SHOPERA

SEVENTH FRAMEWORK PROGRAMME

SHOPERA Project Meeting

Lissabon, 2015-10-14

T1.3. Manoeuvrability Criteria

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[2015-10-14, 9:15-10:00 (15 min.)]

Existing Manoeuvrability Criteria:
IMO Standards for Ship Manoeuvrability

- *IMO Standards for Ship Manoeuvrability*, Res. MSC.137(76), 2002: ship's manoeuvring abilities are evaluated in simple manoeuvres in calm water:

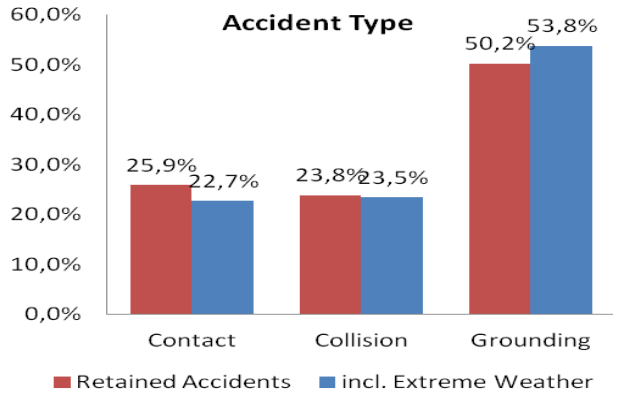
Turning	Initial turning	Yaw-checking
Course-keeping	Emergency stopping	

- Concerns: IMO Standards do not address manoeuvrabiliy
  - in waves and wind,
  - in restricted waters and
  - at low speed

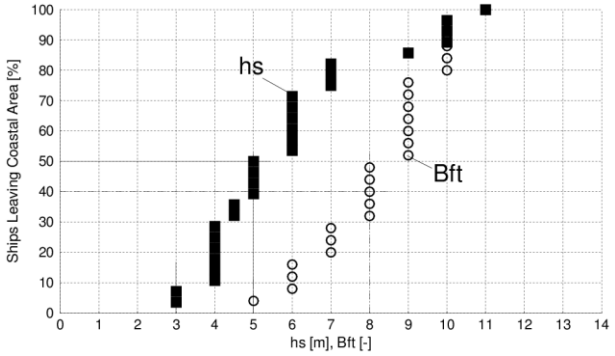
- Is there need for additional criteria?
  - One of the tasks of steering is withstanding environmental forces
  - Because environmental forces are ship-specific,
  - Minimum ability to with stand environmental forces should be normed

Scenarios of Extreme Conditions

- Weather-vaning in extreme weather in the open sea:
  - Less strict requirements to manoeuvring: ship must be able to change heading into seaway and keep this heading
  - Severe weather conditions: => how severe?
  - Is there need for manoeuvrability in extreme seaway?: safety can be ensured by Weather Criterion, even if ship cannot manoeuvre
- Escaping increasing storm in coastal waters:
  - Strong functional requirements to manoeuvrability: In principle, any manoeuvre, in wind and waves from any direction
  - This scenario was the background behind 2012 and 2013 Interim Guidelines
  - Weather conditions are moderate: in increasing storm, captains look for shelter or leave to open sea
- Manoeuvrability at reduced speed in restricted areas:
  - Required during approaching or entering ports: navigational restrictions => low speed, low rudder efficiency
  - Strong wind, frequently strong current, no large waves
  - Such criteria will not lead to minimum power requirements => no potential conflict with EEDI



Accident types with and without extreme weather conditions



Environmental conditions during <u>problems with steering and propulsion ability</u>, both in coastal areas and in the open sea

Manoeuvrability Criteria

- Weather-vaning in extreme weather in the open sea:
  - weather-vaning: ship must be able to change heading into seaway and keep
  - practical criterion: keep heading in bow to bow-quartering waves
- Escaping increasing storm in coastal waters:
  - In principle, any manoeuvre, in wind and waves from any direction
  - Practical criteria: the ship must be able to
    - Keep course in waves and wind from any direction
    - Keep speed of at least 4.0 knots in waves and wind from any direction
- Manoeuvrability at reduced speed in restricted areas:
  - Manoeuvring at reduced speed in strong wind in restricted areas
  - Practical criteria: course-keeping at specified reduced speed
    - in strong wind
    - in shallow water near channel wall or near bank
    - in shallow water during overtaking by a quicker ship

SHOPERA Proposal for Additional Manoeuvrability Criteria: Summary

Scenarios	Functional Requirements	Criteria	Environmental Conditions
Extreme weather in open sea	*Weather-vaning in bow seaway*	1. *Keep heading in bow to bow-quartering waves*	*Severe [to extreme]*
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 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 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 simple model tests / numerical simulations / empirical formulae for different effects
  - Different effects are combined in a simple numerical model

SHOPERA Assessment Procedure: Principles

- FEASIBILITY:
  - Procedure should be based on technology presently available in the industry
  - It should be as accurate as presently practicable and inexpensive
  - Methods and tools should be available to any shipyard and administration

- FLEXIBILITY:
  - Designer and administrations should be free to choose assessment methods: model tests, numerical methods, empirical formulae or combination of these methods, depending on designer needs
  - Designer should be able to leverage innovations when necessary: if high-fidelity assessment methods are used, designer should be able to use them to his advantage (reduction of power)
  - Ease of updates: if better numerical or experimental methods or empirical formulae are developed, procedure should be able to accommodate them without the need to revise Guidelines

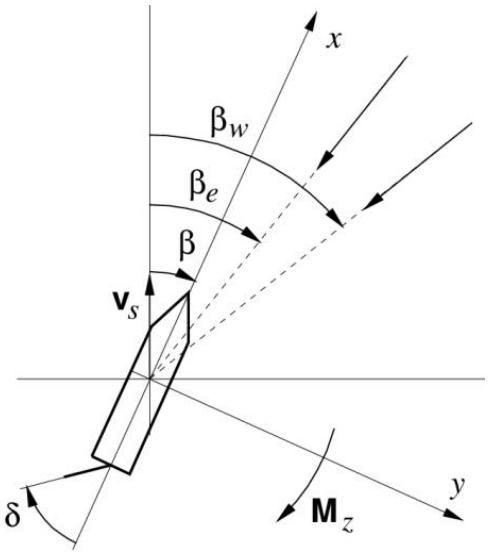
- EASE OF APPROVAL:
  - Despite inevitable simplifications, the procedure should be based on first principles and take into account all relevant physics
  - Procedure should allow verification or replacement of any result during design or approval, without the need to redo the full assessment => modular procedure
  - Each block should be based on simple computations or simple experiments: well-controlled conditions (e.g. steady-state)

SHOPERA Assessment Procedure: Description

$$
\begin{aligned}
X_s + X_w + X_d + X_R + T &= 0 \\
Y_s + Y_w + Y_d + Y_R &= 0 \\
N_s + N_w + N_d + N_R &= 0
\end{aligned}
$$

Calm-water	Wind	Wave drift forces	rudder forces	thrust => power

- Oscillatory wave forces and moments can be neglected, because their time scale is much shorter than time scale of manoeuvre
- Solution of steady equilibrium equations in horizontal under influence of time-average forces (wind, waves, manoeuvring, rudder, propeller …)
- Any contribution can be defined individually, independently from other contributions, with different methods: simple empirical formulae, numerical methods, model tests, …
- Designers have freedom to choose methods for each component depending on particular project needs
- As long as designer can verify methods used, Administrations should approve assessment results
- SHOPERA task: provide ready to use toolbox of different complexity methods for all components



SHOPERA Assessment Procedure: Analogy to MSC.1/Circ.1200

- The sense of the proposed practical assessment procedure is similar to Alternative Assessment of the Weather Criterion, ref. MSC.1/Circ.1200 and MSC.1/Circ.1227 (not hydrodynamically, but methodologically!)
- Although capsize tests at zero forward speed in beam seaway (=Weater 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
- Alternative Weather Criterion procedures are well established in the industry
- Note: Alternative Weather Criterion assessment allows only model tests as methods; SHOPERA approach is much more flexible

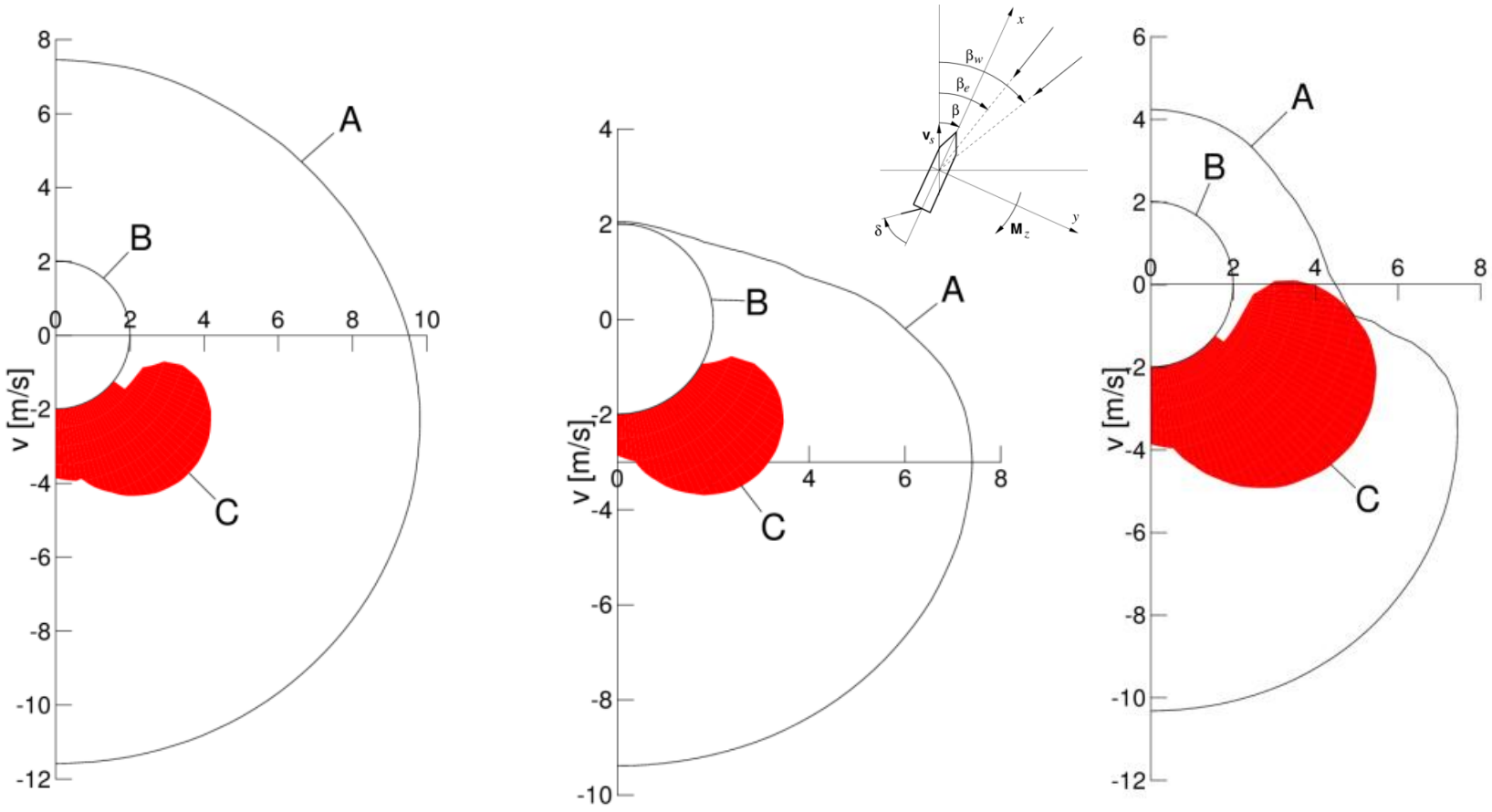
SHOPERA Assessment Procedure: Evaluation of Components

Contribution	Compo-nents	Model Tests	Numerical Methods	Empirical Methods
Calm-water	X,Y,N	Static PMM tests (steady drift)	Double-body CFD simulations (steady drift)	Empirical formulae: Inoue, Kijima, Matsunaga, Kang & Hasegawa
Wave drift forces	X,Y,N	Drift forces in regular waves at different speeds and headings	Drift forces in regular waves: potential methods CFD	Semi-empirical formulae for drift forces at different speeds and headings
Wind forces	X,Y,N	Static wind channel tests	Static wind forces: CFD	Empirical methods: Blendermann data Blendermann formula Fujiwara method
Shallow water, bank, overtaking	Y,N	Static PMM tests (steady drift)	Double-body CFD simulations (steady drift)	Empirical formulae
Rudder forces	X,Y	Static model tests: towing with working propeller	CFD simulations: No free surface Rotating propeller	Semi-empirical method: Söding (ONR, Brix, 1993)
Propeller model: open-water characteristics	T -> J,n,P_D	Open-water propeller tests	Open-water propeller simulations: potential methods, CFD	Propeller series
Engine	P_D available	static model (engine diagramm)		

Required Developments of Methods: Summary

- Model tests: available for all components, acceptable by IMO
- Numerical methods:
  - Available, (perhaps) accepted by IMO: open-water propeller simulations
  - Available; comparison/benchmarking and convincing of stakeholders is required:
    - PMM (steady drift) CFD simulations: unlimited depth, shallow water, bank effects, overtaking
    - Wind forces and moment from CFD simulations
    - Rudder forces in propeller race by CFD simulations
  - Development is required (=> benchmarking, convincing stakeholders):
    - Time-average wave forces (X,Y) and moment (N): potential methods and CFD
- Empirical methods:
  - Available, (perhaps) accepted by IMO: propeller series
  - Available; comparison/benchmarking and convincing of stakeholders is required:
    - Steady calm-water reactions
    - Wind forces and moment
    - Rudder forces in propeller race
  - Development is required (=> benchmarking, convincing stakeholders):
    - Time-average wave forces (X,Y) and moment (N)
    - Shallow water, bank effects, overtaking

Questions?



Lines "required power equal to available power" (A), "advance speed 4.0 knots" (B) and "rudder angle 25° " (C) for situations with sufficient installed power (left); power defined by advance speed in head seaway (middle) and power defined by steering ability in beam seaway (right)