

Prediction of capsizing probability of an intact ship for the performance based criteria



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Contents of the presentation

- Reviewing work for IMO/Intact stability code (IS Code)
 - Revised IS Code
 - Short term and Long term tasks
- Performance based criteria
 - Restoring force variation in waves
(Parametric Rolling, Pure loss)
 - Broaching
 - Stability of the dead ship
- Conclusion

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The review of the Intact stability code

- IMO/Intact stability code (IS-code)
 - The application of Weather criterion on the large passenger ship
 - Parametric rolling of the large container ship
 - An overall review on the basis of the provision of the mandatory part of the code



- Short term: Provision of the mandatory part of the code (finalize: 2007)
- Long term : Performance based criteria
 - Performance based criteria should take account of scenarios
 - Restoring force variation in waves (Parametric Rolling, Pure loss)
 - Broaching
 - Stability of the dead ship



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Outcome of SLF50 (April 30-May 4, 2007)

- Short term task
 - The revision of Intact Stability code (IS-Code) was completed (for the approval and subsequent adoption in MSC 83)
 - [Structure of IS Code]
 - Part A (mandatory) : General Criteria and Weather criterion
 - Part B (recommendation and guideline)
 - Part C (Explanatory note): will be separated as MSC/Circ.
- Long term task (2008-2010)
 - In terms of long term tasks, the Sub-committee agreed to develop enhanced framework for the development of new generation intact stability criteria and to develop procedures for direct assessment (as part of an alternative for published criteria) for the identified phenomena



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Revised IS-Code

● Structure of IS Code

Part A (mandatory) , B (recommendation) and C (Explanatory note)

Part A (mandatory)

$$\int_0^{30(\text{deg.})} GZ(\phi) d\phi \geq 0.055m \cdot \text{rad}$$

$$\int_0^{40(\text{deg.})} GZ(\phi) d\phi \geq 0.09m \cdot \text{rad}$$

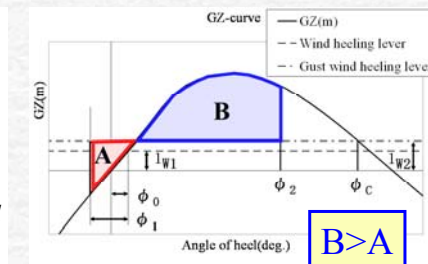
$$\int_0^{40(\text{deg.})} GZ(\phi) d\phi - \int_0^{30(\text{deg.})} GZ(\phi) d\phi \geq 0.03m \cdot \text{rad}$$

$$GZ(\phi_{\max}) \geq 0.2m$$

$$\phi_{\max} \geq 25 \text{ deg rees}$$

$$GM_0 \geq 0.15m$$

General Criteria Res. A.167



Weather Criterion
Res. A.562(14)



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Long term task (2008-2010)

The development of new generation criteria and procedures for direct assessment as part of an alternative for published criteria

1. Stability failures under dead ship conditions
2. Stability failures in following seas associated with matters related to stability variation in waves
3. Stability failures caused by parametric resonance, including consideration of matters related to large accelerations and loads on cargo and stability variation in waves
4. Stability failures caused by broaching including consideration of matters related to manoeuvrability and course keeping ability as they affect stability.



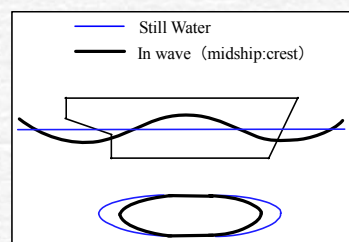
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Parametric Rolling?

- A resonant roll induced by periodic restoring variation in waves. Significant rolling could occur when the roll frequency is equal to half the encounter frequency.
- In following waves with small forward velocity when the GM is small. The ship could face danger of capsizing.
- In head or beam seas when the GM is large. the onboard cargo could be damaged because of large acceleration due to roll.



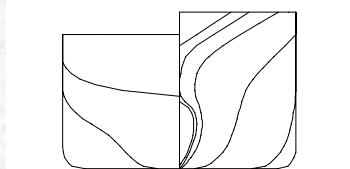
Knee bending corresponds to the periodic restoring variation in waves



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An accident due to parametric rolling

- In the early 1990's, several container ship reported the occurrence of heavy rolling in head seas
- These container ship hull forms characterized by large bow flare and large flaring stern
- An accident of C11 class container (large container) due to parametric rolling
 - Heave to condition in head seas
 - Large roll motion 35deg – 40 deg.



Recent large container (6600TEU post-panamax container)



Cargo damage of the C11 container



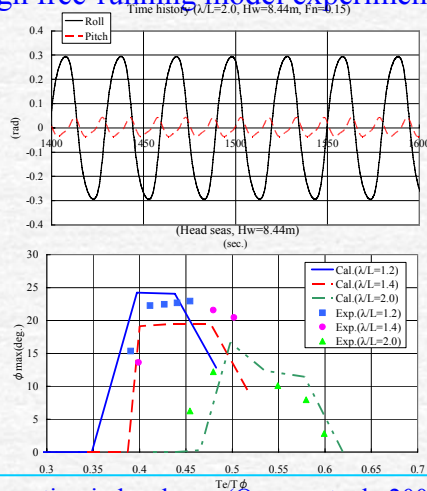
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Estimation of roll motion due to parametric rolling in head seas

- Comprehensive Research through free-running model experiments and computation is carrying out.



Free-running model experiments in NMRI (Taguchi et. al., 2002)



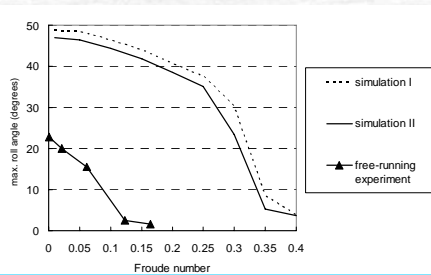
Computation of roll motion in head seas (Ogawa et. al., 2007)

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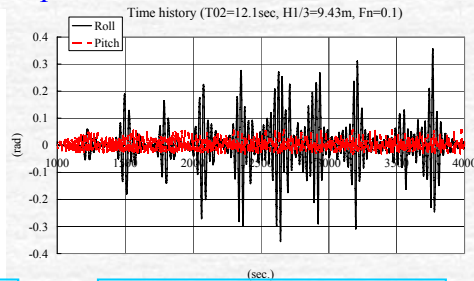
Awaiting solution in terms of parametric rolling

- There are certain discrepancy between experiments and computation in irregular waves.
- The probabilistic theory for parametric rolling is under development.

Extensive research is required for the performance based criteria.



Maximum roll angle in irregular waves (Japan : IMO/SLF49/5/7, 2006)



Simulation in irregular waves (Ogawa et. al., 2007)

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Broaching

- A phenomenon where a ship cannot keep her constant course despite maximum steering efforts.
Often it occurs with surf-riding in following and quartering waves. Sometimes it is reported to occur due to successive wave attacks.



- Numerical model with aid of captive model tests for measuring manoeuvring forces in waves is useful to evaluate broaching. (Hashimot et.al., 2004)

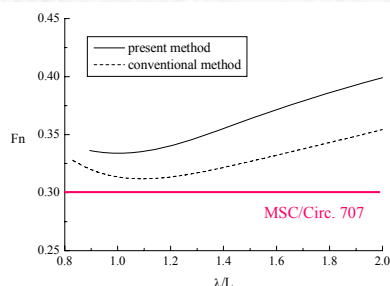
Experiments of broaching in the following seas (80m Square towing tank of NMRI)



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Estimation of broaching

- The direct numerical simulation could provide a more reliable threshold as a function of wave conditions for the given ship.
- Existing Circ.707 as a ship independent guidance specifies it as the Froude number of 0.3 for any ships and any wave conditions.



The surf-riding thresholds for the purse seiner in following seas by numerical simulations (Hashimoto et. al., 2004) with wave steepness 1/10 (Japan :IMO/SLF49/5/6, 2006.)

- Estimation method in irregular waves should be developed.
- Determination of wave conditions should be required for the deterministic performance based criteria



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The importance of operational guidance

- Phenomena such as broaching and parametric roll cannot be completely prevented by design.
- Therefore, measures must be taken in ship operations to avoid these stability failure events.
- The performance-based criteria for design should be applicable for all the modes of stability failures.
- Additionally, the performance-based criteria for parametric roll and broaching should be developed for operational use in the form of on-board ship-specific guidance.

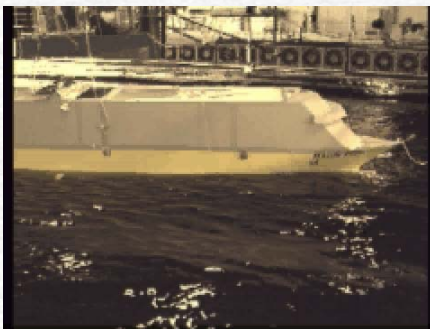
(SLF50/4/4 Japan, the Netherlands and the United States)



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Dead ship condition

SOLAS ChapterII-1 Regulation 3.8 : Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.



Weather Criterion assumes dead ship condition in beam winds and waves.

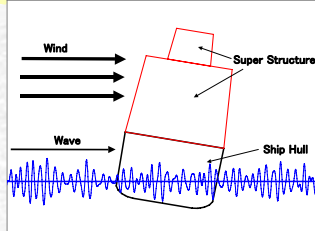
Beam winds and waves are the severest condition for the ship under dead ship condition.

Free drifting test of the large passenger ship in beam winds and waves
(Seakeeping basin in MARIN as a research cooperation)



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New type of ships and weather criterion (WeC)



Recent large passenger ship, Ro-Ro and so forth:
Large windage area and long natural roll period

→ Out of range of the application of WeC

Short term : Not amend the text of IS-code but alternative measure
(alternative assessment of WeC by means of a series of model tests)

Long term: Performance based criterion

→ Needs for the proper prediction method of the capsizing probability
under dead ship condition for ensuring the adequate safety



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Estimation of capsizing Probability by means of the piece-wise linear method (Paroka, 2005)

Long term probability of capsizing

The capsizing probability in a stationary sea state

$$P_N = 1 - \left(1 - P^*(T)\right)^{(N \times 365 \times 24 \times 3600) / T}$$

$$P^*(T) = \int_0^\infty \int_0^\infty \int_0^\infty f(H_{1/3}, T_{01}, W_s)$$

$$\cdot P(H_{1/3}, T_{01}, W_s, T) dH_{1/3} dT_{01} dW_s$$

$$P(H_{1/3}, T_{01}, W_s, T) =$$

$$P_l P_T(\phi > \phi_{m0} \text{ or } \phi < -\phi_{m0}) P_A(A > 0; \phi > \phi_{m0}) +$$

$$P_w P_T(\phi > \phi_{m0} \text{ or } \phi < -\phi_{m0}) P_A(A < 0; \phi < -\phi_{m0})$$

P_T : the probability of at least one up-crossing or down-crossing at the border between the first and second range, ϕ_{m0} or $-\phi_{m0}$

P_l and P_w : the probability of up-crossing toward leeward and that of down-crossing toward windward under the assumption of Poisson process

P_A : the probability of diverging behavior of the roll motion in the second range near to the angle of vanishing stability

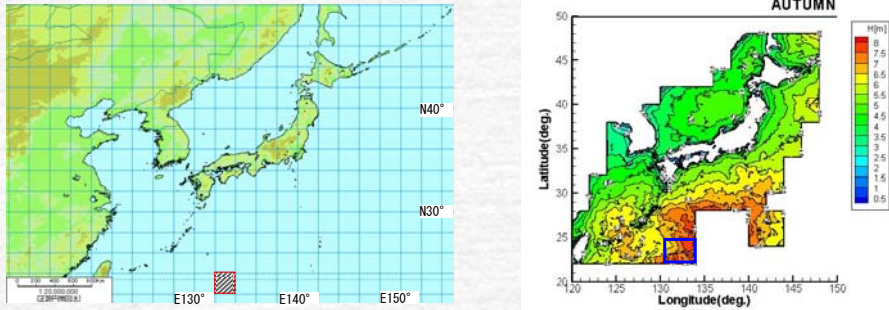
● Beam winds and waves were assumed

● The effect of drift motion was taken into account (Ogawa, 2006)



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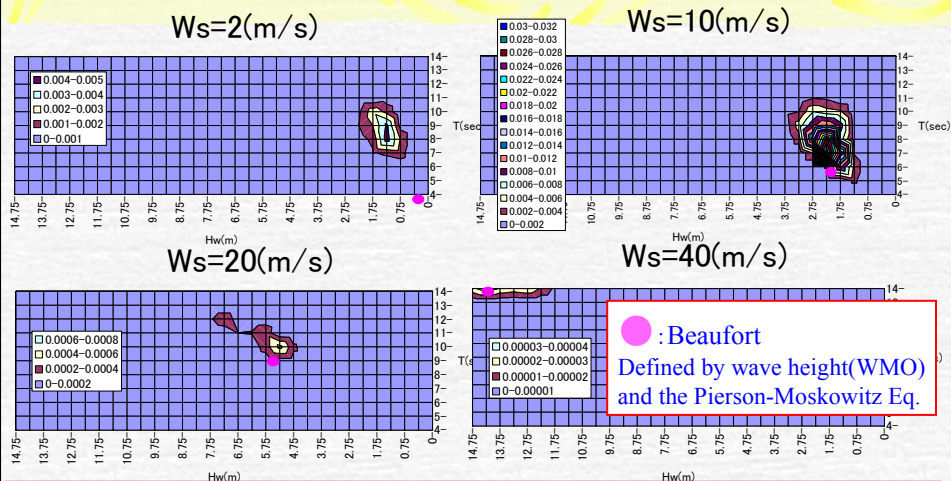
Study for the effect of a correlation of winds with waves on capsizing probability



Sea area : South-east area off the Minami-daito islands
 Domestic regulation for the ship through this sea areas is similar to the international regulation
 Period : 1994-2003(10years), autumn(September-November)
 One of the severest sea area due to typhoon in autumn

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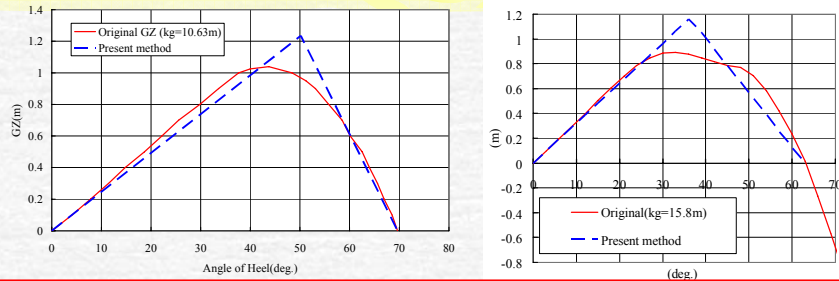
Wave height – period diagram in each wind speed



Wind speed-Wave period : longer than that in Beaufort chart
 Wind speed-Wave height : larger than that in Beaufort chart

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Assessment of the capsizing probability



Piece-wise linear approximation of righting lever curve with critical KG

left: Ro-PAX ferry, right: Large passenger ship

- Large heeling moment due to a large windage area

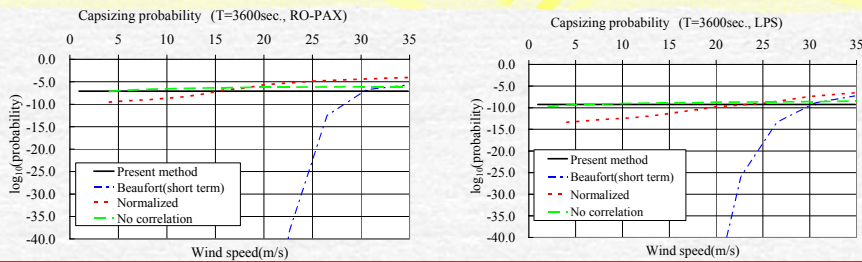
- Wide breadth and shallow draught ($B/d > 3.5$)

: the coefficient of effective wave steepness becomes larger than 1
(incorrect analytically)



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Long term capsizing probability (Ogawa, 2007)



left: Ro-PAX ferry, right: Large passenger ship

- A ship with the loading condition, which is governed by the weather criterion, has an adequate safety in terms of stability under dead ship conditions.

- The correlation of winds and waves has much effect on the capsizing probability and can not be neglected for the rational evaluation of the capsizing probability under dead ship condition



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A way to the performance based criteria

- Stability variation in waves, parametric resonance:
Extensive research is required for the performance based design.
In particular, estimation in irregular waves for the assessment of capsizing and cargo damage is important.
- Broaching:
Estimation method in irregular waves should be developed for the deterministic performance based criteria.
Determination of wave conditions should be required.
- Dead ship condition:
Practical prediction method has been developed.
Through the estimation of the long term capsizing probability, the safety level of conventional vessel should be assessed for the unconventional ships.



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A way to the performance based criteria (continue)

- The importance of operational guidance:
The performance-based criteria for parametric roll and broaching should be developed for operational use in the form of on-board ship-specific guidance.

A part of the present study was carried out cooperating with the Japan Ship Technology Research Association through the part of the Japanese project for the stability safety that is supported by the Nippon Foundation.

Thank you for your attention



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