

New Generation Intact Stability Criteria: Broaching



by

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Introduction

- IMO is going to develop new generation intact stability criteria by 2012 for allowing the use of first-principle tools .
- These will cover
 - Harmonic resonance under dead ship condition,
 - Manoeuvring-related problems such a broaching-to,
 - Stability variation problems such as parametric rolling.
- It was agreed that the new criteria should consist of vulnerability criteria and performance-based criteria, i.e. direct stability assessment.

Introduction

- The intersessional correspondence group on intact stability (ISCG) was established at SLF 51 (July 2008) and was instructed to collect draft criteria and sample calculation results from Member States and NGOs.
- Responding to the invitation, the delegation of Japan submitted its proposals with sample calculation results, which are based on its earlier submission to SLF 51 (SLF 51/4/3), to the ISCG.
- This paper describes the contents of its submission for wider discussion at this conference.

Broaching

- Broaching is a phenomenon where a ship cannot keep constant course despite maximum steering efforts and experiences a significant yaw motion in an uncontrolled manner.
- This could occur with surf-riding or with successive wave attacks.
- The latter mode can be avoided with appropriate steering efforts such as a differential control (Spyrou, 1997) or an optimal control (Maki & Umeda, 2009).
- Therefore, the former case is the target of the design criteria.

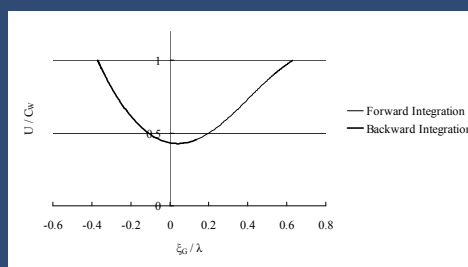
BROACH: vulnerability criterion

- Capsizing due to broaching associated with surf-riding can be prevented if surf-riding is avoided.
- Therefore, surf-riding threshold can be used as a vulnerability criteria.
- Prediction methods of surf-riding threshold for ship self-propelled in regular dead following waves are well established as hetero- or homoclinic bifurcation. Several numerical or analytical methods are available and well validated.
- A remained problem is how to determine wave steepness and wave length for realising appropriate safety level.

BROACH: vulnerability criterion

Numerical global bifurcation analysis

- Makov (1969)
- e.g. Umeda et al. (2007b)

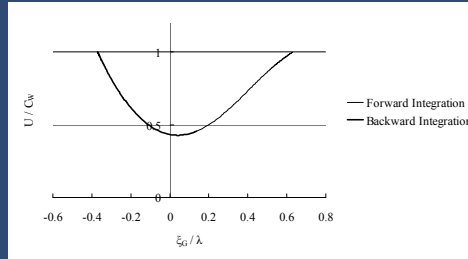


- Perturbation Analysis - Ananniev (1966)
- Melnikov analysis,
 - Kan (1989) by approximating surge damping as linear.
 - Spyrou (2006) by approximating surge damping as cubic.
 - General formula (Umeda et al., 2009) by approximating surge damping as n-th order polynomial.

BROACH: vulnerability criterion

Numerical global bifurcation analysis

- Makov (1969)
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$$\frac{T_e(c_w; n) - R(c_w)}{f} = \sum_{i=1}^n \sum_{j=1}^i \frac{C_{ij} (-2)^j}{\sqrt{\pi}} \Gamma\left(\frac{j+1}{2}\right) \Gamma\left(\frac{j+2}{2}\right)$$

Melnikov analysis

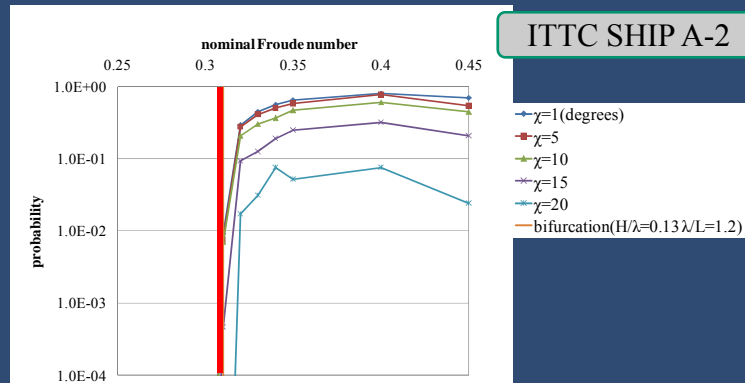
- $C_{ij} \equiv \frac{c_i}{f k^j} \binom{i}{j} \frac{(f k)^{j/2}}{(m + m_k)^{j/2}} c_w^{i-j}$ treating surge damping as linear.
- Spyrou (2006) by approximating surge damping as cubic.
- General formula (Appendix 2) by approximating surge damping as n-th order polynomial.

BROACH: direct assessment method

- Monte Carlo simulation requires prohibitive large costs so that combination of deterministic and probabilistic approach can be recommended. (Umeda et al., 20007c; Themelis & Spyrou, 2007)
- The method by Umeda et al. (2007c) is as follows:
 - deterministic critical zone of capsizing due to broaching is identified by repeating numerical simulation using a coupled surge-sway-yaw-roll model in the time domain.
 - Secondly, the probability density of local wave steepness and wave length, which is obtained from Longuet-Higgins's theory, is integrated within the deterministic critical zone.
 - The wave statistics of the North Atlantic is used for calculating long-term probability.
 - The method was successfully validated with the Monte Carlo simulation.

BROACH: sample calculation

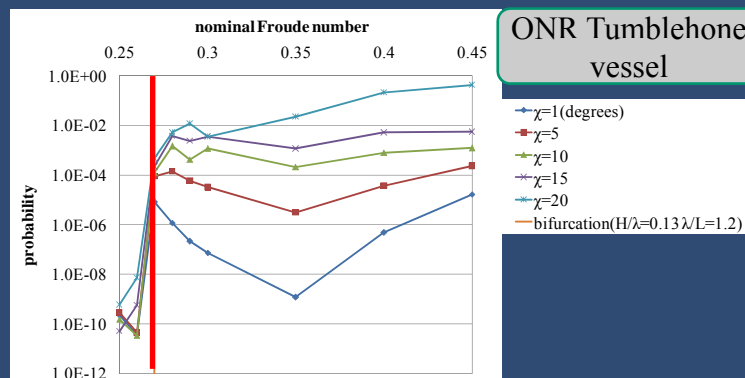
Hourly capsizing probability due to broaching in the North Atlantic



Surf-riding threshold: $F_n=0.310$ with $H/\lambda=0.13, \lambda/L=1.2$.

BROACH: sample calculation

Hourly capsizing probability in the North Atlantic



Surf-riding threshold: $F_n=0.270$ with $H/\lambda=0.13, \lambda/L=1.2$.

BROACH: sample calculation

- For these two ships if we assume that the required safety level in hourly capsizing probability is 10^{-6} , the relevant critical speed for surf-riding can be obtained with the wave steepness of 0.13 and the wave length to ship length ratio of 1.2. Further sample calculations are required to obtain a final proposal.

Concluding remarks

- Sets of vulnerability criterion and direct assessment method for stability under dead ship condition and broaching are proposed together with sample calculation results.

ACKNOWLEDGEMENTS

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