipping Co., CALMAC Ferries Ltd.
• Develop and fine-tune existing high fidelity hydrodynamic simulation software tools for efficient analysis of the seakeeping and manoeuvring performance and safety of ships in complex environmental and adverse weather conditions (including the consideration of winds and waves).

• Perform seakeeping and manoeuvring model tests in seaway using a series of prototypes of different ship types to provide the required basis for the validation of employed software tools. Validated software tools for the manoeuvrability assessment of ships in adverse weather conditions will be integrated into a ship design software platform and combined with a multi-objective optimization procedure, looking for sufficient powering and steering requirements for safe ship operation in adverse weather conditions while keeping the right balance between ship economy, efficiency and safety of the ship and the environment.

• Put together design teams that comprise designers, shipyards, owners, classification societies and national administrations to conduct investigations on the impact of the proposed new Guidelines for minimum propulsion power and steering efficiency to maintain manoeuvrability in adverse conditions on the design and operational characteristics of various ship types. The impact of EEDI will be investigated in parallel by implementation of the developed holistic optimisation procedure in a series of case studies.

1.3 Structure of the project
The work is organised into the following work packages:

• WP1 - Environmental Conditions and Requirements for Different Ships provides met-ocean data to validate the proposed adverse weather conditions, defines relevant ship types and sizes, conducts a risk analysis of marine accidents related to manoeuvring in adverse weather conditions and proposes safety criteria to be addressed by the project.

• WP2 - Development and Refinement of Numerical Hydrodynamic Tools performs development and refinement of numerical hydrodynamic tools. It is expected to significantly improve the current state-of-the-art in the scientific field of manoeuvring in adverse weather conditions by improving the capabilities of a series of numerical methods.

• WP3 - Experimental Studies provides experimental data for validation of the tools by performing seakeeping and manoeuvring model tests for a series of prototypes of different ship types to provide the required basis for the validation of numerical methods.

• WP4 - Validation, Sensitivity Studies and Level 1 Methods validates numerical tools using model test data. Selected test cases will be used for an open international benchmark study to evaluate the present state-of-the-art of numerical methods. Simple models of propulsion and steering devices and engine will be developed for the implementation in the numerical simulation tools. Simplified assessment methods (referred to as Level 1 methods) will be developed to reveal the safety margins of ship designs. Intact stability problems will be addressed in a coupled way with manoeuvrability in adverse weather conditions.

• WP5 - Adaptation/Integration of Tools - Multi-objective Optimisation Platform integrates software tools for hydrodynamic assessment of ships in adverse weather conditions into a ship design software platform and sets up multi-objective optimisation procedures to assess ship’s performance holistically,
looking for the manoeuvrability requirements in adverse weather conditions while keeping balance between economy, efficiency and safety.

- **WP6 - Application – Case Studies** conducts investigations on the impact of the proposed new guidelines on the design and operational characteristics of various ship types, by implementation of the developed integrated holistic optimisation procedure in a series of case studies. This will be achieved by putting together teams that comprise designers, classification societies, yards and universities, while operators and ports will provide expertise and data.

- **WP7 - Dissemination, Exploitation, Submission to IMO** disseminates the results of the project to the public, provides for exploitation of the results through submission to IMO of new guidelines for sufficient manoeuvrability in adverse weather conditions, including minimum power and steering performance requirements, and develops exploitation plan for resulting knowledge, numerical tools, software and design methods. Wide dissemination of the project results will be facilitated through technical publications in international scientific journals and conferences.

## 2 Third SHOPERA Workshop

### 2.1 Summary of presentations and discussion

The third public SHOPERA workshop was hosted by LR and jointly organised by LR, NTUA and ITTC Manoeuvring Committee on April 14, 2016 in London with representatives from the ITTC Seakeeping, Stability and Performance Committees. The aim of this workshop was to communicate the findings from the elaboration of the project to the wider scientific and technical community, to enhance collaboration of the SHOPERA partners with other research teams working on the same or similar research topics in Japan, Korea, The Netherlands as well as with the ITTC Manoeuvring Committee and Seakeeping Committee and to obtain valuable feedback from the external participants regarding the set objectives and the procedures adopted in order to meet these objectives.

The participants to the 3rd public SHOPERA workshop were welcomed by Tim Kent on behalf of the hosting organization (LR) and the project manager Apostolos Papanikolaou (NTUA). Besides representatives of the SHOPERA consortium, there were also presenters and participants form the ITTC Committees for Manoeuvring, Seakeeping, Stability and Performance, members of the SHOPERA Advisory committee and other external experts. The objectives of the workshop were presented by Apostolos Papanikolaou, NTUA.

The morning session started with the presentation of Vladimir Shigunov (DNV), who discussed the SHOPERA Proposal for additional Manoeuvrability Criteria addressing three different adverse scenarios: extreme weather in open sea, escaping increasing storm in coastal waters and low speed in restricted areas. Alternative assessment procedures, i.e. comprehensive and simplified (Level 2) were described.

Hironori Yasukawa, (Hiroshima University) presented the Japanese R & D Project on Manoeuvring in Adverse Condition and Minimum Power Requirement of Ships. The main objectives of this Project are the development of numerical models and procedures to address manoeuvring in waves (both time domain and non-time domain) and wave-induced steady forces (added resistance in regular waves, steady lateral force and yaw
moment and wave-induced steady forces in irregular waves), the validation of the manoeuvring model in waves and the development of an analysis method of manoeuvring limit and motion stability in wind and waves.

Yeon Gyu Kim, Dong Jin Yeo (KRISO), Sang Hyun Kim (Inha Univ.) presented current research activities on manoeuvring in waves in Korea. In this respect, objectives and results of six selected papers, published from 2006 to 2015 and two research projects, i.e. *Fundamental research for the analysis of ship’s integrated ability of manoeuvring and seakeeping* (KRISO) and *Development Technology Development to Improve Added Resistance and Ship Operational Efficiency for Hull Form Design* (MOTIE) were briefly presented.

Pierre-Emmanuel Guillerm (Ecole Centrale de Nantes), delivered a presentation on the development of manoeuvring in waves standard for model tests and numerical simulation methods addressing related problems (i.e. course keeping in waves, broaching, turning ability in waves), related IMO criteria, current and future challenges and methodologies to address manoeuvring in waves. Finally, results of related work on broaching at E.C. Nantes were presented and discussed.

Yonghwan Kim (Seoul National University) presented the work in ITTC Seakeeping Committee on Seakeeping Analysis Coupled with Manoeuvring Problem. A series of ITTC SKC Procedures were briefly discussed and emerging problems were identified. The formulation for the Seakeeping-Manoeuvring Interaction was discussed and obtained results on turning trajectories were presented. Effects of Seakeeping and Manoeuvring on Ship Operation Efficiency were discussed, including course keeping, speed loss due to wind and waves followed by suggestion for future collaborative works.

Gregory Grigoropoulos (NTUA) presented a review of regulatory work in IMO regarding the issue of minimum power lines, followed by a brief review of the objectives and results of the JASNAOE project and the SHOPERA project.

### 2.2 List of attendees

#### 2.2.1 SHOPERA partners

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2.2.3 External participants

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<td>Land Rover Bar</td>
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<td>NTUA</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3 List of presentations

1. Vladimir Shigunov (DNVGL), **SHOPERA: Criteria, Assessment Framework, Methods**
2. Hironori Yasukawa, (Hiroshima University), **Japanese R & D Project on Manoeuvring in Adverse Condition and Minimum Power Requirement of Ships**.
3. Yeon Gyu Kim, Dong Jin Yeo (KRISO), Sang Hyun Kim (Inha Univ.) **Research Activities on Manoeuvring in Waves in Korea**.
4. Pierre-Emmanuel Guillerm (Ecole Centrale de Nantes), **How to develop manoeuvring in waves standard for model tests and numerical simulation methods**.
5. Yonghwan Kim (Seoul National University), **Seakeeping Analysis Coupled with Manoeuvring Problem**.
6. Gregory Grigoropoulos (NTUA), **Towards more rational guidelines to determine minimum propulsion power for Safe Operation under adverse Weather Conditions**
3 Workshop Presentations
3.1 Vladimir Shigunov (DNVGL), SHOPERA: Criteria, Assessment Framework, Methods
ITTC-SHOPERA Workshop
London, 2016-04-14

SHOPERA:
Criteria, Assessment Framework, Methods

V. Shigunov, DNVGL, Hamburg, Germany

[2016-04-14, 9:15-9:45 (30 min.)]
### SHOPER Proposals for Additional Manoeuvrability Criteria: Summary

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Functional Requirements</th>
<th>Practical Criteria</th>
<th>Environmental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme weather in open sea</td>
<td>Weather-vaning in bow seaway</td>
<td>1. Keep heading in bow to bow-quartering waves</td>
<td>Severe [to extreme]</td>
</tr>
</tbody>
</table>
| Escaping increasing storm, coastal waters     | Any manoeuvre, in wind and waves from any direction | 2. Keep course in waves and wind from any direction  
3. Keep speed of at least [4.0] knots in waves and wind from any direction | Moderate [to severe]                   |
| Low speed in restricted areas                 | Course-keeping at low speed                   | Course-keeping at reduced speed in strong wind without waves  
4. in shallow water  
5. In shallow water near channel wall / bank  
6. In shallow water during overtaking by a quicker ship | Strong wind, strong current, no large waves |
Assessment Procedure: Choice of Methods

- **IMO Manoeuvrability Standards** are evaluated in full-scale trials => impossible in adverse weather conditions
- Direct evaluation of above criteria in transient model experiments with self-propelled models in irregular waves and wind => impractical at the present technology state in industry:
  - Statistical predictions require many seaway realisations => too expensive
  - Only few facilities exist world-wide => impractical for routine design
  - Verification by the Administration is impossible => impractical for approval
  - Large variability and uncertainty of results in marginal cases (depending on steering time history) => impossible to verify results
- Direct numerical simulation of manoeuvres in waves => not mature enough yet for routine design and approval

- Alternative procedure proposed in SHOPERA:
  - Separate evaluation of different forces (wind, waves, rudder, …) from simple model tests / numerical simulations / empirical formulae for different effects
  - Defined forces are combined in a simple numerical model
• Oscillatory wave forces and moments can be neglected, because their time scale is much shorter than time scale of manoeuvre.

• Solution of motion equations in horizontal plane under time-average forces (wind, waves).

• Note: motion equations and solution procedure may be as well time-dependent: system (1) specifies converged solution.

• Any term can be defined individually, independently from other contributions, with different methods: simple empirical formulae, numerical methods, model tests, …

• Designers are free to choose methods depending on needs of particular project => as long as designer can verify methods, Administrations should approve results.

\[
\begin{align*}
X_s + X_w + X_d + X_R + T &= 0 \\
Y_s + Y_w + Y_d + Y_R &= 0 \\
N_s + N_w + N_d + N_R &= 0
\end{align*}
\]
The sense of the proposed practical assessment procedure is similar to (well established in the industry) *Alternative Assessment of the Weather Criterion*, ref. MSC.1/Circ.1200, MSC.1/Circ.1227 (not hydrodynamically, but methodologically!), although capsize tests at zero forward speed in beam seaway (=Weather Criterion) are much easier to do than transient manoeuvres in seaway (both conditions control & statistics),

still, more accurate and more efficient procedure is used, based on series of separate simpler tests in well-controlled conditions to define separately different contributions in the analytical model:

- drift in beam wind (=> steady equilibrium heel angle),
- roll decay in calm water (=> roll damping),
- roll in regular beam waves (=> effective wave slope),
- results of which are put together in a simple mathematical model

Note: Alternative Weather Criterion assessment allows only model tests as methods; SHOPERA approach is much more flexible
## Comprehensive Assessment Procedure

### Methods

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Components</th>
<th>Model Tests</th>
<th>Numerical Methods</th>
<th>Empirical Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calm-water</td>
<td>X, Y, N</td>
<td>Static PMM tests</td>
<td>Double-body CFD simulations (steady drift)</td>
<td>Empirical formulae: Inoue, Kijima, Matsunaga, Kang &amp; Hasegawa</td>
</tr>
<tr>
<td>Wave drift forces</td>
<td>X, Y, N</td>
<td>Drift forces in regular waves at different speeds and headings</td>
<td>Drift forces in regular waves: * potential methods * CFD</td>
<td>Semi-empirical formulae for drift forces at different speeds and headings</td>
</tr>
<tr>
<td>Wind forces</td>
<td>X, Y, N</td>
<td>Static wind channel tests</td>
<td>Static wind forces: CFD</td>
<td>Empirical methods: Blendermann data Blendermann formula Fujiwara method</td>
</tr>
<tr>
<td>Shallow water, bank, overtaking</td>
<td>X, Y, N</td>
<td>Static PMM tests</td>
<td>Double-body CFD simulations (steady drift)</td>
<td>Empirical formulae</td>
</tr>
<tr>
<td>Propeller model: open-water characteristics</td>
<td>T -&gt; J, n, P_D</td>
<td>Open-water propeller tests</td>
<td>Open-water propeller simulations: potential methods, CFD</td>
<td>Propeller series</td>
</tr>
<tr>
<td>Engine</td>
<td>P_D available</td>
<td></td>
<td>Engine diagramm</td>
<td>Manufacturer’s data? Testing?</td>
</tr>
</tbody>
</table>

*verification by ROs on case-by-case basis*

“recommended” methods possible
How much Freedom Do we Have:
Sensitivity of Results to Errors in Forces & Moments

Two criteria were evaluated:
- Ship should be able to maintain advance speed of at least 4.0 knots in waves and wind from any direction
- Ship should be able to keep prescribed course in waves and wind from any direction

Aim of study: investigate sensitivity of the solution to changes in the forces and moments

To do this,
- coefficients of all forces and moments were changed (each in turn) by ±10%
- the required installed power was evaluated for significant wave heights 0 to 10 m and zero-upcrossing wave periods from 7 to 15 s

Results: percentage of change of required installed MCR at $h_s=5.5$ m due to change of each force or moment coefficient by 10%:

<table>
<thead>
<tr>
<th>Contributions</th>
<th>Change of $x$-force by 10%</th>
<th>Change of $y$-force by 10%</th>
<th>Change of $z$-moment by 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calm-water terms</td>
<td>3.0</td>
<td>3.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Wind terms</td>
<td>2.5</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Time-average wave terms</td>
<td>3.8</td>
<td>3.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Rudder terms</td>
<td>1.5</td>
<td>3.4</td>
<td>-</td>
</tr>
</tbody>
</table>
To evaluate criteria, nonlinear system of 3 equations (1) should be solved for all possible speeds and seaway directions:

1. *Advance speed of at least 4.0 knots in all seaway directions*  => check that $P_{D,\text{req}}/P_{D,\text{av}}<1$ along the line 4.0 knots

2. *Steering ability in all seaway directions*  => check $P_{D,\text{req}}/P_{D,\text{av}}<1$ along line $\delta=\delta_{\text{max}}$ (or $C_{LR}=C_{LR,\text{max}}$)

- Solution of 3 coupled nonlinear equations
- Large number of calculation cases: all wave directions * all speeds
- Difficult post-processing
  ⇒ Approval by ROs on case-by-case basis
  ⇒ Simpler assessment procedure required for Administrations

Criteria (1) and (2) fulfilled
Criterion (1) marginally fulfilled in head seaway
Criterion (1) marginally fulfilled in bow-quartering seaway
Criterion (2) marginally fulfilled in beam seaway
• Simple enough to be approved by Administrations alone, without involving ROs (Classes), if no advanced methods (numerical or experimental) are used
• Simplifications: reduced number of assessment cases, perhaps reduced number of terms in equations
• Even simpler empirical methods for different contributions are allowed
• Complexity of an MS Excel spreadsheet calculation
• Boundary conditions: all physics is the same as in the Comprehensive Assessment => Simplified Assessment is first-principles assessment procedure, not empirical
• The same criteria are enforced as in the Comprehensive Assessment, e.g.
  – 4.0 knots Propulsion Ability (in all seaway directions)
  – Steering Ability (in all seaway directions)
  – Weather-Vaning Ability (in head to bow-quartering waves)
  – ...
Work in progress

First examples shown here:

• Low-speed engine with CPP
• Single rudder behind single propeller
• Two criteria:
  – Propulsion ability: keep speed of at least [4.0] knots in waves and wind from any direction
  – Steering ability: keep course in waves and wind from any direction
Simplified Assessment of 4.0 knots Propulsion Ability: Simplifications

• Starting point:

\[
\begin{align*}
X_s + X_w + X_d + X_R + T(1 - t_H) &= 0 \\
Y_s + Y_w + Y_d + Y_R &= 0 \\
N_s + N_w + N_d - Y_R L_{pp} / 2 &= 0
\end{align*}
\]  

(solved for all forward speeds and in all seaway directions)

• Requirement: the ship should be able to keep forward speed of at least 4.0 knots in seaway from any direction

• SIMPLIFICATIONS:
  – Bow seaways are most critical for required power at given speed => it is enough to consider seaways from 0 to \([60]^{\circ}\) off-bow
  – Influence of drift on required power can be neglected => only 1st equation of system (1) is required
  – However, \(X_d\) should be taken as maximum between 0 and \(60^{\circ}\) off-bow)

\[
X_s + X_w + X_d + X_R + T(1 - t_H) = 0
\]  

(2)
Simplified Assessment of 4.0 knots Propulsion Ability: Validation

- Validation of the Simplified Assessment of 4.0 knots Propulsion Ability:
- 4 bulk carriers, 3 tankers, 4 container ships
- Significant wave heights from 0.0 to 9.5 m
- Comparison:
  - x-axis: \( \frac{P_{D^{\text{req}}}}{P_{D^{\text{av}}}} \) according to Comprehensive Assessment of 4.0 knots Propulsion Ability
  - y-axis: \( \frac{P_{D^{\text{req}}}}{P_{D^{\text{av}}}} \) according to Simplified Assessment of 4.0 knots Propulsion Ability, eq. (5)
- Simplified Assessment is sufficiently accurate, slightly conservative
- Conservativeness is higher for \( \frac{P_{D^{\text{req}}}}{P_{D^{\text{av}}}} > 1.0 \), which are not relevant anyway

\( \frac{P_{D^{\text{req}}}}{P_{D^{\text{av}}}} \) according to Simplified (y-axis) vs. Comprehensive (x-axis) Assessment of 4.0 knots Propulsion Ability for 4 bulk carriers (□, ▲, ▼, ●), 3 tankers (■, ▲, ▼) and 4 container ships (□, ▲, ▼, ○) in waves of significant wave heights from 0.0 to 9.5 m
Simplified Assessment of Steering Ability: Simplification 1

- **Starting point:**
  \[
  X_s + X_w + X_d + X_R + T(1-t_H) = 0 \\
  Y_s + Y_w + Y_d + Y_R = 0 \\
  N_s + N_w + N_d - Y_R L_{pp}/2 = 0
  \]
  (solved for all forward speeds and in all seaway directions)

- **Requirement:** the ship should be able to keep course in seaway from any direction

- **Both capability of the steering system and capability of propulsion (which influences steering ability) are required to fulfill this requirement and should be integral parts of this assessment, e.g.:**
  - Ships with powerful propulsion may have a smaller rudder
  - Ships with weaker propulsion may compensate this with larger steering devices

- **SIMPLIFICATION:** Application of Comprehensive Assessment to about 15 ships shows that steering ability is challenged in the largest degree in seaway directions close to beam:
  - Point with maximum $P_{D,req}/P_{D,av}$ along the line $\delta=\delta_{max}$ is close to beam seaway
  - „Critical“ conditions for course-keeping are close to beam seaway directions

⇒ Simplified Assessment of Steering Ability needs to be carried out in beam seaways only
Simplified Assessment of Steering Ability: Simplification 2

- Analysis of different terms in (1) using Comprehensive Assessment shows that all terms are not negligible ⇒ terms cannot be simply omitted
- Define

\[ l_s \equiv \frac{N_s}{Y_s}, \quad l_w \equiv \frac{N_w}{Y_w}, \quad l_d \equiv \frac{N_d}{Y_d} \]  

and combine 2nd and 3rd equations from (8) as

\[ Y_w^{90} (l_w - l_s) + Y_d^{90} (l_d - l_s) = Y_R \left( l_s + \frac{L_{pp}}{2} \right) \]  

- Analysis of terms of converged Comprehensive solution in „critical“ conditions shows:

\[ l_s \sim \frac{L_{pp}}{2}, \quad l_w << l_s, \quad l_d << l_s, \]  

thus eq. (12), i.e. 2nd and 3rd equations from (8), can be simplified as

\[ Y_R = -\left( \frac{l_s}{l_s + \frac{L_{pp}}{2}} \right) \left( Y_w^{90} + Y_d^{90} \right) \]  

- Introduce for convenience new definition:

\[ b \equiv \frac{l_s}{l_s + \frac{L_{pp}}{2}} = \frac{Y_s \cdot l_s}{Y_s \cdot l_s + Y_s \cdot L_{pp}/2} = \frac{N_s}{N_s + Y_s L_{pp}/2} = \frac{N'_s}{N'_s + Y'_s/2} \]
Simplified Assessment of Steering Ability: Validation of Simplifications

- Thus, equation system (8) is reduced to:

\[ X_s + X_w^{90} + X_d^{90} + X_R + T(1 - t_H) = 0 \]
\[ Y_R = -b\left( Y_w^{90} + Y_d^{90} \right) \]

in beam seaways

- First equation defines maximum attainable speed in beam seaway => maximum attainable steering force; second equation checks whether this steering force is sufficient for steering

- Validation: \( P_{D_{\text{req}}}/P_{D_{\text{av}}} \) according to (17) vs. Comprehensive Steering Ability Assessment for 15 ships

- Value of \( b \) is taken here as exact value

\[ b = \frac{N_s}{N_s + Y_s L_{pp}/2} \]

in "critical" conditions for Steering Ability from Comprehensive Assessment

\( P_{D_{\text{req}}}/P_{D_{\text{av}}} \) according to (17) with exact \( b \) taken from Comprehensive Assessment (1) (y axis) vs. \( P_{D_{\text{req}}}/P_{D_{\text{av}}} \) from Comprehensive Assessment (x axis) for 4 bulk carriers (■, ▲, ▼, ○), 3 tankers (■, ▲, ▼) and 4 container ships (□, △, ▼, ○) in waves of \( h_s \) from 0.0 to 9.5 m
Simplified Assessment of Steering Ability: Approximations: Coefficient b

- Coefficient b:

\[
b = \frac{N_s}{N_s + 0.5L_{pp} Y_s} = \frac{N'_s}{N'_s + 0.5Y'_s}
\]  

(22)

- \(b\) depends on drift angle \(\beta\) in „critical“ conditions for steering ability

- Value of \(b\) in „critical“ conditions was evaluated using Comprehensive Assessment and compared with \(b\) values at various drift angles for 11 ships (4 bulk carriers, 4 container ships, 3 tankers)

- This comparison shows: using \(b\) at drift angle of \(\beta = 5^\circ\) leads to a maximum conservative error (overestimation) for \(b\) up to 16% and reasonable results of the Simplified Assessment

\[
P_{D_{req}}/P_{D_{av}} \text{ according to eq. (17) with } b \text{ calculated as } b = \frac{N'_s}{(N'_s + 0.5Y'_s)} \text{ at drift angle } \beta = 5^\circ \text{ (y axis) vs. } P_{D_{req}}/P_{D_{av}} \text{ according to Comprehensive Assessment (x axis) for 4 bulk carriers (■, △, ▽, ●), 3 tankers (■, △, ▽) and 4 container ships (□, △, ▽, ○) in waves of significant wave height from 0.0 to 9.5 m}
The designer can freely select between three assessment procedures:

**Comprehensive Assessment Procedure:**
Most accurate assessment, based on solution of coupled nonlinear motion equations. Unlike in the 2012 Guidelines, designer is free to choose evaluation methods (numerical, experimental or empirical) for different forces depending on particular design needs. This level is necessary for ships with innovative propulsion and steering arrangements.

**Simplified Assessment Procedure:**
Reduced number of assessment cases, reduced complexity of the motion equations. All relevant physics for propulsion and steering is taken into account: first-principle assessment, not empirical. Similar in complexity to Level 2 assessment in 2013 Guidelines, but (a) no empirics concerning “required advance speed”, and (b) more flexibility regarding methods, e.g. model tests to define added resistance in waves are not necessary.

**Sufficient Propulsion and Steering Ability Check:**
Based on pure empirical formulae to define required installed power as function of main ship parameters (deadweight, block coefficient, windage area, rudder area, engine type). Similar in complexity to the existing Level 1 of 2013 Guidelines, but takes into account propulsion and steering characteristics (not only the deadweight and installed power).
Questions?

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3.2 Hironori Yasukawa, (Hiroshima University), Japanese R & D Project on Manoeuvring in Adverse Condition and Minimum Power Requirement of Ships.
Japanese R & D Project on Maneuvering in Adverse Condition and Minimum Power Requirement of Ships

Hironori YASUKAWA
(Hiroshima University, Japan)
1. Introduction of Japan’s activity

JASNAOE Research Panel

• The minimum power requirement guidelines are now under development at the IMO.

• The Japan Society of Naval Architects and Ocean Engineers (JASNAOE) started to develop a research strategy on this topic by establishing a research panel with experts in Japan.

• Toward developing a physics-based prediction method of maneuvering motion of ships in adverse weather condition, a collaborative research is now under way and will conclude by October 2016. This is supported by ClassNK.

• One of goals of this research is to establish the physics-based prediction method which can be used to evaluate validity of the interim level 2 guidelines.
1. Introduction of Japan’s activity

Major Participants

• Hiroshima University
• Osaka University
• Hokkaido University
• National Research Institute of Fisheries Engineering
• National Maritime Research Institute
• Mitsubishi Heavy Industries, Nagasaki R & D center
• ClassNK
1. Introduction of Japan’s activity

Tasks

1. Maneuvering model in waves
2. Wave-induced steady forces with ship’s forward velocity
3. Validation of the maneuvering model in waves
4. An analysis method of maneuvering limit and motion stability in wind and waves
2. Maneuvering model in waves

Policy

• **Practical tool:**
  • Reasonable computational time
  • Based on the existing methods with tank test results to ensure the reliability

• **Two theoretical methods:**
  • *A time domain simulation* method (like a ship handling simulator model)
  • *Non-time domain method*: checking the *equilibria condition and the motion stability in adverse condition* based on the theory of motion dynamics and stability
  • Base model should be same for both.
2. Maneuvering model in waves

A basic idea

- Total ship motion = Maneuvering + Wave-induced motion
- Maneuvering is low frequency motion: base motion
- Wave-induced motion is high frequency motion: a linear problem based on low frequency motion
2. Maneuvering model in waves

Details

1. Maneuvering: MMG model (4DOF version) + wave-induced steady forces

2. Wave-Induced motions: a linear time domain Strip Method (6DOF) on the assumption of a quasi-steady state treatment (no memory effect)
   • Change of encounter frequency
   • Change of wave direction
   • Change of speed
2. Maneuvering model in waves

Calculation flow

Engine model:
- Torque rich
- Revo. control

1. Maneuvering model
  + Wave-induced steady forces

2. Seakeeping model

- Ship position (X, Y)
- Heading angle (ψ)
- Ship speed (U)

- Motion oscillations
  for cal. of thrust and
torque fluctuations
  for rudder control
3. Wave-induced steady forces

Calculation methods of Wave-Induced Steady Forces

• Added resistance in regular waves:
  - Strip method + Prof. Maruo’s far field theory + empirical method for diffraction wave component correction

• Steady lateral force and yaw moment:
  - Strip method + Kashiwagi’s far field theory
  - Zero speed 3D panel method (no forward speed effect)

• Wave-induced steady forces in irregular waves:
  - Averaged value of the short term predictions
3. Wave-induced steady forces

Validation of the methods(1) added resistance coef. in head waves

Strip theory based Kochin-Function Method with correction

**KVLCC2**

- KVLCC2 Full $H_w=3.30m$
- Exp. Cal.
- $U=5.0kn$
- $U=10.0kn$
- $U=15.5kn$

**KCS**

- KCS Full $H_w=2.26m$
- Exp. Cal.
- $U=5.0kn$
- $U=10.0kn$
- $U=15.0kn$
- $U=24.0kn$
3. Wave-induced steady forces
Validation of the methods (2)
steady lateral force and yaw moment coef. in beam waves

Strip theory based Kochin-Function Method
Handymax B/C

\[ C_Y = \begin{cases} 
-15 & \text{if } \lambda/L < 0.5 \\
0 & \text{if } 0.5 \leq \lambda/L \leq 1.5 \\
15 & \text{if } \lambda/L > 1.5 
\end{cases} \]

\[ C_N = \begin{cases} 
-2 & \text{if } \lambda/L < 0.5 \\
0 & \text{if } 0.5 \leq \lambda/L \leq 1.5 \\
2 & \text{if } \lambda/L > 1.5 
\end{cases} \]
4. Validation of the maneuvering model in waves

Free-running tests on ship maneuvering in irregular waves !!

National Research Institute of Fisheries Engineering: Square Tank

Length: 60m
Width: 25m
Depth: 3.2m
4. Validation of the maneuvering model in waves

Wave maker

- 80 segmented wave maker with wave absorbing beach
4. Validation of the maneuvering model in waves

Hs=6m, $\delta=35\text{deg}$ Turning in Irregular Waves for KVLCC2

Square Tank of National Research Institute of Fisheries Engineering: 60m x 25 m x 3.2m
4. Validation of the maneuvering model in waves

Turning simulation in irregular waves for KVLCC2 (Hs=6m, δ=35deg)
4. Validation of the maneuvering model in waves

Ship motions during turning in regular waves(1)

$H_w/L = 0.02, \lambda/L = 0.7, \chi = 90\text{deg}, \delta = 35\text{deg}$ for S-175
4. Validation of the maneuvering model in waves

Ship motions during turning in regular waves (2)

$H_w/L = 0.02, \lambda/L = 0.7, \chi = 90\text{deg}, \delta = 35\text{deg}$ for S-175
5. Maneuvering limit and motion stability in wind and waves

Background: non-time domain method

1. Time domain method is useful. But when discussing some criteria or rules, the method is too complicated.
2. Some indexes representing the maneuvering characteristics in wind and waves
3. Those are:
   • Steady condition of a ship straight moving in wind and waves: check helm, hull drift angle, heel angle and ship speed, and
   • Yaw stability
5. Maneuvering limit and motion stability in wind and waves

Calculation Procedure:
non-time domain method(1)

1. Consider the ship straight moving in waves and wind with constant propeller revolution using auto-pilot.
2. The ship reaches to the steady-state condition with certain check helm, hull drift angle, heel angle and ship speed. \(\rightarrow\) Equilibria of surge-sway-yaw-roll + steering models (motion equations)
5. Maneuvering limit and motion stability in wind and waves

Motion equations to be solved

Surge \[(m + m_x)\ddot{u} - (m + m_y)v\dot{r} = X_H + X_P + X_R + X_A + X_W\]

Sway \[(m + m_y)\ddot{v} + (m + m_x)ur - m_y l_y \ddot{\phi} = Y_H + Y_R + Y_A + Y_W\]

Yaw \[\left( I_z + J_z \right) \ddot{\chi} = N_H + N_R + N_A + N_W\]

Roll \[\left( I_x + J_x \right) \ddot{\phi} - m_y l_y \ddot{v} - m_x l_x \dot{u}r + 2\mu \dot{\phi} + \beta \ddot{\phi} \phi + mgGM\phi = K_H + K_R + K_A + K_W\]

Steering \[T_E \dot{\delta} + \delta = -K_p (\psi - \psi_c) - K_p T_D r\]

Neglecting the high frequency motions !!
5. Maneuvering limit and motion stability in wind and waves

Calculation Procedure: non-time domain method (2)

3. At the equilibria condition, check the motion stability. 
   → Locally linear stability analysis of the equilibria by calculating eigenvalues of the Jacobean matrix

   If all real parts of eigenvalues are negative, the equilibrium is stable.
5. Maneuvering limit and motion stability in wind and waves

Free-running tests in wind and waves to know the maneuvering limit!!

Square Tank of National Research Institute of Fisheries Engineering: 60m x 25 m x 3.2m
5. Maneuvering limit and motion stability in wind and waves

Wind blowers

- 108 wind fans attached to a X-Y towing carriage
5. Maneuvering limit and motion stability in wind and waves

A Handymax bulk carrier

1/61.18 scaled model with super-structures

<table>
<thead>
<tr>
<th></th>
<th>ship</th>
<th>model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{bp}$ (m)</td>
<td>178.0</td>
<td>2.9091</td>
</tr>
<tr>
<td>$L_{WL}$ (m)</td>
<td>181.0</td>
<td>2.9591</td>
</tr>
<tr>
<td>$B$ (m)</td>
<td>32.26</td>
<td>0.5273</td>
</tr>
<tr>
<td>$D$ (m)</td>
<td>21.14</td>
<td>0.3455</td>
</tr>
<tr>
<td>$d$ (m)</td>
<td>11.57</td>
<td>0.1891</td>
</tr>
<tr>
<td>DWT (ton)</td>
<td>47500</td>
<td></td>
</tr>
<tr>
<td>MCR (KW)</td>
<td>7930</td>
<td></td>
</tr>
<tr>
<td>$D_p$ (m)</td>
<td>5.51</td>
<td>0.09</td>
</tr>
</tbody>
</table>
5. Maneuvering limit and motion stability in wind and waves

Typical experimental results

Beaufort No8  $H_s=5.5\text{m}$  ITTC wave spectrum, constant $V_w=19\text{m/s}$. 

Moving forward  Resting  Moving backward

70.3 rpm  63.9 rpm  57.5 rpm
5. Maneuvering limit and motion stability in wind and waves

Comparison of required prop. revo. and power (zero speed case)

Good agreement between experiment and calculation.
5. Maneuvering limit and motion stability in wind and waves

Comparison of power in head waves

![Graph showing the comparison of power in head waves against significant wave height. The graph includes lines for Plimit, estimation at U=4kt and U=0kt, data points for experiment at U=0kt, and the level 2 requirement at U=4kt.](image-url)
5. Maneuvering limit and motion stability in wind and waves

Equilibria condition in bow seas (cal. at 4 kts)

Beaufort No. 8\((H_s=5.5m, V_w=19m/s)\) ITTC, \(K_p=3, T_D=10s\)
5. Maneuvering limit and motion stability in wind and waves

Engine power in bow seas (cal. at 4 kts)

Beaufort No. 8\((H_s=5.5\text{m}, V_w=19\text{m/s})\)  ITTC, \(K_p=3, T_D=10\text{s}\)

The ship can keep a straight course in head and bow seas under the Beaufort No.8
5. Maneuvering limit and motion stability in wind and waves

Propeller torque in bow seas (cal. at 4 kts)

Beaufort No. 8
$H_s=5.5\text{m}, V_w=19\text{m/s}$

Beaufort No. 10
$H_s=9\text{m}, V_w=26.5\text{m/s}$
6. Conclusions

• Outline of Japanese R & D project on maneuvering in adverse condition and minimum power requirement of ships

• Some of the achievements obtained in the project related to followings:
  • Maneuvering model in waves
  • Wave-induced steady forces with ship’s forward velocity
  • Validation of the maneuvering model in waves
  • Maneuvering limit and motion stability in wind and waves

• Future work: evaluation of validity of the interim level 2 guidelines.
Thank you for your kind attention!
3.3 Yeon Gyu Kim, Dong Jin Yeo (KRISO), Sang Hyun Kim (Inha Univ.) Research Activities on Manoeuvring in Waves in Korea.
Research Activities on Manoeuvring in Waves in Korea

KRISO : Yeon Gyu KIM, Dong Jin YEO
Inha Univ. : Sang Hyun KIM

2016.04.14
Introduction

☐ Papers
  ■ 6 Selected Papers

☐ Project Plan 1
  ■ KRIOS’s Own Research Project

☐ Project Plan 2
  ■ MOTIE’s (Ministry Of Trade, Industry and Energy) Research Project

☐ Other Activity
  ■ Manoeuvring Meeting under SNAK/KTTC

- Cross flow concept and Long wave approximation
- Diffraction force modelling

\[ Y = \frac{1}{2} \rho V D \int C'_c (x) \frac{d(x)}{d_0(x)} v_r (x) dS \]

\[ N = \frac{1}{2} \rho V D \int \left( \frac{2}{\rho D} k_N a_{11} + C'_c (x) x \right) \frac{d(x)}{d_0(x)} v_r (x) dS \]

- \( C'_c, k_N \) are obtained from manoeuvring coefficients (Yv, Yr, Nv, Nr) or results of slender body theory and vortex shedding phenomenon.
Comparisons with the captive model tests in waves
- Target ship: 9000TEU Container ship (1/72 model)
- $F_n=0.235$, $L_w/L=1$, $H/L_w=1/30$, heading=45deg
Paper 2


- Analysis of wave effects on the manoeuvrability
- Model tests of KVLCC (1/100 model) in waves with wave directions, lengths and amplitudes
- Only 2nd-order wave forces which were measured in the tests are considered in the simulation.
- Test condition: 0m/s, 2 amplitudes, 5 wave lengths
Paper 2

Fig. 11. 2nd order wave force coefficient (y-force)

Fig. 12. 2nd-order wave moment with respect to the wave incident angle (N-moment)

Fig. 13. The results from 35° turning tests in a head sea

Fig. 14. Results of 35° turning tests in a beam sea
Paper 3


- Time-domain Ship Motion Program WISH was used.
  \[ m(\ddot{u}_0 - \dot{v}_0 \dot{r}_0) = X_H + X_P + X_R + X_W \]
  \[ m(\ddot{v}_0 + u_0 \dot{r}_0) = Y_H + Y_R + Y_W \]
  \[ I_{xx} \ddot{\phi}_0 = K_H + K_R + K_W \]
  \[ I_{zz} \ddot{r}_0 = N_H + N_R + N_W \]

- W denotes the 2nd-order mean drift force. : Direct pressure integrated method

- 4-DOF MMG model for maneuvering model

\[ \vec{F}_H = \vec{F}_{pot.} + \vec{F}_{lift} + \vec{F}_{visc.} \]
Comparisons with the published experiment data

Fig. 6. Comparison of turning trajectories in calm water: S-175 container ship, port-side turning test, $\delta = 35^\circ$.

Fig. 9. Comparison of turning trajectories in regular waves: S-175 container ship, $F_n = 0.15$, $\gamma = 90^\circ$, $\delta = -35^\circ$, (a) $\lambda/L = 0.7$, (b) $\lambda/L = 1.0$, and (c) $\lambda/L = 1.2$. 
Paper 3

- Other paper (J. of SNAK 2011.12)
- Consideration of weakly body nonlinearity (wetted body in Froude-Krylov & Restoring Force)
Paper 4


- 3-D Panel Method for the effects of radiation, diffraction and forward speed (NLOAD3D of ABS)
- Viscous effects on the manoeuvring related forces and moments were added.

\[ \bar{F} = \bar{F}_{Pot} + \bar{F}_{Lift} + \bar{F}_{Drag} + \bar{F}_{F.K.} + \bar{F}_{Vis} + \bar{F}_{Ext} \] (Yen et al., 2010)

- Comparisons with PMM tests in following regular waves (Target ship : KCS)
Figure 7 Simulated manoeuvring motions of KCS in calm water

Figure 10 Surge and sway forces, yaw moment and pitch angle of KCS during a drift test in wave of $\lambda/L = 1.5, H_s/L = 0.026, \chi = 0^\circ$
Paper 4

- Other paper (Proceeding of SNAK 2012.05)

Fig. 8 Comparison of 35 deg. rudder turning trajectories of S-175 in regular waves ($\chi = 180\,\text{deg.}$)

Fig. 9 Comparison of 35 deg. rudder turning trajectories of S-175 in regular waves ($\chi = 90\,\text{deg.}$)
**Paper 5**


- PMM Tests in head waves were carried out.
- The forces & moments are obtained by taking average of more than twenty periods.
- **Target Ship**: 4600TEU Container ship (similar with KCS)
Results of PMM Tests in Head Waves

- Static Drift Test
- Pure Sway Test
- Pure Yaw Test

Hydrodynamic Coefficients

Results of Static Drift Test

[Graphs showing hydrodynamic coefficients vs. drift angle and wave length]

- **Purpose**: To compare and analyze the advanced speed of ships with different rudder rotational velocity and autopilot coefficients in regular waves.

- **Method**: Commercial simulation tool + DLL type subroutine
Wave conditions (Target Ship : VLCC, L\textsubscript{pp} = 315m)

<table>
<thead>
<tr>
<th>Wave amplitude (Ship)</th>
<th>Wave amplitude (Model)</th>
<th>Wave period (Ship)</th>
<th>Wave period (Model)</th>
<th>Wave direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>3m</td>
<td>0.0381 m</td>
<td>8.87 sec.</td>
<td>1 sec.</td>
<td>45° 90° 135°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.57 sec.</td>
<td>1.3 sec.</td>
<td></td>
</tr>
</tbody>
</table>

Result

With same autopilot coefficient

With optimum autopilot coefficient
Mean rudder force in the X-direction (N)

- Wave period 1.0 s
- Wave period 1.3 s

Rudder rotational velocity (deg./s)

Mean rudder force in X

Significant heading angle (deg.)

- Wave period 1.0 s
- Wave period 1.3 s

Rudder rotational velocity (deg./s)

Significant Heading angle
Project Plan 1

- **Seed Project (KRISO’s Own Project)**
  - **Project Title**: Fundamental research for the analysis of ship’s integrated ability of maneuvering and seakeeping (PM: Yeon Gyu KIM)
  - **Project Period**: 2016.01.01 ~ 2016.12.31 (1 Year)
  - **Contents**
    - Investigation of the prediction method of ship’s integrated ability of maneuvering and seakeeping
    - Investigation of the model test equipment and method of ship’s integrated ability of maneuvering and seakeeping
    - Fundamental research of numerical analysis technology of ship’s dynamic motion by CFD and HPC
    - Investigation of sea test method using the training ship of Korea Maritime & Ocean University
Project Plan 1

Main Project (To be expected)

- Project Title: Development of the key technology for the analysis of ship’s integrated ability of maneuvering and seakeeping
- Project Period: 2017.01.01 ~ 2019.12.31 (3 Years)
- Contents
  - Development of program of integrated simulation of ship’s maneuvering and seakeeping (Verification with the model test)
  - Development of the model test method and securement of the experiment data for verification
  - Development of numerical analysis technology of ship’s integrated ability of maneuvering and seakeeping by CFD and HPC
  - Sea test of Training ship of Korea Maritime and Ocean Univ.
Project Plan 1

- Wave condition: IMO’s Adverse weather condition

<table>
<thead>
<tr>
<th>Ship length, m</th>
<th>Significant wave height $h_s$, m</th>
<th>Peak wave period $T_p$, s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 200</td>
<td>4.0</td>
<td>7.0 to 15.0</td>
</tr>
<tr>
<td>$200 \leq L_{PP} \leq 250$</td>
<td>Parameters are obtained by linear interpolation</td>
<td></td>
</tr>
<tr>
<td>More than $L_{PP} = 250$</td>
<td>5.5</td>
<td>7.0 to 15.0</td>
</tr>
</tbody>
</table>

- Target ship: KVLCC2, KCS, Training Ship (including Sea Test)

From http://blog.naver.com/pcc_751
Project Plan 2

MOTIE’s Project for National Core Technology Development

- Project Title: Technology Development to Improve Added Resistance and Ship Operational Efficiency for Hull Form Design (PI: Prof. Yonghwan Kim (SNU))
- Project Period: 2016. 03. 01 ~ 2019. 12. 31 (4 years)
- Participating Organizations: SNU, Inha Univ., HHI, SHI, DSME, LR, ABS, KR (Maybe more in the 2nd year)
- Budget: 4 million Euros

Main Tasks

- Development of advanced technology for the prediction of added resistance and operational efficiency
- Set-up of database for added resistance and operational efficiency: experiment and computation
- Development of analysis methods and procedure for minimum power prediction in harsh ocean environment
- Development of element SWs for optimum hull-form design, including added resistance and operational efficiency
Project Plan 2

Technology Development

Validation and Database

Ship Operability Prediction

Element SWs Development

Optimum Hull-form Design
Accomplishment process (Maneuvering Part)

- Based on CFD
  - Implementation of Maneuvers in Waves
  - Virtual Captive Model Tests in Waves
  - Application to Mathematical Model
- Based on EFD
  - Captive Model Tests in Waves
  - Application to Mathematical Model

Validation and verification of maneuvering performance in waves

Assessments of ship steering performance and operational safety in waves and rough sea

Method development to estimate ship steering performance and operational safety in rough sea
Conclusions

- 6 Selected Papers were introduced.
- 2 Project Plans were introduced.
  - KRISO’s own research project and MOTIE’s research project
  - These projects are started in 2016.
- SNAK/KTTC/Manoeuvring Meeting
  - Manoeuvring Meeting was started on Feb. 2016.
  - Purpose: Discussion about the technology on Manoeuvrability including this topic
  - Two times Meeting per year
Thank you.
3.4 Pierre-Emmanuel Guillerm (Ecole Centrale de Nantes), How to develop manoeuvring in waves standard for model tests and numerical simulation methods.
Manoeuvring seminar, London april 2016

How to develop manoeuvring in waves standard for model tests and numerical simulation methods

Contents

• What is Manoeuvring in waves?

• IMO criteria

• Questions/Challenges

• Methodologies available

• Example of broaching modeling

• Conclusions

PIERRE-EMMANUEL GUILLERM
What is Manoeuvring in waves?

Single expression, many applications:

• Course keeping ability in wave:
  • Head wave
    • Wave frequency motion
    • Small heading deviation
  • Beam to Following waves
    • Low-encounter frequency, large heading

• Broaching
  • $\lambda/L \approx 1.25$, large H/L
  • Stability limit

• Turning ability in waves
  • Ability to perform manoeuvres in adverse condition, to stay away from obstacles (shore)
IMO criteria:

> Standards for manoeuvring MSC.137(76):

- Ship characteristics during the following manoeuvres should be studied:
  - Turning, zig-zag test, Emergency stop, Course-keeping

- Condition for tests:
  - Calm environment, deep unrestricted water
  - 90% ship speed or 85% maximum power output.

- Criteria:
  - Turning ability, Initial turning ability, Yaw-checking, Course keeping ability, Stopping ability

- No specific norm or manoeuvres in waves and wind.
IMO criteria:

> 2008 IS Code, Part A, Ch. 1, [1.2]: Dynamic stability phenomena in waves:

- Some ships are more at risk of encountering critical stability situations in waves.
- **IMO recognizes that performance-oriented criteria for the identified phenomena need to be developed and implemented to ensure international level of safety.**

- **Second generation stability criteria:**
  - 5 failure modes:
    - (Excessive acc., pure loss of stability, parametric roll, broaching, dead ship condition)
  - 2 levels of assessment.
  - 2 failure modes are linked to manoeuvring in following waves:
    - Broaching, Excessive acceleration

- Criteria still discussed by IMO members.
IMO criteria:

> Marine environment protection committee (MEPC 232(65) may 2013):

“Minimum propulsion power to maintain manoeuvrability of ships in adverse conditions”

• Adverse conditions definitions:

<table>
<thead>
<tr>
<th>Significant wave height $h_s$, m</th>
<th>Peak wave period $T_p$, s</th>
<th>Mean wind speed $V_w$, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>7.0 to 15.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ship length, m</th>
<th>Significant wave height $h_s$, m</th>
<th>Peak wave period $T_p$, s</th>
<th>Mean wind speed $V_w$, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 200</td>
<td>4.0</td>
<td>7.0 to 15.0</td>
<td>15.7</td>
</tr>
<tr>
<td>$200 \leq L_{pp} \leq 250$</td>
<td>Parameters linearly interpolated depending on ship’s length</td>
<td>7.0 to 15.0</td>
<td>15.7</td>
</tr>
<tr>
<td>More than $L_{pp} = 250$</td>
<td>Refer to paragraph 1.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IMO criteria:

Marine environment protection committee (MEPC 232(65) may 2013):

2 levels of assessment

•A/ minimum power line

$$Min\ Power\ line\ value = a \times (DWT) + b$$  \hspace{1cm} DWT = \text{deadweight tons}

Table 1: Parameters a and b for determination of the minimum power line values for the different ship types

<table>
<thead>
<tr>
<th>Ship type</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk carrier which DWT is less than 145,000</td>
<td>0.0763</td>
<td>3374.3</td>
</tr>
<tr>
<td>Bulk carrier which DWT is 145,000 and over</td>
<td>0.0490</td>
<td>7329.0</td>
</tr>
<tr>
<td>Tanker</td>
<td>0.0652</td>
<td>5960.2</td>
</tr>
<tr>
<td>Combination Carrier</td>
<td>see tanker above</td>
<td></td>
</tr>
</tbody>
</table>

•B/ simplified assessment

3.1 The simplified assessment procedure is based on the principle that, if the ship has sufficient installed power to move with a certain advance speed in head waves and wind, the ship will also be able to keep course in waves and wind from any other direction. The minimum ship speed of advance in head waves and wind is thus selected depending on ship design, in such a way that the fulfilment of the ship speed of advance requirements means fulfilment of course-keeping requirements. For example, ships with larger rudder areas will be able to keep course even if the engine is less powerful; similarly, ships with a larger lateral windage area will require more power to keep course than ships with a smaller windage area.
IMO criteria:

Marine environment protection committee (MEPC 232(65) May 2013):
Evolution of the guidelines 2012 → 2013:

• Evolution of minimum power lines from 3 to 2 levels of assessment:

<table>
<thead>
<tr>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Minimum power</td>
<td>• Minimum power</td>
</tr>
<tr>
<td>• Simplified assessment</td>
<td>• Simplified assessment</td>
</tr>
<tr>
<td>• Comprehensive assessment</td>
<td></td>
</tr>
<tr>
<td>• Course keeping in any direction</td>
<td></td>
</tr>
<tr>
<td>• Turning ability</td>
<td></td>
</tr>
<tr>
<td>• Model based simulations</td>
<td></td>
</tr>
</tbody>
</table>
Challenges

• Manoeuvring in waves has received more attention than before and will receive even more attention in the coming years:
  • Concerns on security at seas
  • Developpement of numerical tools,

• The physics and statistical aspects are more complex than generally assumed.
  • No standard at the moment
  • No direct criteria

• What is specific in manoeuvring in waves
  • Large variation of immersed volume and GM
  • Large variation of propeller inflow
  • Interaction between wave flow, appendages and hull
  • Results/behaivor may depend on initial conditions
Questions/Challenges

What are the situations/scenarii to be checked?
- Keep heading in a seaway, change heading in a seaway?
- escaping in increasing storm (minimum speed, U-turn, ...)?
- manoeuvring at reduced speed in restricted water with strong wind?

What are the conditions associated (wind, wave, current, engine)?
- MPEC 232(65)?

What are the required outputs of the standard manoeuvres?
- values, statistics, occurrence?

What would be acceptable for IMO and classification societies in terms of results?
- Repetitivity, parameter to measure, dispersion, confidence level

How to define standard manoeuvres/methodology to assess the situations?
- (depending on the type of ship)
Methodologies to address manoeuvring in waves

Model tests
- Free sailing model tests
- Wide basin for turns
- Long basin with oblique waves for course keeping
- Modeling of engines
- Modeling rudder auto-pilot

Numerical simulations by various methods
- Superposition methods
- Two-time scale methods with coupling
- Coupled methods based on Impulse response functions for merging seakeeping & manoeuvring frequencies
- RANS CFD
Methodologies to address manoeuvring in waves

Model tests are difficult:
- Very long and large tank making big waves (only few model bassin are suitable)!
- Transient model experiment with propeller in irregular wind and waves
- Hundreds of runs to reach statistical representativeness,
- Reproductibility: dependance of time history (wave, course, rudder, initial conditions...)

Numerical simulations (tools are still not mature)
- CFD: not mature and hundreds of runs to performed
- Model-based simulations.
  - Numerous methods adapted to different sailing condition (course-keeping, broaching, etc...)
- Need for experimental data (model building, validation)
- How to validate (since expe are difficult)!
Methodologies to address manoeuvring in waves

Example of related work on broaching at ECNantes

- Mixing Forced motions tests, free-sailing model and model-based simulations

- Towing tank are used to derive hydrodynamic coefficients in waves at zero encounter frequency from forced motion tests

- A mathematical model of broaching in build from the towing tank tests

- A free running model is used in the large wave tank to validate the mathematical model.

- The model is then used as a tool to study the ship behavior in different situation/configuration.
Broaching study
Broaching study

- **Identification des coefficients sur houle**

  - **Essais de traction droite à \( \xi_c/\lambda \) constant**

- **Essais de traction droite à \( \xi_c/\lambda \) variable**

\[
\begin{align*}
  f_A(\omega_e) &= (1 + a_1 \omega_e + a_2 \omega_e^2) \\
  f_F(\omega_e) &= c_1 (1 - e^{c_2 \omega_e^2}) \\
  f_{off}(\omega_e) &= (1 + b_1 (1 - e^{b_2 (\omega_e - b_3)^2}) + b_4)
\end{align*}
\]
Broaching study

- Identification des coefficients sur houle
  - Essais de dérive avec $\xi_c/\lambda$ constant (gisement $\chi = 8^\circ$)

\[
\begin{align*}
  & f_{XA}(\chi, \omega_e) = a_{1x} + a_{2x} \chi^2 + a_{3x} |\chi|^3 \\
  & f_{Xoff}(\chi, \omega_e) = b_{1x} + b_{2x} \chi^2 + b_{3x} |\chi|^3 \\
  & f_{YA}(\chi, \omega_e) = a_{1y} + a_{2y} \chi^2 + a_{3y} |\chi|^3 \\
  & f_{Yoff}(\chi, \omega_e) = b_{1y} + b_{2y} \chi^2 + b_{3y} |\chi|^3 \\
  & f_{NA}(\chi, \omega_e) = a_{1n} + a_{2n} \chi^2 + a_{3n} |\chi|^3 \\
  & f_{Noff}(\chi, \omega_e) = b_{1n} + b_{2n} \chi^2 + b_{3n} |\chi|^3
\end{align*}
\]
Broaching study

Prédiction du comportement sur houle pour $F_n > 0.3$

- Essais de garde-cap ($\lambda/L_w = 1.25$ et $H/\lambda = 0.05$).

$F_n = 0.3$

$F_n = 0.35$

$F_n = 0.4$
Modes de navigation sur houle

- Comportement du navire SANS contrôle actif du gouvernail pour $F_n = 0.4$ ($\lambda/L_{wl} = 1.25$ et $H/\lambda = 0.05$).
Propose background and methodology: for example combining both numerical and experimental tools.

What kind of simulations (combine num/expe) should be performed to get accurate models? How to validate them?

Propose representative new standard manoeuvres to be studied expe or num? (depending on the type of ship)

Once the methodology is set, what kind of DoE should be prepared to get a good estimate of ship behavior in waves?

Highlight need for background research?
Conclusions:

• Manoeuvring in waves has received more attention than before and will receive even more attention in the coming years.:
  • Concerns on security at seas
  • Criteria will push this
  • Developpement of numerical tools, need for experiments

• The physics and statistical aspects are more complex than generally assumed.
  • No standard at the moment

• Need for background research
  • Experimental: validation data
  • Numerical: improve knowledge of models strength and weakness, validation
  • Methodology: mix expe and numerical approach?

• Model tests will continue to play a role, the complexity will become more in the future.

• Provide support to define appropriated classification requirements
3.5 Yonghwan Kim (Seoul National University), Seakeeping Analysis Coupled with Manoeuvring Problem.
ITTC MC Joint Workshop
April 14, 2016, London, UK

Seakeeping Analysis
Coupled with Manoeuvring Problem

- Seakeeping Committee -

Presented by

Yonghwan Kim
(Seoul National University)
ITTC SK Members (28\textsuperscript{th} Term)

- Adolfo Marón, CEHIPAR (Spain)
- Ayhan Akinturk, NRC (Canada)
- Chengsheng Wu, CSSRC (China)
- David Hayden, NSWCCD (USA)
- Florian Sprenger, MARINTEK (Norway)
- Frederik Gerhardt, SSPA (Sweden)
- Katsuji Tanizawa, NMRI (Japan)
- Pepijn de Jong, Delft U. (Netherlands)
- Yonghwan Kim, SNU (Chair, Korea)
The Seakeeping Committee is primarily concerned with the behavior of ships underway in waves. The Ocean Engineering Committee covers moored and dynamically positioned ships, including the modeling and simulation of waves, wind and current.
ITTC SKC: TOR

1. Update the state-of-the-art for predicting the behavior of ships in waves, emphasizing developments since the 2014 ITTC Conference.

2. Review ITTC Recommended Procedures relevant to seakeeping, including CFD procedures, and a. identify any requirements for changes in the light of current practice, and, if approved by the Advisory Council, update them, b. identify the need for new procedures and outline the purpose and contents of these.

3. Update ITTC Recommended Procedure 7.5-02-07-02.5, Verification and Validation of Linear and Weakly Non-linear Seakeeping Computer Codes to include the verification and validation of ship hydro-elasticity codes.

4. Update ITTC Recommended Procedure 7.5-02-07-02.1, Seakeeping Experiments, to include tests specific to active stabilization systems, with particular attention to the modelling of the control system and the prediction of full scale behavior. If possible, update the corresponding procedure for high speed craft.

5. Review ITTC Recommended Procedures 7.5-02-05-06, Structural Loads, and 7.5-02-05-07, Dynamic Instability Tests, and propose updates, if any.

6. Develop a new procedure for the determination of speed reduction coefficient \( fw \) in the EEDI formula. Coordinate and exchange information with the Specialist Committee on Performance of Ships in Service.

7. Develop a new procedure for model scale sloshing experiments.

8. Review the research considering the impact of seakeeping on propulsion and manoeuvring performance. Coordinate and exchange information with the Manoeuvring Committee.

9. Survey and/or collect benchmark data for seakeeping problems, such as motion, loads, sloshing, slamming, added resistance, full-scale measurements.

10. Continue the collaboration with ISSC committees, including Loads and Responses and Environment Committees.

11. Support a joint workshop on manoeuvring in waves with the Manoeuvring and the Stability in Waves Committees and the Specialist Committee on Performance of Ships in Service, for example on the subject of minimum power requirements for safe manoeuvring in adverse sea conditions and model testing methods to investigate this.
Technical Issues in SK Analysis Including Manoeuvring
In real seaways....
In real seaways....
In Experiment ...

Turning test in irregular waves: NRIFE (2015)
Technical Issues (1)

SKC Procedure:
• 7.5-02-07-02.1, Seakeeping Experiments
• 7.5-02-07-02.2: Predicting Power Increase in Waves
• 7.5-02-07-02.3: Experiments on Rarely Occurring Events

Representative Issues
• Free-running test
• Particularly in oblique seas
• Control and measurement issues
  - Course keeping scheme
  - Rudder control: time histories of control signal and rudder angle
  - Thrust and torque measurement
  - Motion measurement system
  - Drift control: degree of freedom, soft spring etc
  - Sensor capacities for longitudinal and transverse forces/moments
Technical Issues (2)

SKC Procedure: 7.5-02-07-02.5: Verification and Validation of Linear and Weakly Nonlinear Seakeeping Computer Codes

- No specific guidance or procedure for coupled seakeeping and manoeuvring analysis.

Computation/Simulation Issues

- Coupled Analysis of Seakeeping and Manoeuvring in Time Domain
  - Coupling scheme/Methodology
    - Total vs. Component-based (e.g. CFD vs. SK+MMG)
  - Different Time Scale
  - Decomposition of terms, particularly viscous effects
  - Accuracy of coefficients
- Hydrodynamic Coefficients in Waves
- SK Formulation for varying speed
- Course Control and Autopilot
- Nonlinear Effects
Emerging Problems

Speed Reduction in Waves (EEDI related issue)

- Seakeeping analysis in short-crested waves and oblique waves
- Numerical simulation in time domain: drift and course keeping
- Nonlinearity of motion responses and forces
- Propulsion-related issues, e.g. thrust reduction, propulsion coefficient

Minimum Power Requirement in Harsh Waves

- Nonlinearities: wave, motion, force
- Ocean environmental conditions
- Extreme analysis
- Validation issues
Coupled Seakeeping-Manoeuvring Analysis
Seakeeping-Maneuvering Interaction

Seakeeping
- 6-DOF Ship Motion
- Linear BVP
- Hydrodynamic Force
  - Froude-Krylov Force
  - Diffraction Force
  - Radiation Force
  - 2nd-order Wave Drift Force

Using direct pressure integrated method

Maneuvering
- 4-DOF Maneuvering Motion
- Modular type model (MMG)
- External Force
  - Hull Force
  - Rudder Force
  - Propeller Force
  - Wave Drift Force

Three component
1. Potential force
2. Lifting force
3. Additional viscous force

Include slip speed and rotation
- Wave Drift Force
  - Hull Force: Potential component

- Moving Velocity
  - Global Ship Position

Include slip speed and rotation
Seakeeping equation

\[ [M_{jk}] \{ \ddot{x}_k \} = \{ F_{F.K.j} \} + \{ F_{Res.j} \} + \{ F_{H.D.j} \} \quad (k, j = 1, 2, ..., 6) \]

- \( F_{Res} \): Restoring force
- \( F_{F.K.} \): Froude-Krylov force
- \( F_{H.D.} \): Hydro dynamic force

\[ \{ F_{F.K.j} \} = - \rho \iint_{\Omega} \left\{ \left( \frac{\partial}{\partial t} - \vec{U} \cdot \nabla \right) \phi_l + \nabla \Phi \cdot \nabla \phi_l \right\} \cdot n_j dS \]

\[ \{ F_{H.D.j} \} = - \rho \iint_{\Omega} \left\{ \left( \frac{\partial}{\partial t} - \left( \vec{U} - \nabla \Phi \right) \cdot \nabla \right) \phi_d + \left[ \frac{\partial \Phi}{\partial t} - \vec{U} \cdot \nabla \Phi + \frac{1}{2} \nabla \Phi \cdot \nabla \Phi \right] \right\} \cdot n_j dS \]

Maneuvering equation

\[ m(\dot{u}_0 - v_0 r_0) = X_H + X_P + X_R + X_W \]
\[ m(\dot{v}_0 + u_0 r_0) = Y_H + Y_R + Y_W \]
\[ I_{xx} \dot{\phi}_0 = K_H + K_R + K_W \]
\[ I_{zz} \dot{\theta}_0 = N_H + N_R + N_W \]

- \( X_H Y_H K_H N_H \): Hull force
- \( X_P \): Propulsion force
- \( X_R Y_R K_R N_R \): Rudder force
- \( X_W Y_W K_W N_W \): Wave drift force

Linearized BVP

\[ \nabla^2 \phi = 0 \quad \text{in fluid domain} \]

\[ \frac{\partial \phi_d}{\partial n} = \sum_{j=1}^{6} \left( \frac{\partial \xi_j}{\partial \eta} n_j + \xi_j m_j \right) - \frac{\partial \phi_l}{\partial n} \quad \text{on } \bar{S}_B \]

\( (m_1, m_2, m_3) = 0 \)
\( (m_4, m_5, m_6) = \vec{n} \times \vec{U} \)

\[ \frac{\partial \zeta_d}{\partial t} - \vec{U} \cdot \nabla \zeta_d = \frac{\partial \phi_d}{\partial z} \quad \text{on } z = 0 \]

\[ \vec{U} = (u_0 - y r_0, v_0 + x r_0, 0) \]

- Propulsion force and rudder force: MMG Model
- **Wave drift force**: Direct pressure integration method
- **Hull force**: decomposed 3 components

\[ \vec{F}_H = \vec{F}_{pot} + \vec{F}_{lift} + \vec{F}_{visc} \quad \text{\( \vec{F}_H = (X_H, Y_H, K_H, N_H) \)} \]

\( \vec{F}_{pot} \): Hydrodynamic force contributed purely by potential flow
\( \vec{F}_{lift} \): Vortex induced hull lift force
\( \vec{F}_{visc} \): Additional viscous damping force
Turning in Waves

- Ship Model: S175
- $\lambda/L=0.7$, $\chi=180\text{deg}$, $A=3.5\text{m}$ ($H/L=0.02$)

- Body fixed coordinate system
- Space fixed coordinate system
Turning Trajectories

- $\chi=180^\circ, \lambda/L=0.7$
- $\chi=180^\circ, \lambda/L=1.0$
- $\chi=180^\circ, \lambda/L=1.2$
- $\chi=90^\circ, \lambda/L=0.7$
- $\chi=90^\circ, \lambda/L=1.0$
- $\chi=90^\circ, \lambda/L=1.2$
Motion Signals

$\lambda/L=0.7, \chi=90\text{deg}$

- Ship speed
- Drift angle
- Yaw velocity
- Heave motion
- Roll motion
- Pitch motion
Effects of Seakeeping and Manoeuvring on Ship Operation Efficiency
Course Keeping

- Approach
  - External forces due to wave and wind
  - Rudder control in transient path
  - Ship in force equilibrium on straight path with steady attitude
  - Observation on heading, motion and speed reduction
Effects of Wind Speed: Speed Loss

- S175, $F_n = 0.15$

Time histories: $V_{WT}=18.5\text{m/s}$, $\psi_{WT}=150\text{deg}$
Effects of Waves: Speed Loss

- S175, $F_n = 0.15$

**Time histories:** SS5, $\chi=150\text{deg}$

- **Total speed**
- **Rudder angle**
- **Heading angle**
- **Drift angle**

**Speed loss (m/s)**
Effects of Wind Speed: Heading Angle and Rudder Angle

- S175, Fn = 0.15
## Effects of Wind:
### Speed Loss and Increase of Resistance

### 180°, 18.5 m/s

<table>
<thead>
<tr>
<th></th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converged speed, $V_w$</td>
<td>4.84 m/s</td>
</tr>
<tr>
<td>Heading angle, $\psi_0$</td>
<td>0.00 deg</td>
</tr>
<tr>
<td>Rudder angle, $\delta$</td>
<td>0.00 deg</td>
</tr>
<tr>
<td>Hull force</td>
<td>-138.61 kN</td>
</tr>
<tr>
<td>Rudder force</td>
<td>0.0 kN</td>
</tr>
<tr>
<td>Propulsion force</td>
<td>263.39 kN</td>
</tr>
<tr>
<td>Wind force</td>
<td>-124.78 kN</td>
</tr>
</tbody>
</table>

### 150°, 18.5 m/s

<table>
<thead>
<tr>
<th></th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converged speed, $V_w$</td>
<td>4.32 m/s</td>
</tr>
<tr>
<td>Heading angle, $\psi_0$</td>
<td>-6.21 deg</td>
</tr>
<tr>
<td>Rudder angle, $\delta$</td>
<td>2.78 deg</td>
</tr>
<tr>
<td>Hull force</td>
<td>-166.45 kN</td>
</tr>
<tr>
<td>Rudder force</td>
<td>-9.65 kN</td>
</tr>
<tr>
<td>Propulsion force</td>
<td>271.90 kN</td>
</tr>
<tr>
<td>Wind force</td>
<td>-95.81 kN</td>
</tr>
</tbody>
</table>
\textit{F}_w \textit{ Prediction}

- \textbf{KVLCC2: Free-Running Simulation}

\begin{itemize}
  \item \textit{V}_{r_{ef}} = 7.95 \text{ m/s}
  \item \textit{V}_w = 6.80 \text{ m/s}
  \item Total speed
  \item Results of speed loss and weather factor
\end{itemize}

<table>
<thead>
<tr>
<th>\textit{V}<em>r</em>{ef}</th>
<th>\textit{V}_w</th>
<th>Speed loss</th>
<th>\textit{f}_w</th>
<th>\textit{f}_w \text{ (MEPC1)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.95 \text{ m/s}</td>
<td>6.80 \text{ m/s} \newline \newline \text{(6.77} \text{ 6.85 m/s)}</td>
<td>1.15 \text{ m/s} \newline \newline \text{(1.10} \text{ 1.18 m/s)}</td>
<td>\textbf{0.855} \newline \newline \text{(0.852} \text{ 0.862)}</td>
<td>\textbf{0.859}</td>
</tr>
</tbody>
</table>

\begin{align*}
\text{Calm water resistance} & \quad \text{Wave force (mean value, 100sec)} \\
\text{Wind force} & \\
\end{align*}
Suggestion for Collaborative Works
Collaboration of ITTC Committees for Ship Manoeuvring

What are common need to improve current and/or future ITTC procedures?

- 7.5-02-06-01 and 7.5-02-07-02.1: Free-running test
- State-of-the-art review and/or new guidance for the coupled seakeeping-manoeuvring analysis

How can we improvement of overall technology?

- Benchmark test, comparative study
- Regular or irregular group activities
Thank you!

Q&A
3.6 Gregory Grigoropoulos (NTUA), Towards more rational guidelines to determine minimum propulsion power for Safe Operation under adverse Weather Conditions
Towards more rational guidelines to determine minimum propulsion power for Safe Operation under adverse Weather Conditions

by G.J. Grigoropoulos, Professor NTUA

Member of 28th ITTC SC PSS
ITTC SC Performance of Ships at Service

Membership

• Names of ten member
• Chairman Jinbao Wang
• Supervision by the ITTC Advisory Council chair Prof. G. Strasser

Activities

• New ISO Standard 15016:2015 on Sea Trials (currently under refinement)
• Specification of fw coefficient involved in the formula of EEDI
• Minimum power requirement for manoeuvring in adverse sea conditions
INTRODUCTION - BACKGROUND

IMO issued Guidelines on Dec. 2012 (MSC-MEPC.2/Circ.11)

On May 2013, 65th MEPC revised slightly minimum power line and (more important) reduced significantly the sea conditions in the simplified method to quite milder ones, especially for the smaller vessels.

A study to assess the seakeeping performance, including added resistance in wind and waves, for four BCs (DWT 30000-176000 T) and one VLCC DWT 306000 T has been carried out in Greece by HCS. In this study the capabilities of the tested vessels to attain a minimum speed with manoeuvring capabilities were investigated using state-of-the-art numerical tools in fully laden and heavy ballast conditions, at the speed provided by MEPC empirical formulas.

The characteristics of the actual propulsion system and the results of the sea trials were taken into account.
RESULTS OF THE INVESTIGATION - 1

On the basis of this study for BCs & Tankers larger than 20000 DWT, the following comments were made:

- In MSC-MEPC.2/Circ.11/ Dec.2012 level 1 method (minimum power line) is milder than level 2 (simplified method), which is irrational.

- This was remedied by 65th MEPC via reducing the sea conditions of level 2 method to quite mild ones. However, there is no reason for differentiating the sea conditions according to ship size.

- On the basis of detailed calculations, the tested vessels proved to be marginal at heavy ballast condition, which is the critical one for these vessels in adverse sea conditions. Heavy ballast condition should be included in the calculations.

- Some bugs were identified in the empirical formula in the specification of the required minimum speed (e.g. submerged lateral area of hull, corrected for breadth effect). They haven’t yet been remedied.
RESULTS OF THE INVESTIGATION - 2

Furthermore:

- There wasn’t any reasoning for associating the minimum speed with the manoeuvring capabilities of the ships.
- The aging and fouling of ships and propellers should be taken into account to provide some margin in both level 1 & level 2, criteria.
- In the study calculations were carried out at the sea conditions specified MSC-MEPC.2/Circ.11 which was available at that time.
- Additional calculations were performed for the quite severe ISC 2008 conditions. Some of the tested ships nearly satisfied these conditions. This demonstrates that there is space to ask for stricter limiting sea conditions than those of MSC-MEPC.2 / Circ.11, which can be identified as realistic, taking into account ocean statistics.
RESULTS OF THE INVESTIGATION - 3

Additional aspects that need further inspection and fixing:

- Most of the existing ships were well above the specified minimum power line. The Greek delegation proposed to compromise at a stricter minimum power line, higher than the current.

- It is reasonable to base the Guidelines on existing installed power levels. The percentage of these designs that should satisfy that line, should be decided. The proper selection and the reliability of the data base of BCs and Tankers over 20000 DWT should be ensured.

- Common procedures and test cases should be decided, before proceeding to this investigation. In any case a study to clarify "what is a safe manoeuvring speed" should be performed.

- Statistics of the ocean provide a basis for establishing realistic limiting sea conditions to be used in the Guidelines for minimum power requirements.
Adopted on [15 May 2015]

AMENDMENTS TO THE 2013 INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS (RES. MEPC.232(65), AS AMENDED BY RES. MEPC.255(67))

IMO/MEPC in its 68th session (May 2015):

ADOPTED amendments jointly proposed by Japan and Greece to the 2013 Interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions, as amended, as set out in the annex to the present resolution;

INVITED Administrations to take the aforementioned amendments into account when developing and enacting national laws which give force to and implement provisions set forth in regulation 21.5 of MARPOL Annex VI, as amended;
Adopted on [15 May 2015]

AMENDMENTS TO THE 2013 INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER TO MAINTAIN THE MANOEUVRABILITY OF SHIPS IN ADVERSE CONDITIONS (RES. MEPC.232(65), AS AMENDED BY RES. MEPC.255(67))

Table 1: Parameters a and b for determination of the minimum power line values for the different ship types

<table>
<thead>
<tr>
<th>Ship type</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk carrier which DWT is less than 145,000</td>
<td>0.0763</td>
<td>3374.3</td>
</tr>
<tr>
<td>Bulk carrier which DWT is 145,000 and over</td>
<td>0.0490</td>
<td>7329.0</td>
</tr>
<tr>
<td>Tanker</td>
<td>0.0652</td>
<td>5960.2</td>
</tr>
<tr>
<td>Combination Carrier</td>
<td>see tanker above</td>
<td></td>
</tr>
</tbody>
</table>
MINIMUM POWER LINE METHOD (BULK CARRIERS)

Minimum Power Line Value - Bulk Carriers

- Initial Approach - DWT < 276K
- Initial Approach - DWT >= 276K
- Revised Approach
- Revised Approach +10%
- Revised Approach +15%
- New-2015

April 14, 2016
Joint ITTC-SHOPERA Public Workshop
MINIMUM POWER LINE METHOD (TANKERS)

Minimum Power Line Value - Tankers

- Initial Approach
- Revised Approach
- Revised Approach +10%
- Revised Approach +15%
- New-2015

April 14, 2016
Joint ITTC-SHOPERA Public Workshop
Objectives: Developing a physics-based prediction method of maneuvering motions of ships in adverse weather conditions and establishing it, so that it can be used to evaluate the validity of the Interim Level 2 Guidelines.

JAPANESE VALIDATION STUDY

Within JASNAOE research project, results of a validation study on the Greek proposal were presented recently. The study pertains to 15 BCs and 15 Tankers built in Japan and sailing at fully laden condition in a fully developed seaway with air prevailing at 9 & 10 BF ($H_{1/3} = 7 & 9$ m). There is no evidence that the hull forms correspond to contemporary designs.

Only fully laden condition has been considered, although the Greek study concluded that the heavy ballast condition is the critical one.

Although the study used different hull forms and different sea conditions, their results are consistent with the Greek study.
In addition, the authors of the study proposed regression curves based on NMRI method for the quick estimation of added resistance, which they conclude that overestimate the actual values.

To avoid seakeeping calculations Grigoropoulos, Loukakis & Perakis proposed “Seakeeping standard series for oblique seas (A synopsis)” (Ocean Engineering, Vol. 27, pp. 111-126, 2000) which provide robust interpolation capabilities within systematic runs of Series 60 hull forms.

JASNAOE developed a numerical simulation program based on 4-DOF equations with course keeping for comprehensive assessment, carried out tank tests in wind and waves at NRI for Fisheries Engineering with good results and sets the comprehensive assessment as a tool for the development of the practical simplified method.

Bugs in Level 2 Assessment should be removed.
Contrary to JASNAOE, SHOPER A assumes a speed of 4 kn. SHOPER A also considers any heading when leaving coastal areas.

Keeps heading bow to bow-quartering waves. JASNAOE avoids head waves.

The database of ships used in the investigations should be agreed to be common and open to any third party so that any discrepancy in the results between the various projects can be easily identified and resolved.

The assumptions made during the analysis should be clear and agreed between the stakeholders.

Tomorrow we will hear about the benchmark study organized by SHOPER A.
THANK YOU ALL
FOR YOUR KIND
ATTENTION!