Energy Efficient Safe SHIp OPERAtion

SHOPER A Workshop
Hamburg, 30 October 2014

WP 1
Environmental conditions and requirements for different ships
Task 1.1 Met-ocean description
WP1: Objectives

- Provide **met-ocean description** for the project
- Define **ship sizes** for ship types considered in the project
- Conduct **risk analysis of marine accidents** related to manoeuvring in adverse weather conditions
- Propose **safety criteria** to be addressed by the project based on a critical review of the current EEDI as well as operational experience from ship operators and other project partners.

Met-ocean data
Accident statistics
Analysis of criteria

30 Oct. 2014
NOW:
Existing EEDI Requirements

END OF PROJECT:
• Updated EEDI requirements
• Improved SoA of numerical tools
• Optimisation for safety & efficiency

WP1: Output

WP1
Met-ocean data
Accident statistics
Analysis of criteria

Dissemination
Exploitation
Submission

WP7

WP2
Adjustment of numerical tools

WP3
Experiments

WP4
Validated numerical tools
Simplified models
Formulations for rules (Level 1)
Intact stability tools

WP5
Optimisation studies

WP6
Case Studies
Know-how & tools

WP7
Recommendations

Phase 1
Phase 2

30 Oct. 2014
SHOPERA · WP1.1
Introduction of Energy Efficiency Design Index (EEDI) represents a major step forward in implementing the regulations on energy efficiency of ships.

It has brought serious concerns regarding the sufficiency of propulsion power and of steering devices to maintain the manoeuvrability of ships in the adverse conditions.

Ship designers might choose to lower the installed power to achieve EEDI requirements.

Implementation of EEDI two phases:
- **Phase 0** – interim assessment procedures to be applied (1 Jan. 2013 - 31 Dec. 2014) within Phase 0 of the EEDI implementation.
- **Phase 1 and later**
To avoid negative effects, such as under-powered ships, a provision was added to regulation 21 in Chapter 4 of MARPOL Annex VI, stating:

“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.”

At MEPC 65 the “2013 Interim Guidelines for determining minimum power to maintain the manoeuvrability of ships in adverse conditions” were adopted (17 May 2013).

For 2013 Interim Guidelines
- Possibility for 2 levels assessment
- Definition of adverse condition
- Definition of “minimum power lines” (assessment level 1) for bulk carriers and tankers (including combination carriers)
- Definition of “required ship speed of advance” (for assessment level 2)
  - Minimum navigational speed (4.0 knots)
  - Minimum course-keeping speed (defined as function of rudder area, ship length, breadth and draft, ship frontal windage area and lateral windage area)

For final guidelines (to be defined)
- Applicability to other ship types
- Verification and possible redefinition of adverse conditions
- Redefinition of “minimum power lines”
- Definition of safety criteria and standards
Task 1.0. Technical Management (DNV)

Task 1.1. Met–ocean description (DNV, IST, GL, EVFH)

Task 1.2. Identification of ships and risk analysis of relevant marine accidents (NTUA, GL, DNV, LR, IST, RINA, DAN, FNK, CAL)

Task 1.3. EEDI and safety criteria (GL, DNV, NTUA, LR, IST, UDE, RINA, DAN, FNK, CAL)

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30-Oct-14
Task 1.1. Met-ocean description
Adverse Conditions - Definition

1.1 "Adverse conditions" mean sea conditions with the following parameters:

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<th>Peak wave period $T_p$, s</th>
<th>Mean wind speed $V_w$, m/s</th>
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<td>7.0 to 15.0</td>
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JONSWAP sea spectrum with the peak parameter of 3.3 is to be considered for coastal waters.

1.2 The following adverse condition should be applied to ships defined as the following threshold value of ship size:

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<th>Ship length, m</th>
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Task 1.1. Met-ocean description

Adverse Conditions - Definition

- Adverse conditions to be analysed from three perspectives:
  - Met-ocean description
  - Ship accident statistics
  - Interviews of ship masters

- Adverse conditions - met-ocean description
  - Developed for coastal waters
  - Deep water
  - Include wind and waves. Current is not included.

- How adverse conditions relate to field data?
- What ship accident statistics is showing?
- Do numerical calculations and model tests confirm these conditions?
Objectives:

- Critical review of adverse conditions in EEDI documents & IMO submissions.
- Effects of ship type and size will be considered.
- Seaway statistics for North Atlantic ship routes (open sea scenario) and in European coastal areas (entranceways to the ports of Rotterdam and Antwerp; North–West Scotland scenario).
- Critical sea state parameters (e.g. spectra) and shallow–water aspects (e.g. topological issues).

- Determined adverse conditions for numerical simulations, model tests and in the case studies, will be revisited based on results and interactions with WP2, WP3, WP6.
Coastal waters
Shipping channels – access to Antwerp

Measuring network:
wind, waves, tide, current

Meetnet Vlaamse Banken

### Wave statistics (example)

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<th>$H_s$ (m)</th>
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**TOTAAL**: 4.85 35.35 39.40 17.23 3.00 0.16 0.01 . . | 100.00
Wind statistics (example)

Correlation
wind speed – wave height

Source:
http://www.vlaamsehydrografie.be/hydrometeoatlas.htm

Shallow water conditions correspond well to the adverse conditions
Different classes:
• Significant wave height
• Tidal level
• Wind direction

Example:
2.50 m < Hs < 3.00 m
3 water level classes
Task 1.1. Met-ocean description
(DNV, IST, GL, EVFH)

- Wave design database for ships, BMT (1986) visual observations, the PM spectrum, IACS 34 Recommendations (2000).

- Operational conditions, visual observations BMT (1986), other data sources, JONSWAP, PM spectrum
Joint probabilities, wind

CMA – marginal distribution and series of conditional density functions

\[ f_{H_m T_p V_c U_w W_1 W_2}(h, t, \theta, v, u, w_1, w_2) = f_{H_m T_p V_c U_w W_1|\theta}(h, t, v, u, w_1|\theta) f_{\Theta}(\theta) f_{W_2}(w_2) \]

- Significant wave height – 3-par. Weibull

\[ f_{H_s}(h) = \frac{\beta}{\alpha} \left( \frac{h - \gamma}{\alpha} \right)^{\beta - 1} \exp \left\{ - \left( \frac{h - \gamma}{\alpha} \right)^\beta \right\} \]

- Wave period – log-normal conditional on Hs

\[ f_{T_p|H_s}(t|h) = \frac{1}{\sigma(h) t \sqrt{2\pi}} \exp \left\{ - \frac{(\ln t - \mu(h))^2}{2\sigma(h)^2} \right\} \]

log-mean and std. are functions of Hs; \( \mu = a_1 + a_2 h_s^{a_3} \) \( \sigma = b_1 + b_2 e^{b_3 h_s} \)
Wind speed – 2-par. Weibull distribution

\[ f_{U_w|H_s}(u | h) = k \frac{u^{k-1}}{U_c^k} \exp \left[ - \left( \frac{u}{U_c} \right)^k \right] \]

Where \( k = c_1 + c_2 h_s^{c_3} \) \( U_c = c_4 + c_5 h_s^{c_6} \) West Shetland

Adverse conditions seem to be more conservative regarding wind
Task 1.1. Met-ocean description
FUGRO- OCEANOR database - WORLDWAVES

Position 1 (54.0°N, 45°W)

Sea states with $H_s \geq 4$ m more often than in coastal areas.
### Task 1.1. Met-ocean description

**(DNV, IST, GL, EVFH)**

- Wave design database for ships, BMT (1986) visual observations, the PM spectrum, IACS 34 Recommendations (2000).

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"Adverse conditions", Uw=19 m/s, for coastal areas JONSWAP gam=3.3

"Adverse conditions" – depending of ship size, ship length below 200 m, Uw=15,7 m/s

30 Oct. 2014

SHOPERA · WP1.1
Task 1.1. Met-ocean description
(DNV, IST, GL, EVFH)

- Sea state steepness, IACS scatter diagram, IACS 34

\[
S_s = \frac{2\pi H_s}{gT_z^2}
\]

\[
S_p = \frac{2\pi H_s}{gT_p^2}
\]

| Hs/Tz | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|       | 0.0256164 | 0.0170858 | 0.0100274 | 0.0062951 | 0.0041038 | 0.0029520 | 0.0021540 | 0.0016476 | 0.0013033 | 0.0010510 | 0.000874 | 0.000753 | 0.000670 | 0.000599 | 0.000539 | 0.000489 | 0.000449 | 0.000413 | 0.000380 |
|       | 0.0138353 | 0.0083400 | 0.0050737 | 0.0031627 | 0.0022544 | 0.0016832 | 0.0013076 | 0.0010563 | 0.0008500 | 0.0006899 | 0.000558 | 0.000443 | 0.000354 | 0.000285 | 0.000226 | 0.000180 | 0.000146 | 0.000119 | 0.000096 |

30 Oct. 2014

SHOPERA - WP1.1
Task 1.1. Met-ocean description
(DNV, IST, GL, EVFH)

- JONSWAP spectrum, gamma parameter, DNV–RP–C205

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High steepness and a narrow wave spectrum can trigger modulational instability → rogue waves
Wave Steepness, DNV-RP-C205
- Hs=5.5m, Tp=7−15s, Lpp>250m
- Hs=4.0m, Tp=7−15s, Lpp≤200m

The limiting values of $S_s$ may, in absence of other reliable sources, be taken as:
- $S_s = 1/10$ for $T_p \leq 6$ s
- $S_s = 1/15$ for $T_p \geq 12$ s

and interpolated linearly between the boundaries. The limiting values of $S_p$ may be taken as:
- $S_p = 1/15$ for $T_p \leq 8$ s
- $S_p = 1/25$ for $T_p \geq 15$ s

and interpolated linearly between the boundaries.

$$S_s = \frac{2\pi}{g} \frac{H_s}{T_p^2}$$

$$S_p = \frac{2\pi}{g} \frac{H_s}{T_p^2}$$
Task 1.1. Met-ocean description
(DNV, IST, GL, EVFH)

- Two peak spectra; e.g. Strekalov & Massel (1971); Ochi (1976), Guedes Soares (1984)
- Two wave systems; total $H_s=5.5m$, $T_p=7-15s$ ($U_w=15.7m/s$), Torsethaugen spectrum (1987, 1993)
Two wave systems; total $H_s=4m$, $T_p=7-15s$ ($U_w=15,7m/s$)
Task 1.1. Met-ocean description
Wave steepness

- Wave Steepness, DNV-RP-C205
- $H_s = 5.5\text{m}, T_p = 7$–$15\text{s}, L_{pp} > 250\text{m}$
- $H_s = 4.0\text{m}, T_p = 7$–$15\text{s}, L_{pp} \leq 200\text{m}$

The limiting values of $S_s$ may, in absence of other reliable sources, be taken as:
- $S_s = 1/10$ for $T_z \leq 6\text{ s}$
- $S_s = 1/15$ for $T_z \geq 12\text{ s}$

and interpolated linearly between the boundaries. The limiting values of $S_p$ may be taken as:
- $S_p = 1/15$ for $T_p \leq 8\text{ s}$
- $S_p = 1/25$ for $T_p \geq 15\text{ s}$

and interpolated linearly between the boundaries.

$$S_s = \frac{2\pi H_z}{g T_z^2}$$
$$S_p = \frac{2\pi H_s}{g T_p^2}$$
Task 1.1. Met-ocean description
Ship routes in the North Atlantic

- Density of VOS reports on the considered area
  Vettor & Guedes Soares (2014).

- Accuracy of the VOS data; bad weather avoidance

HIPOCAS data base
Background of SOLAS:
- HARDER: collisions happen mostly in calm water, and very rare at $H_s > 4.0 \text{ m}$
- Groundings were not taken into account – note however that adverse weather conditions are more relevant to groundings than to collisions
- Therefore, further databases should be evaluated (GOALDS?)

Accident investigation: grounding in heavy weather of bulk carrier *Pasha Bulker*:
- Figure: number of ships at anchor vs. $H_s$: 80% of ships at $H_s=4.5 \text{ m}$ and 20% of ships at $H_s=6.0 \text{ m}$

- Accident investigation reports of MAIB (Marine Accidents Investigation Branch): in work
- Interviews with ship masters (container ships and bulk carriers): in work
- ANEP-79 (2007) Controllability and Safety in a Seaway:
  - Operability for most operations: Bft6, $H_s=4.0$ to $6.0 \text{ m}$
  - Rescue and patrol: no weather limitations
Environmental Conditions

- **MEPC 65/4/3**, Annex 1 (2013), *Minimum Power Guideline*: $H_s = 4.0$ to $5.5$ m
- **SOLAS (HARDER)**: $H_s < 4.0$ m
- **Grounding of bulk carrier** *Pasha Bulker*: $H_s = 6.0$ m
- **ANEP-79 (2007)** Controllability and Safety in a Seaway $H_s = 4.0$ to $6.0$ m (operability) up to maximum wave heights (rescue and patrol)

- **Ongoing work:**
  - Accident investigation reports by MAIB (Marine Accidents Investigation Branch)
  - Interviews with ship masters (container ships and bulk carriers)

- **Masters of about 50 container ships, bulk carriers and tankers have been questioned.**
The first-phase validation of the adverse conditions has been carried out using data from deep water and coastal area as well as ship accident statistics and interviews of ship masters.

The next phase of Task 1.1 will provide, between others, assessment of the probability of occurrence of the adverse conditions along the main North Atlantic routes. Therefore some conclusions presented herein maybe revised in the second phase of Task 1.1.

The occurrence of sea states being in the range of adverse conditions varies significantly in deep and coastal waters.

The suggested sea states may include combined wave systems (wind sea and swell), particularly in deep water. Also wind conditions seem to be different in deep water and coastal areas. Further, current has impact on ships’ manoeuvrability; this effect is still not sufficiently investigated.
Conclusions and way ahead

- Some of the proposed sea states in the adverse conditions are very steep and can trigger very steep abnormal waves. The deep water and coastal data confirm existence of such steep sea states. They are recommended to be investigated further in numerical simulations and model tests as they may impact ships’ manoeuvrability.

- It is also recommended to apply in WP 2 and WP 3 both the PM as well as JONSWAP spectrum with different parameter gamma (e.g. 3.3 and 6.0). The calculations planned to be carried out in WP 2 could also include a two-peak spectrum. The results should be compared with ones obtained by using the proposed adverse conditions.

- Further investigations will need to combine environmental description based on an analysis of new data sets with an analysis of ship accident statistics, especially groundings and strandings in heavy weather, and results from interviews of ship masters.
So far, masters of about 50 container ships, bulk carriers and tankers have been questioned. Questioning of the masters, especially of the ship types not considered so far, is an important activity for the identification of manoeuvrability criteria and environmental conditions.

Distinguishing between coastal areas and open sea needs to continue to the second phase of Task 1.1. It is proposed that to investigate effects of increase of storm intensity with respect to wave steepness and wave height, on ships’ manoeuvrability. For low-speed manoeuvrability criteria, both the wind speed and current speed are recommended to be studied.

Gustiness factor for ship manoeuvrability in wind and in combined waves and wind is to be defined. Wind conditions are the same. Relation between wind speed and wave height is different.
Task 1.1: Met-ocean conditions

Thank you for your attention