Some Design Criteria in Basic Ship Design

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Ship Design I

MSc in Marine Engineering and Naval Architecture

Design Criteria

- Depending on the type and mission of the ships, during the initial design stage several design criteria can be used to evaluate specific aspects of the ship performance:
  - Intact Stability
  - Damaged Stability
  - Dynamics
  - Maneuverability
  - Course stability
- These criteria can be used either as objective functions of constrains during the ship optimization process
- Each criterion specifies the relevant variables and the acceptance limits
- Empirical methods are presented to determine some of the variables at the initial design stage

Intact Stability

Criteria for Intact Stability (1)

In accordance to IACS (2004) the applicable criteria are:

- Passenger and cargo ships, of any size, with/without cargo on deck:
  - IMO Res. A.749 (18), Chapters 3.1, 3.2 and 4.1, with the amendments from MSC Res.75 (69).
- *Offshore supply vessels*, of any size:
  - IMO Res. A.749 (18) Chapters 3.2 and 4.5, with the amendments from MSC Res. 75 (69).
- Pontoons, of any size :
  - IMO Res A.749 (18) Chapter 4.7 with the amendments from MSC Res. 75 (69).

Criteria for Intact Stability (2)

- Towing Boats:
  - IMO Res. A.749 (18), Chapter 3.1, with the amendments from MSC Res. 75 (69),
  - As an alternative, if applicable:
    - IMO Res. A.749 (18), Chapters 4.5, with the amendments from MSC Res. 75 (69).

Criteria for Intact Stability (3)

- Towing boats (cont.)
  - Additionally:
    - The residual area between a righting lever curve and a heeling lever curve developed from 70% of the maximum bollard pull force acting in 90° to the ship-length direction should not be less than 0,09 m.rad. The area has to be determined between the first interception of the two curves and the second interception or the angle of down flooding whichever is less.
    - Alternatively, the area under a righting lever curve should not be less than 1.4 times the area under a heeling lever curve developed from 70% of the maximum bollard pull force acting in 90° to ship-length direction. The areas to be determined between 0° and the 2nd interception or the angle of down flooding whichever is less.

Criteria for Intact Stability (4)

- Towing boats (cont.)
  - The heeling lever curve should be derived by using the following formula:

$$b_h = 0.7\ TH \cos \Theta / 9.81\ \Delta$$

where:

b_h = heeling arm [m]

T = maximum bollard pull [kN]

H = vertical distance [m], between the towing hook and the centre of the propeller

Δ = loading condition displacement [t]

Criteria for Intact Stability (5)

- Types of ships not included in the IACS recommendation:
  - Fishing vessels
  - Sailing vessels
  - Special purpose vessels, MODUs (Mobile Offshore Drilling Units)
  - Dynamically supported craft
  - Multi-hull craft

IMO A.749 - Non-Passenger Ships

$\int GZ.d\theta$ ($0 < \theta < 30°$) $\geq$	0.055	m.rad
$\int GZ.d\theta$ ($0 < \theta < 40°$) $\geq$	0.090	m.rad
$\int GZ.d\theta$ ($30° < \theta < 40°$) $\geq$	0.030	m.rad
GZ ($\theta = 30°$) $\geq$	0.20	cm
GZ_{max} at angle $\theta \geq$	30°	
$GM \geq$	0.15	m

IMO A.749 – Passenger Ships

$\int GZ.d\theta$ ($0 < \theta < 30°$) $\geq$	0.055	m.rad
$\int GZ.d\theta$ ($0 < \theta < 40°$) $\geq$	0.090	m.rad
$\int GZ.d\theta$ ($30° < \theta < 40°$) $\geq$	0.030	m.rad
GZ ($\theta = 30°$) $\geq$	0.20	cm
GZ_{max} at an angle $\theta \geq$	30°	
$GM \geq$	0.15	m
Heel. Angle Max. (passengers at 1 side)	10°	
Heel. Angle Max. (maneuvering)	10°	

IMO HSC 2000 Stability Criteria

- The High Speed Craft Code (HSC) includes some specific stability criteria (IMO Resolution MSC.97(73), 2001) for:
  - Hydrofoil craft (Annex 6)
  - Multi-hull craft (Annex 7)
  - Mono-hull craft (Annex 8)
- HSC is a craft capable of maximum speed of

$$V(\mathrm{m/s}) \geq 3.6\,\nabla^{0.1667}\ (\mathrm{m}^3)$$

- HSC is applicable to high speed craft engaged in international voyages, either passenger (not more then 4 hours from refuge) or cargo (GT>500 and not more than 8 hours from refuge) at operational speed
- HSC is not applicable to sailing ships, pleasure craft, fishing ships

Intact Stability of Multi-Hull Vessels

- Catamaran vessels have a difficulty in satisfying the generic requirement of GZmax at $\theta \geq 30°$
- HSC defines GZmax at $\theta \geq 10°$ for multi-hull vessels (only for high-speed craft)
- Japan has suggested a specific intact stability criteria for catamarans (SLF 50/4/6, 2007) , which is under discussion, that proposes $\theta \geq 10°$ together with some changes in the other requirements

NES 109 – Naval Ships

$\int GZ.d\theta$ ($0 < \theta < 30°$) $\geq$	0.080	m.rad
$\int GZ.d\theta$ ($0 < \theta < 40°$) $\geq$	0.133	m.rad
$\int GZ.d\theta$ ($30° < \theta < 40°$) $\geq$	0.048	m.rad
GZ ($\theta = 30°$) $\geq$	0.20	cm
GZ_{max} at angle $\theta \geq$	30°	
$GZ_{max} \geq$	0.30	m
GZ ($\theta = 0°$) >	0	m
$GM \geq$	0.30	m
Heeling angle due to Wind <	30°	
Heeling angle Max. (passengers at 1 side)	15°	
Heeling angle Max. (maneuver)	20°	
Angle of extinction of stability $\geq$	70°	

Intact Stability - Empirical Criteria

Rahola Criteria (Any Ships)

GZ ($\theta = 20°$) $\geq$	0.14	m
GZ ($\theta = 30°$) $\geq$	0.20	m
$\theta max \geq$	40°	
$\int GZ.d\theta$ ($0 < \theta < \theta max$) $\geq$	0.08	m.rad

Coastal Ships

$GM \geq$	0.055*B
$GM <$	0.080*B

Criteria Implemented in AVEVA (1)

- IMO A167 Intact Stability Criteria
- IMO 749 Intact Stability Criteria Non-Passenger
- IMO A749 Intact stability Criteria Passenger
- MARPOL 73/78 (Oil tankers)
- Load Line (Oil Tankers > 150m, bulk carriers > 100m)
- PASSENGER Ship Rules (S. I. No. 1216)
- RO-RO Ship Rules
- 1990 PASSENGER Ship Rules (One compartment flooding)
- 1990 PASSENGER Ship Rules (Two or more comp. flooding)
- CHEMICAL TANKERS IMO A212 L > 150
- NES 109 Intact Stability Criteria
- NES 109 Damaged Stability Criteria

Criteria Implemented in AVEVA (2)

- IMO A469 Intact Stability criteria for Offshore Supply Vessels
- SPECIAL PURPOSE SHIPS IMO A534
- USSR 1987 PASSENGER SHIPS
- GAS CARRIERS
- Grain criteria
- Norwegian Fishing Vessel
- CHEMICAL TANKERS IMO A212 L < 150
- NES 109 Intact with ice
- German Ministry of Transport L <= 100
- Mobile Offshore Drilling Units
- MODU Intact Stability Weather Criterion

Damaged Stability

Ship Dynamics

Lamb and Baxter

Period of Roll (*Balanço*)

$$T_{ROLL} = 2.0067 \cdot B \left\{ \frac{0.13 \cdot \left[Cb \cdot (Cb + 0.2) - 1.1 \cdot (Cb + 0.2) \cdot (2.2 - D/T) \cdot (1.0 - Cb) + \left(D/B \right)^2 \right]}{GM} \right\}^{1/2}$$

Period of Pitch (*Cabeceio*)

$$T_{PITCH} = \frac{1.775}{Cw} \sqrt{T \cdot Cb \cdot \left(0.6 + 0.36 \frac{B}{T} \right)}$$

Period of Heave (*Arfagem*)

$$T_{HEAVE} = 2.0067 \sqrt{\frac{T \cdot Cb \cdot \left(0.333 \frac{B}{T} + 1.2 \right)}{Cw}}$$

Acceptance criteria:

$$\frac{T_{ROLL}}{T_{PITCH}} \neq 2.0$$

$$\frac{T_{ROLL}}{T_{HEAVE}} \neq 2.0$$

$$\frac{T_{PITCH}}{T_{HEAVE}} \neq 2.0$$