The fundamental solution against invasive alien species carried by ballast water: Ballast-free ship

Assoc. Prof. Devrim Bülent Danışman
İstanbul Technical University
Naval Architecture and Ocean Engineering Faculty
Ata Nutku Ship Model Testing Labartory

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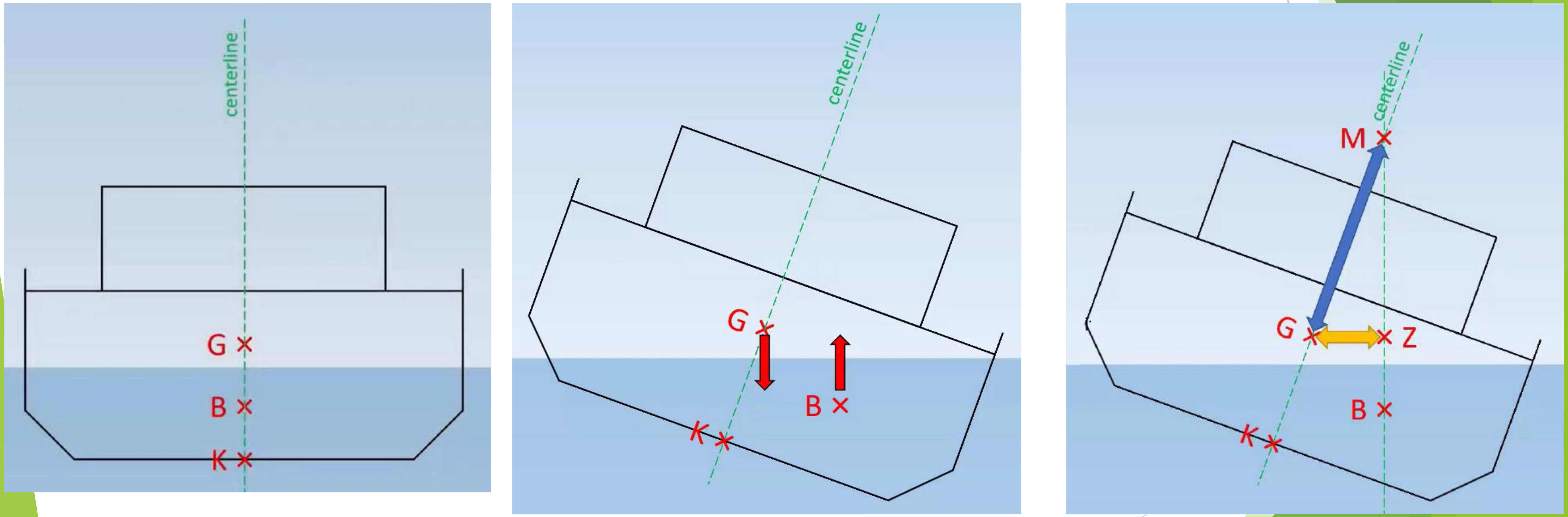
Management in Invasion Alien Species Prevention and Control

Contents

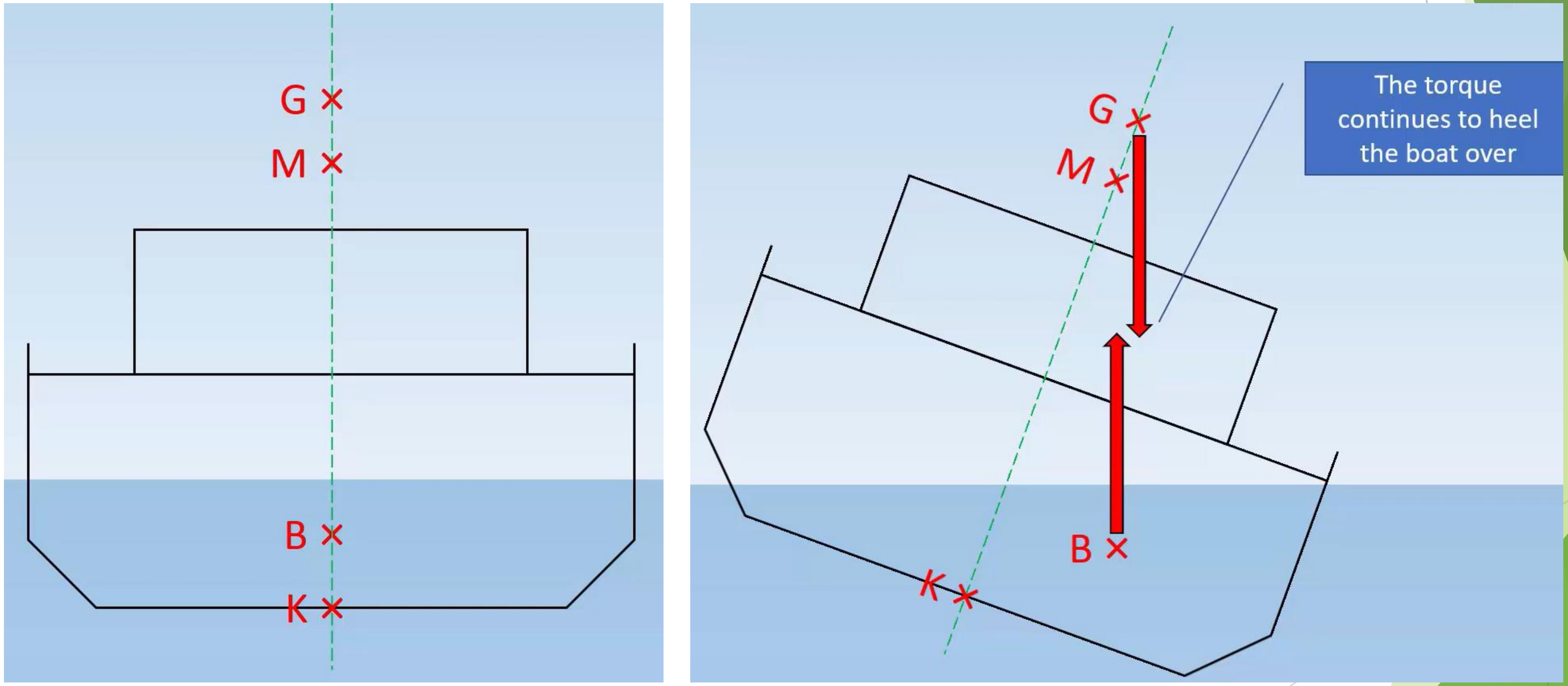
Ballast for ship safety

- Ships are mainly designed for the full load condition.
- Stability problem arises when travelling in empty (lightship) conditions. To overcome this issue ballast water is used to adjust the center of gravity of ships.
- In lightship condition propeller immersion problem occurs. That affects the propulsion efficiency.
- Ships need more ballast water since they are getting lighter due to technological advances.
- Ships need to comply with the IMO's stability criteria for all loading conditions. These regulations include special criteria that prevent ships from being over-stable (stiff) as well.

Ballast for ship safety: Full Load Condition



Ballast for ship safety: Lightship Condition



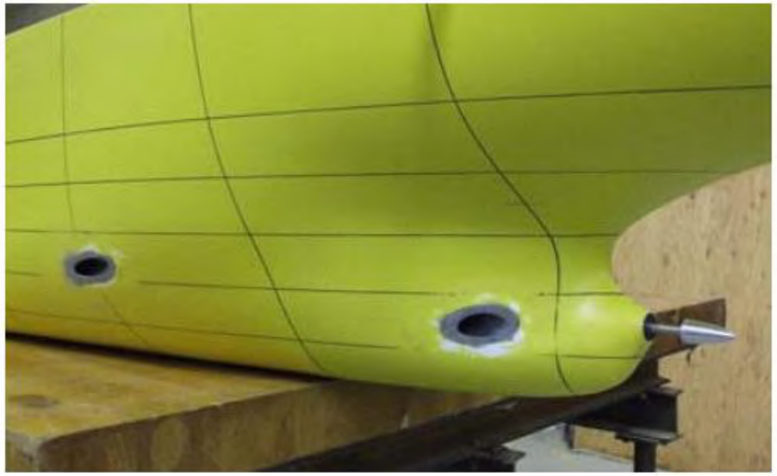
Ballast Operations and Ballast water Treatment Systems

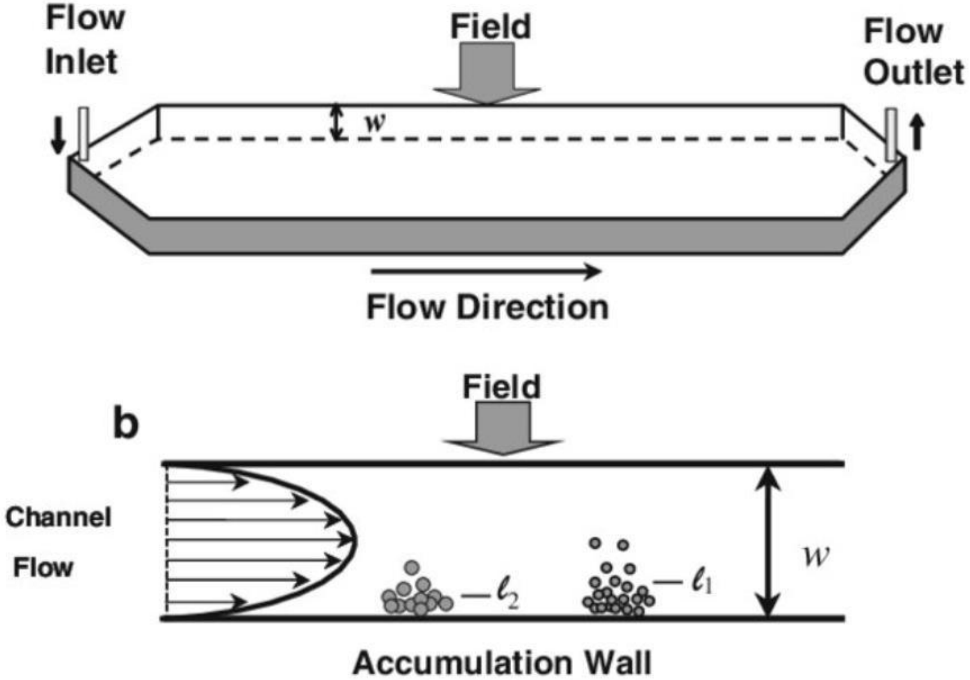
- Ships need to take ballast in order to maintain stability for safety
- Ballast operations need to be planned carefully in order to prevent structural damage on ships.
- The use of BWTS by ships is mandatory from 2024
- BWTS increase the complexity of the ship piping systems. Ballasting duration becomes very long which has an adverse effect on the safety of the seas.
- BWTS need a significant amount of electrical power, this increases the load on the ships' generators as well as adversely affects the carbon footprint.
- BWTS cannot completely prevent sediment accumulation due to the filtering capacity. Additionally, some BWTS do not include pre-treatment systems. As a result, Some species that survive the ballast treatment system may find a home in the sediment accumulated in the ballast tank.
- The obvious solution: Ballast-Free Ships

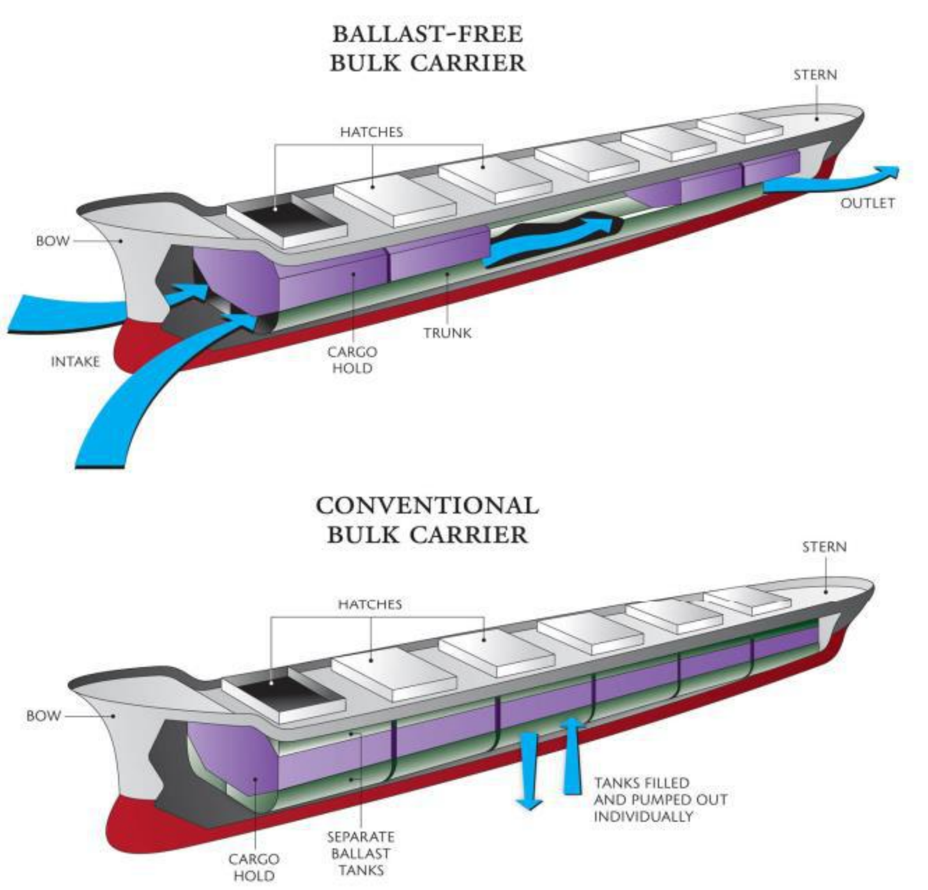
Ballast-free ship classifications

- Bouyancy control-based designs
- Hull form geometry-based designs
  - Monohull concepts
  - Multihull concepts

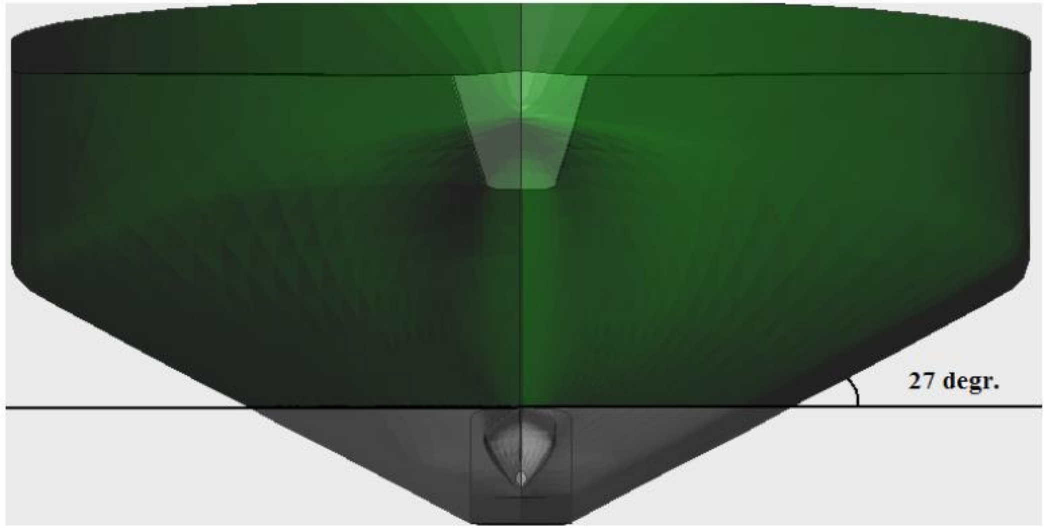
Buoyancy control-based designs (Kontinis 2010)



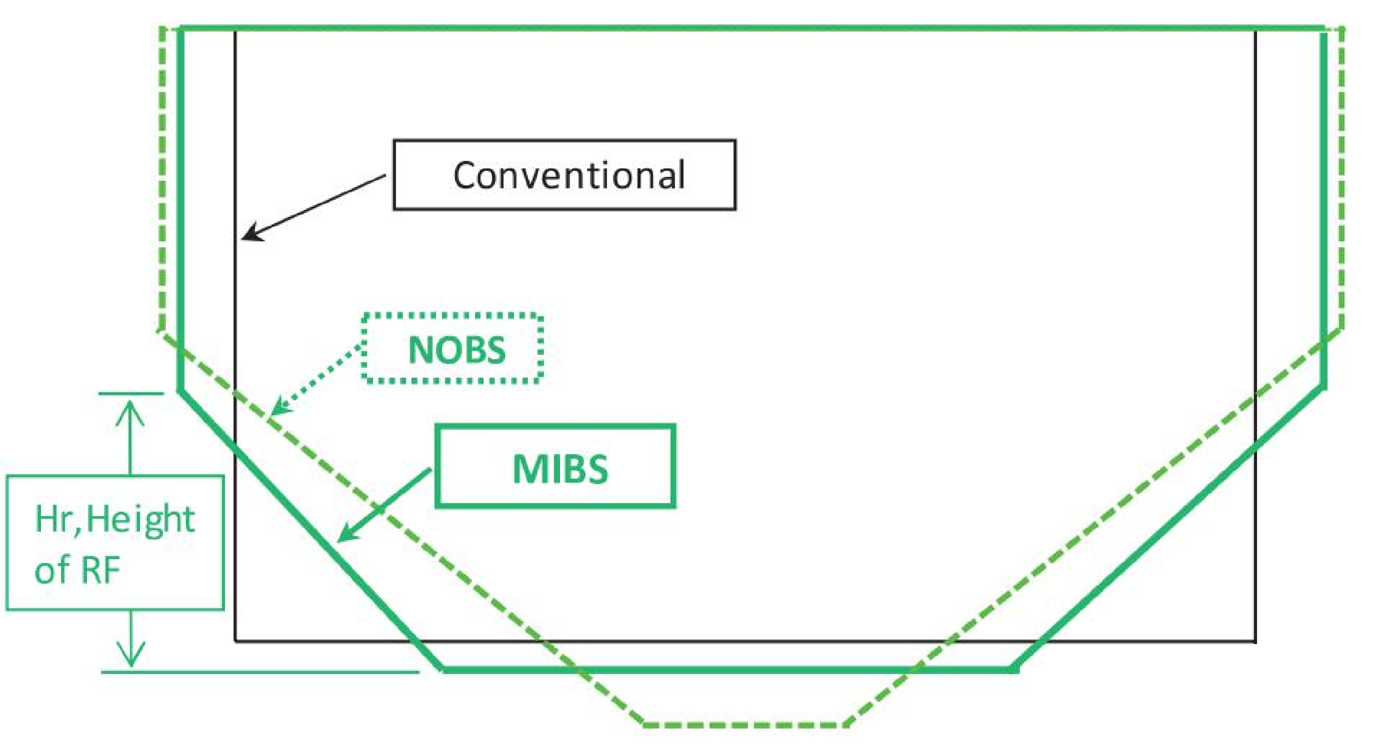




Hull form geometry-based designs
Monohull concepts

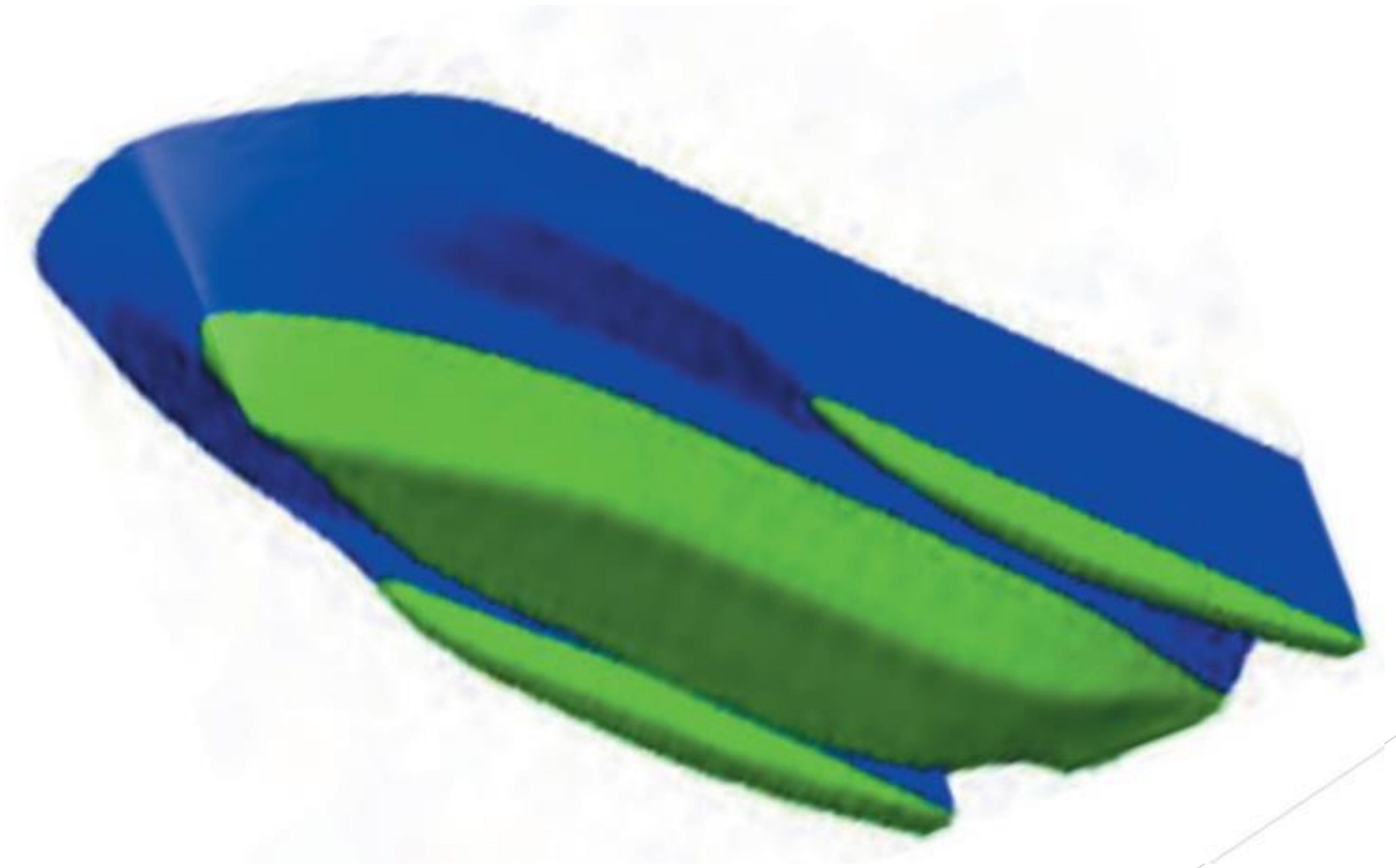


King (2010)

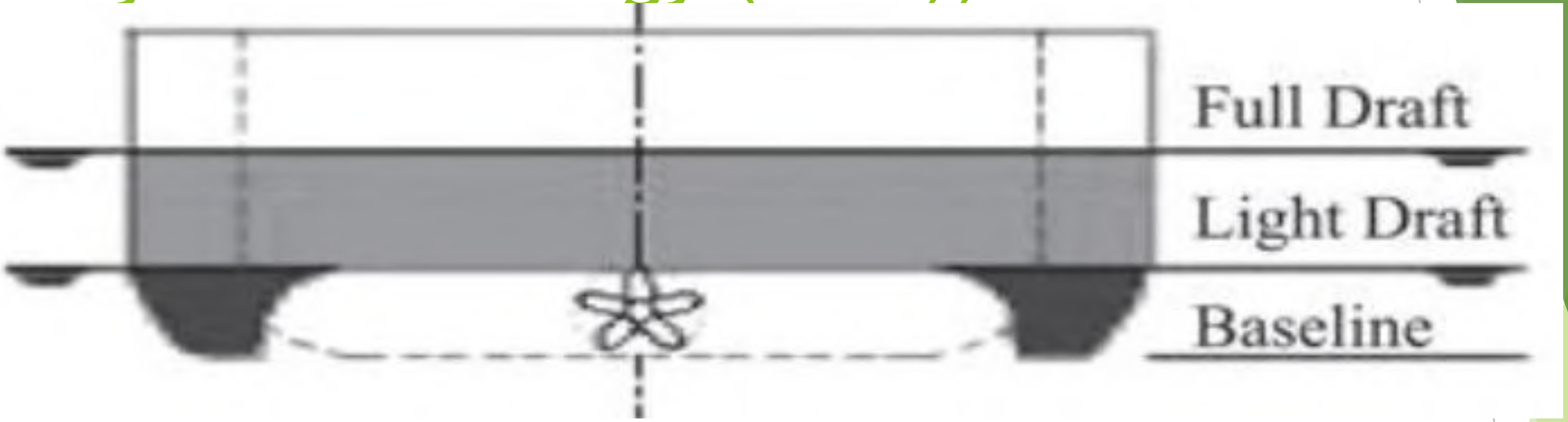


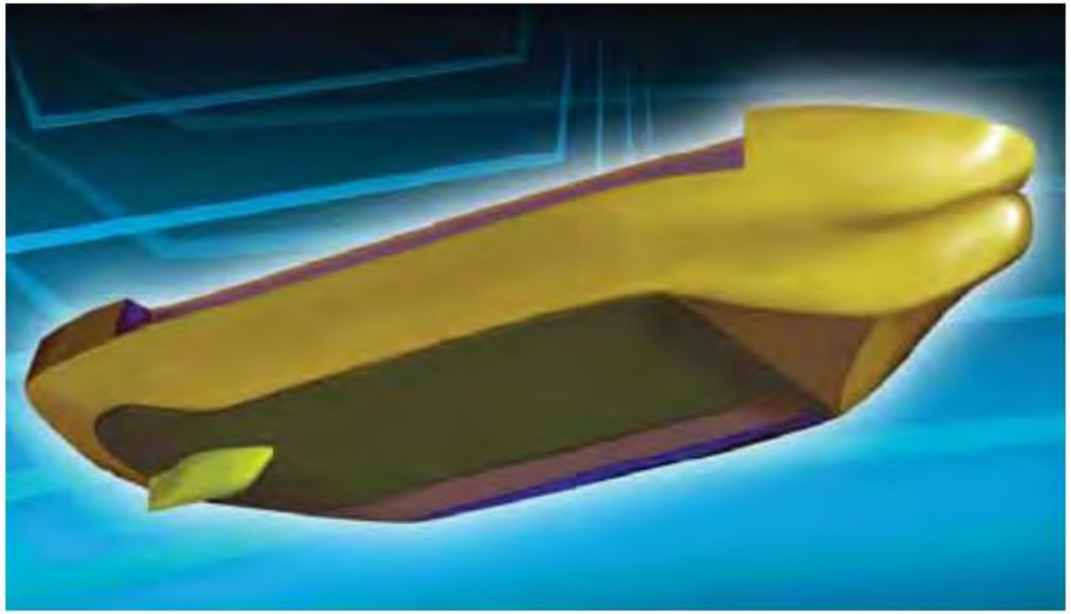
Kashiro (2017)

Multihull concepts: Cathedral Hull (DNV Concept)



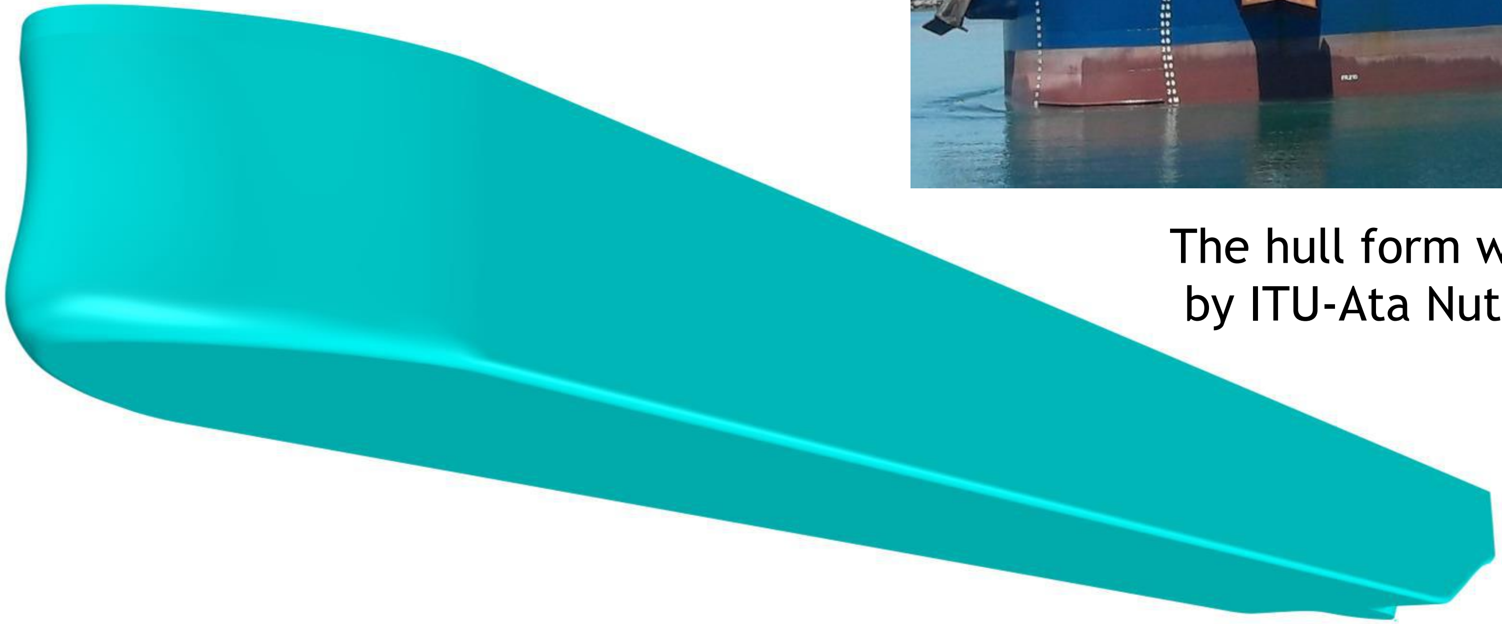
Multihull concepts: Monomaran (Delft University of Technology (DUT))





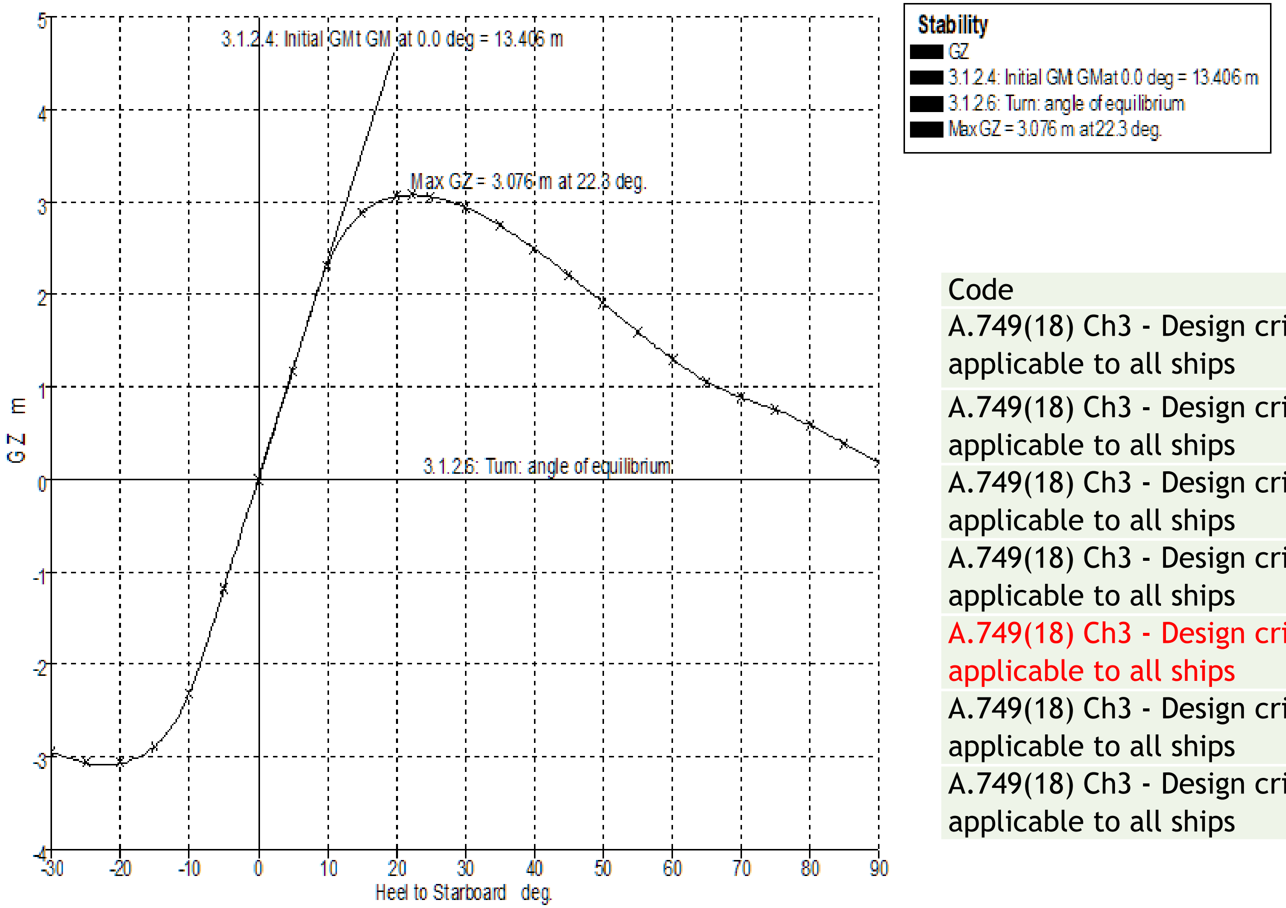
Designing a Ballast-free equivalent of an existing Bulk Carrier (MAORI)

Length	140.422	m
Beam	17.000	m
Draugth	5.527	m
Loaded Displacement	12171	ton
Ballast Displacement	7518	ton
Lightssip	2856	ton
Design Speed	10	knot



The hull form was designed and model tests performed by ITU-Ata Nutku Ship Model Testing Laboratory

Stability Calculations for Lightship Condition

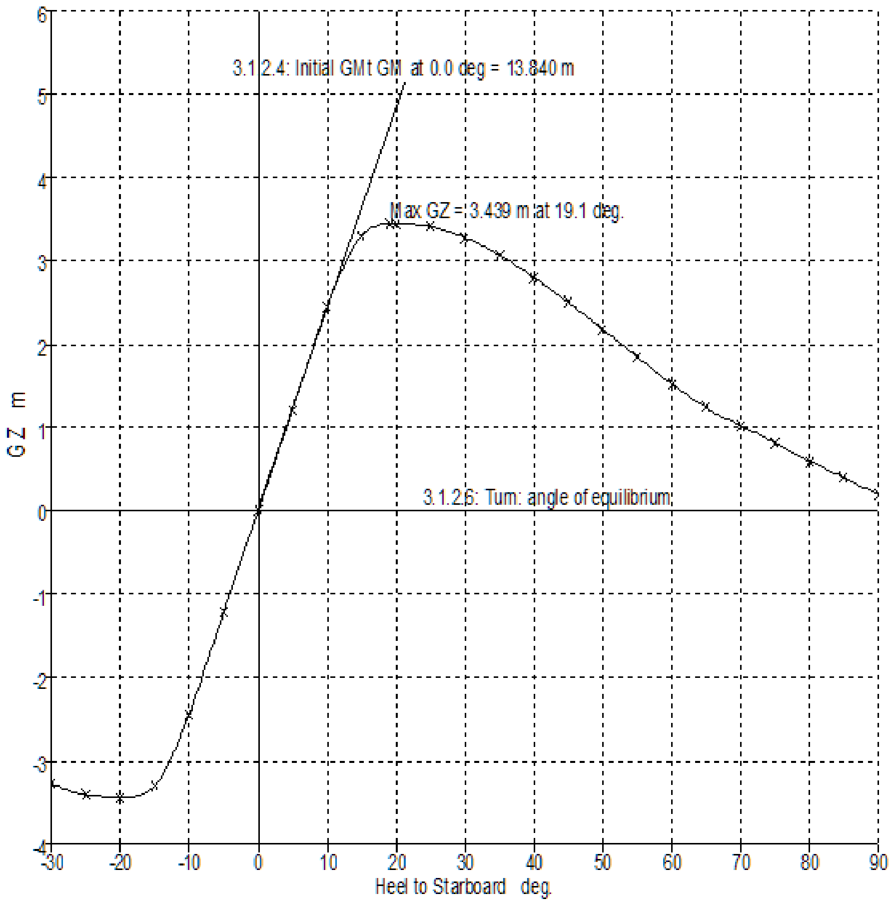


Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 30	3.1513	m.deg	70.2583	Pass	+2129.50
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 40	5.1566	m.deg	97.6115	Pass	+1792.94
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 30 to 40	1.7189	m.deg	27.3531	Pass	+1491.32
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.2: Max GZ at 30 or greater	0.200	m	2.939	Pass	+1369.50
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ	25.0	deg	22.3	Fail	-10.91
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt	0.150	m	13.406	Pass	+8837.33
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.6: Turn: angle of equilibrium	10.0	deg	0.0	Pass	+100.00

Stability calculations made by using Maxsurf-Stability Software

Ballast-Free Design - Monomaran

Monomaran - Stability Calculations for Lightship Condition

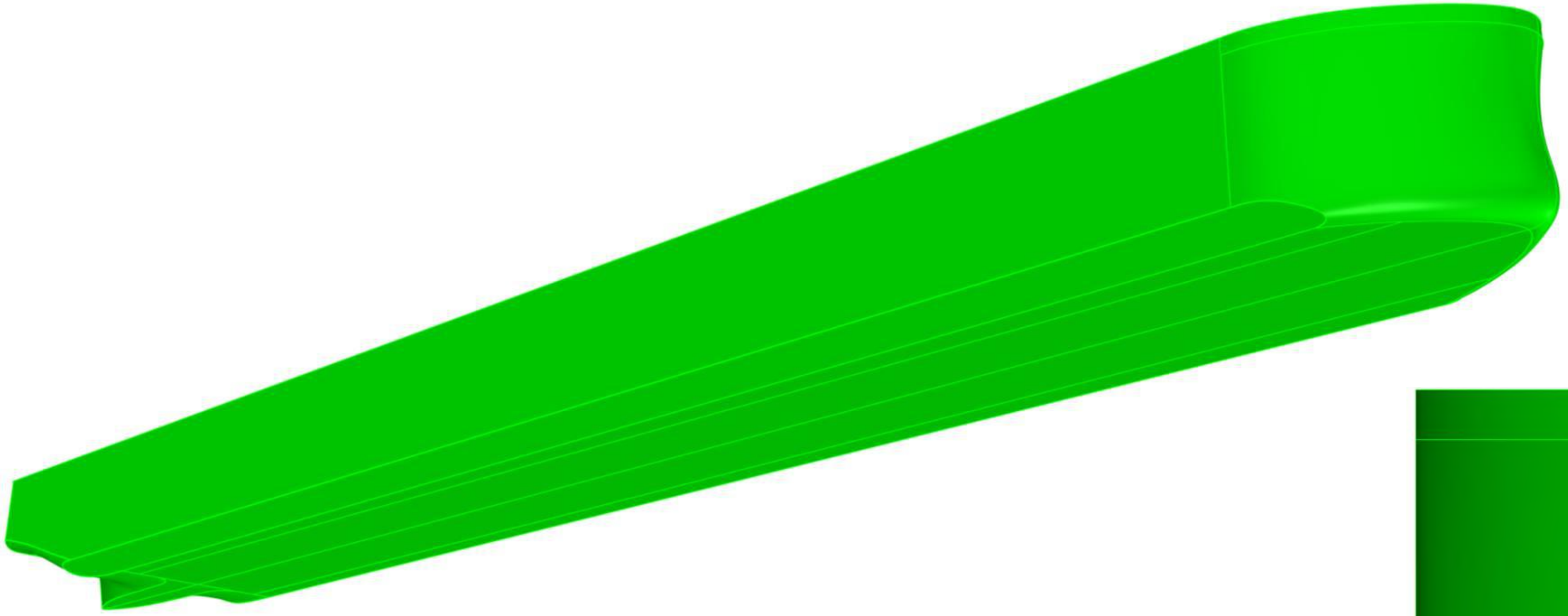


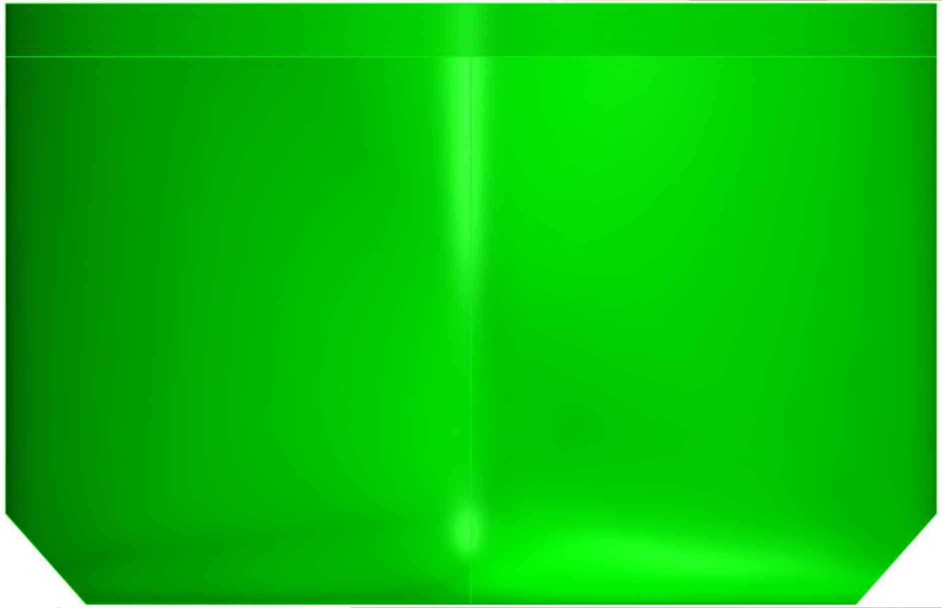
Stability
- GZ
- 3.1.2.4: Initial GMt GMat 0.0 deg = 13.840 m
- 3.1.2.6: Turn: angle of equilibrium
- Max GZ = 3.439 m at 19.1 deg.

Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 30	3.1513	m.deg	77.7179	Pass	+2366.22
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 40	5.1566	m.deg	108.2901	Pass	+2000.03
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 30 to 40	1.7189	m.deg	30.5722	Pass	+1678.59
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.2: Max GZ at 30 or greater	0.200	m	3.275	Pass	+1537.50
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ	25.0	deg	19.1	Fail	-23.64
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt	0.150	m	13.840	Pass	+9126.67
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.6: Turn: angle of equilibrium	10.0	deg	0.0	Pass	+100.00

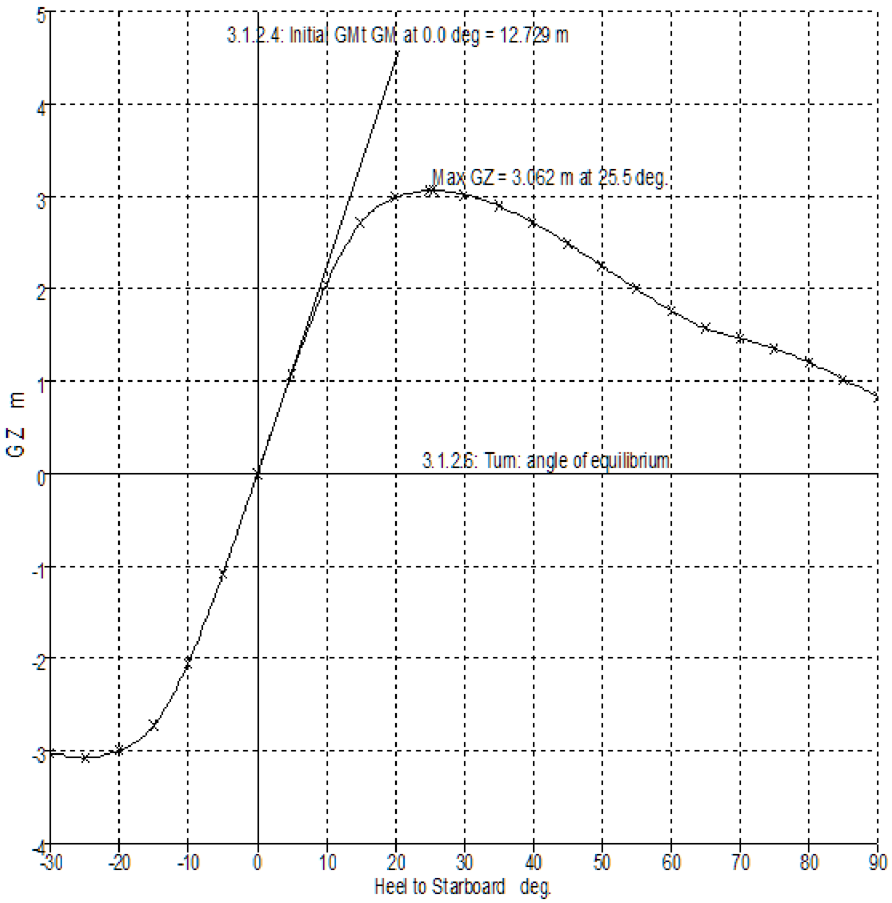
Stability calculations made by using Maxsurf-Stability Software

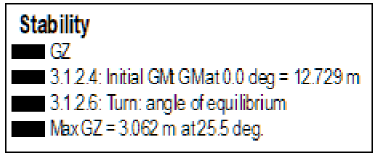
Ballast-Free Design – Chamfered Mid-Ship Section





Chamfered Hull - Stability Calculations for Lightship Condition





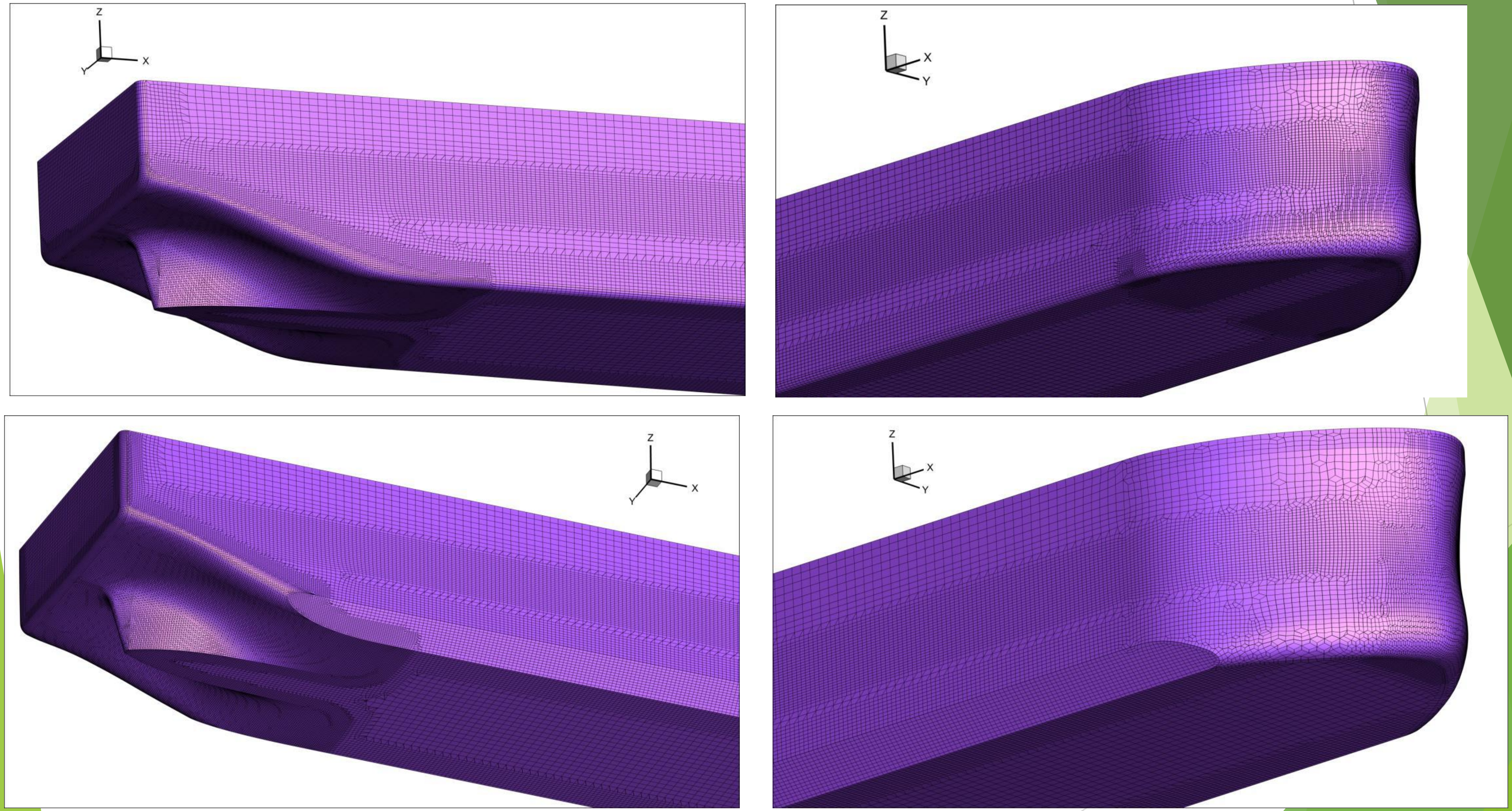
Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 30	3.1513	m.deg	67.4328	Pass	+2039.84
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 40	5.1566	m.deg	96.2757	Pass	+1767.04
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 30 to 40	1.7189	m.deg	28.8429	Pass	+1577.99
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.2: Max GZ at 30 or greater	0.200	m	3.019	Pass	+1409.50
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ	25.0	deg	25.5	Pass	+1.82
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt	0.150	m	12.729	Pass	+8386.00
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.6: Turn: angle of equilibrium	10.0	deg	0.0	Pass	+100.00

Stability calculations made by using Maxsurf-Stability Software

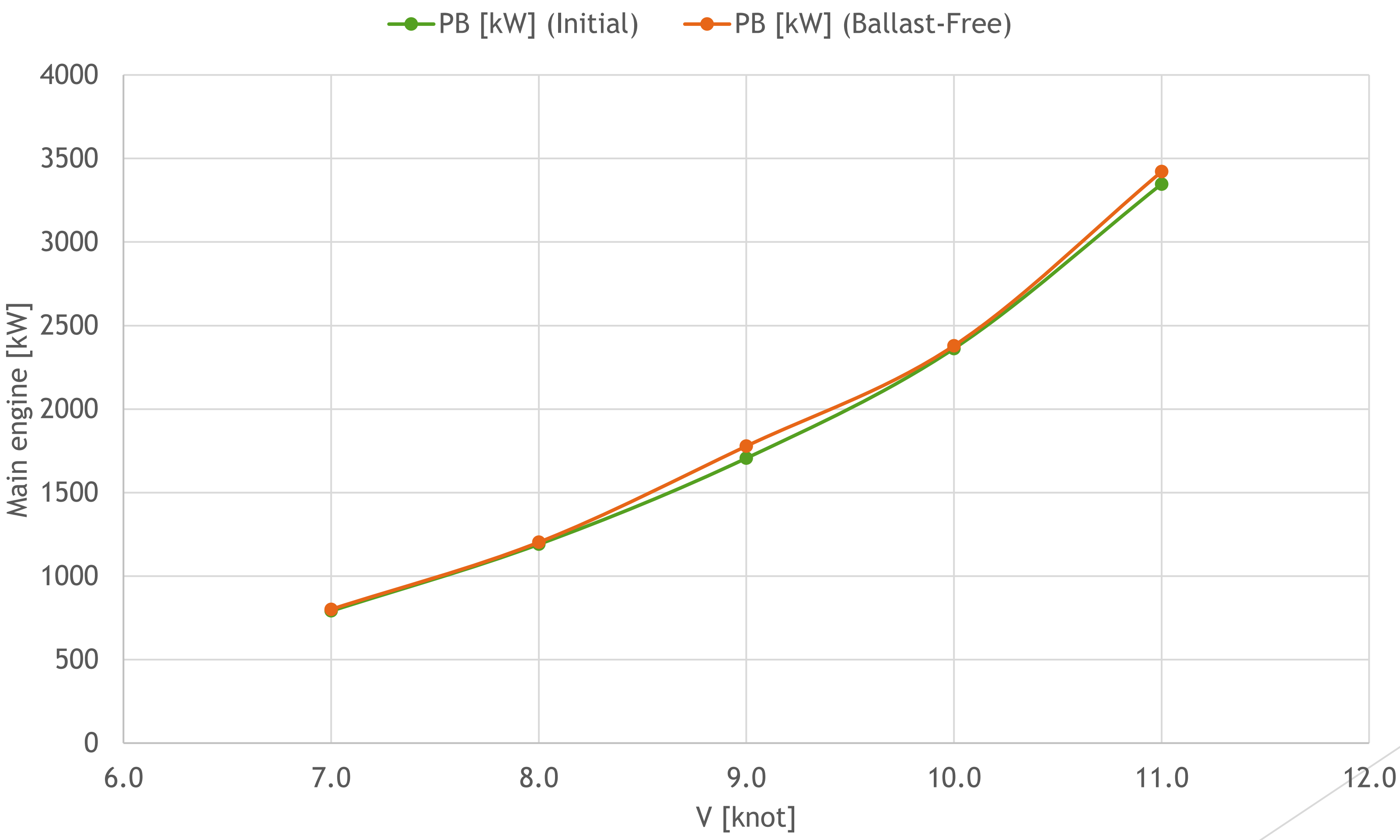
Hydrodynamic Performance Evaluation by means of a computational study

- The initial and ballast-free hulls put into a CFD study to investigate the change in engine power demand at the design speed
- Numeca Fine / Marine software is used under an Academic License. The software has been widely used in projects performed in the ITU-Ata Nutku Ship Model Testing Laboratory.
- Both hulls were put into the computational study for a speed series to obtain a power curve.

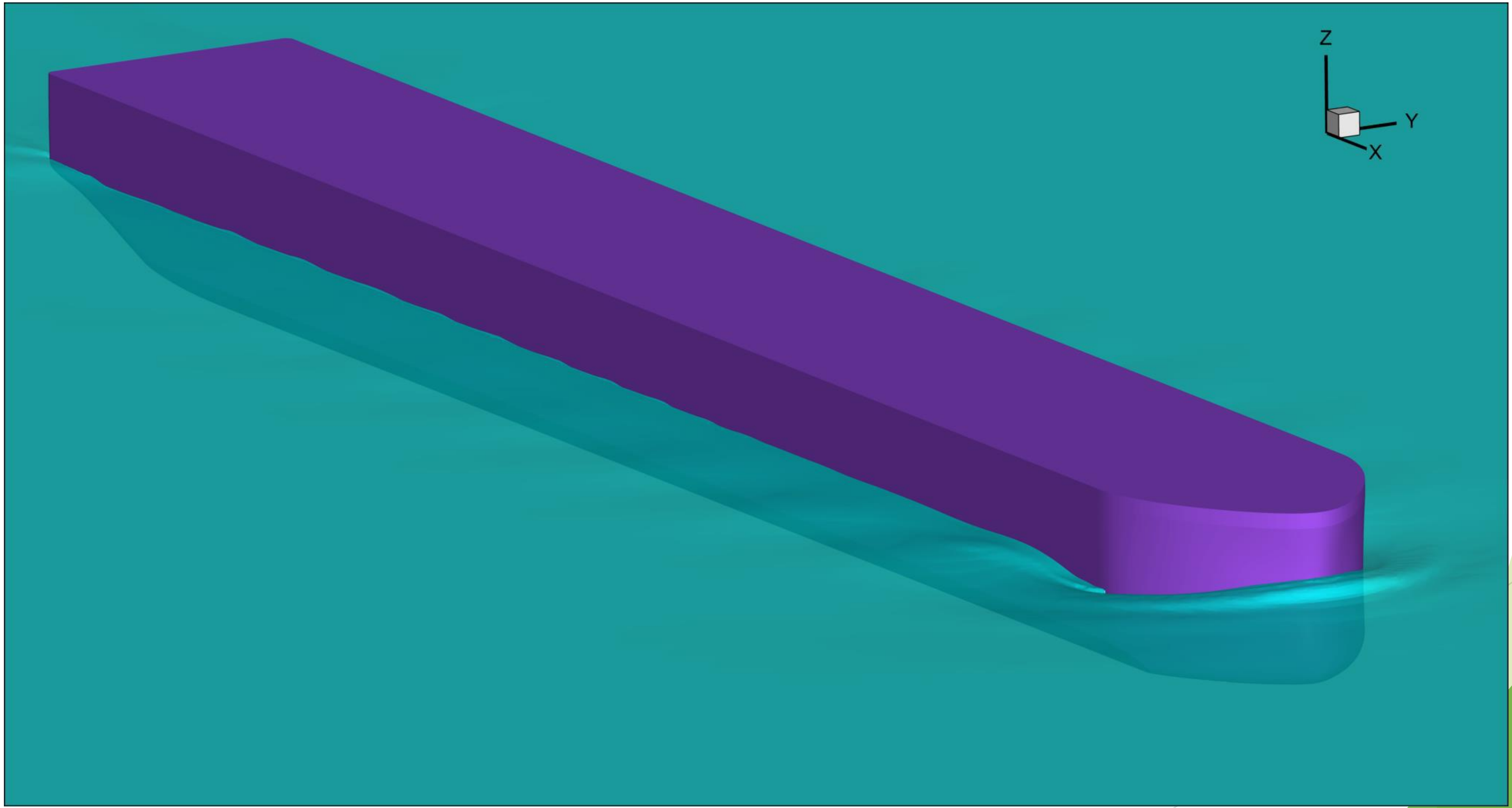
Grid discretisation for initial and ballast-free design
Approx. 1.4 M volume elements.



Main engine power comparison



Wave deformations around the ballast-free ship



Conclusion

- Ballast-free ship design is possible
- In this particular example the power increase is negligible so the EEDI value is not affected.
- There are several additional issues to be addressed like structural design, propeller immersion and, class approvals.
- Ballast-free ships may need to carry permanent ballast to adjust trim and heel. Trim correction in rivers is mandatory.
- Ballast-free hull design varies according to the ship type and initial stability calculations. For instance, if the ship has a full hull form and a large GZ value chamfered hull form may be preferred.
- Monomaran type hull form is worth investigating, especially for the ships that have negative GZ value at the lightship condition.
- Computational studies should be verified by the towing tests.

ITU – Naval Architecture and Ocean Engineering Faculty
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