University of Stavanger

A parametric study on the initial transverse stability of suspension ships

CoTech#90

Jialin Han[1]

Motohiko Murai[2]

1. Faculty of Engineering, Yokohama National University
2. Faculty of Environment and Information Sciences, Yokohama National University

YNU 横浜国立大学 YOKOHAMA National University

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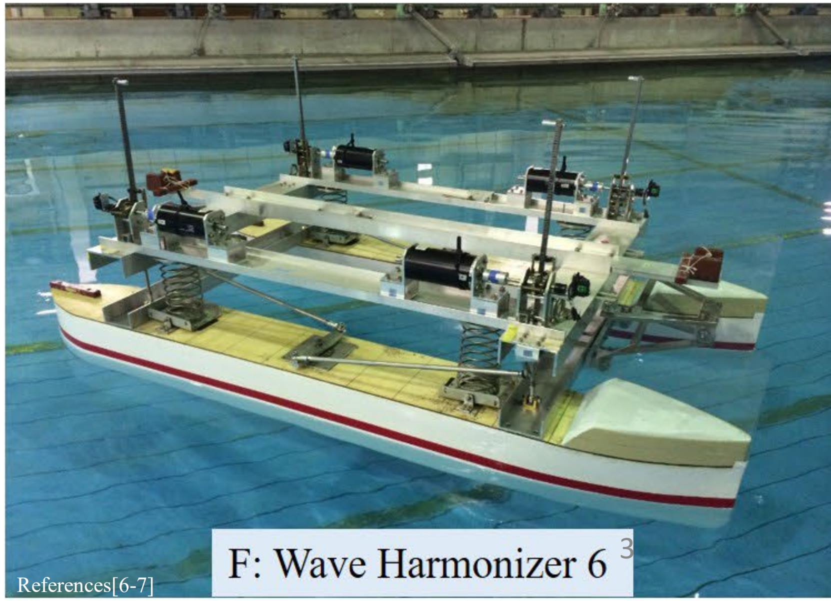
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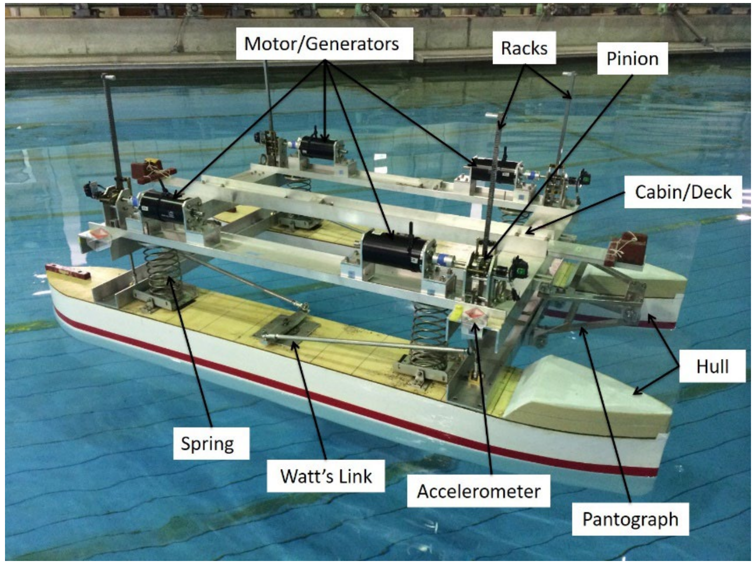
Introduction

- What is a suspension ship?



✓ 9 degree-of-freedom;
✓ Heave, pitch, and roll motions of the cabin are separable from those motions of the hull; while relative yaw, sway, and surge between the two are constrained;
✓ The motion of the cabin and the hull can be modified by using appropriate control systems.

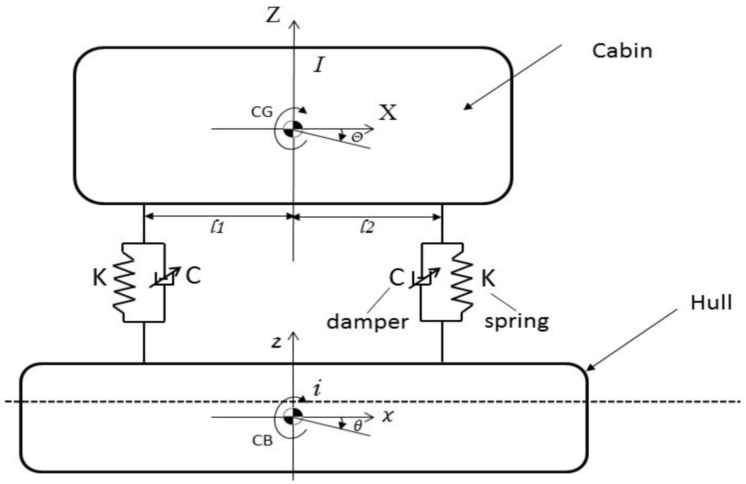
- Why use suspensions on a ship?

Source: Photobucket, Road Surface

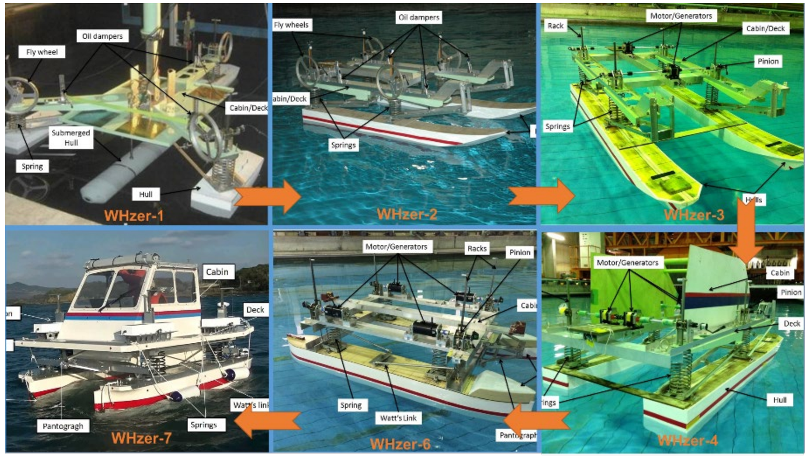
Source: Wikipedia, Natural Resource

Source : Auto.howstuffworks

Source: www.velodynemarine.com



- What are the objectives of this study?



✓ Several types of suspension ships have been developed and tested in a towing tank.
✓ Control strategies have been proposed and verified in those experiments.

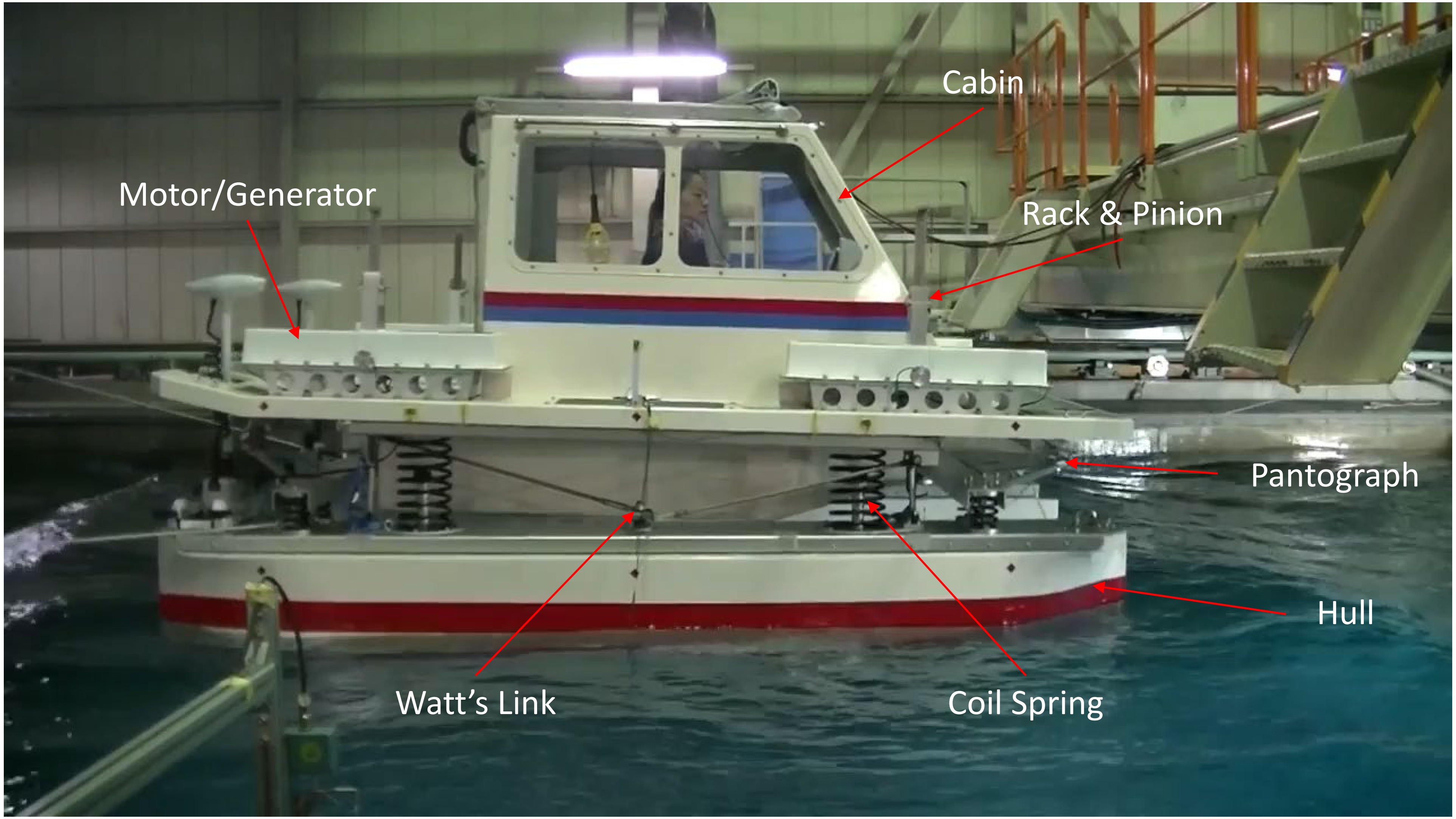
☐ Investigate characteristics of the initial transverse stability of suspension ships;
☐ Provide a deeper insight into the structure design of suspension ships.

Design Principle of Suspension Ships

Safe

&

Comfortable



Feature of suspension ships

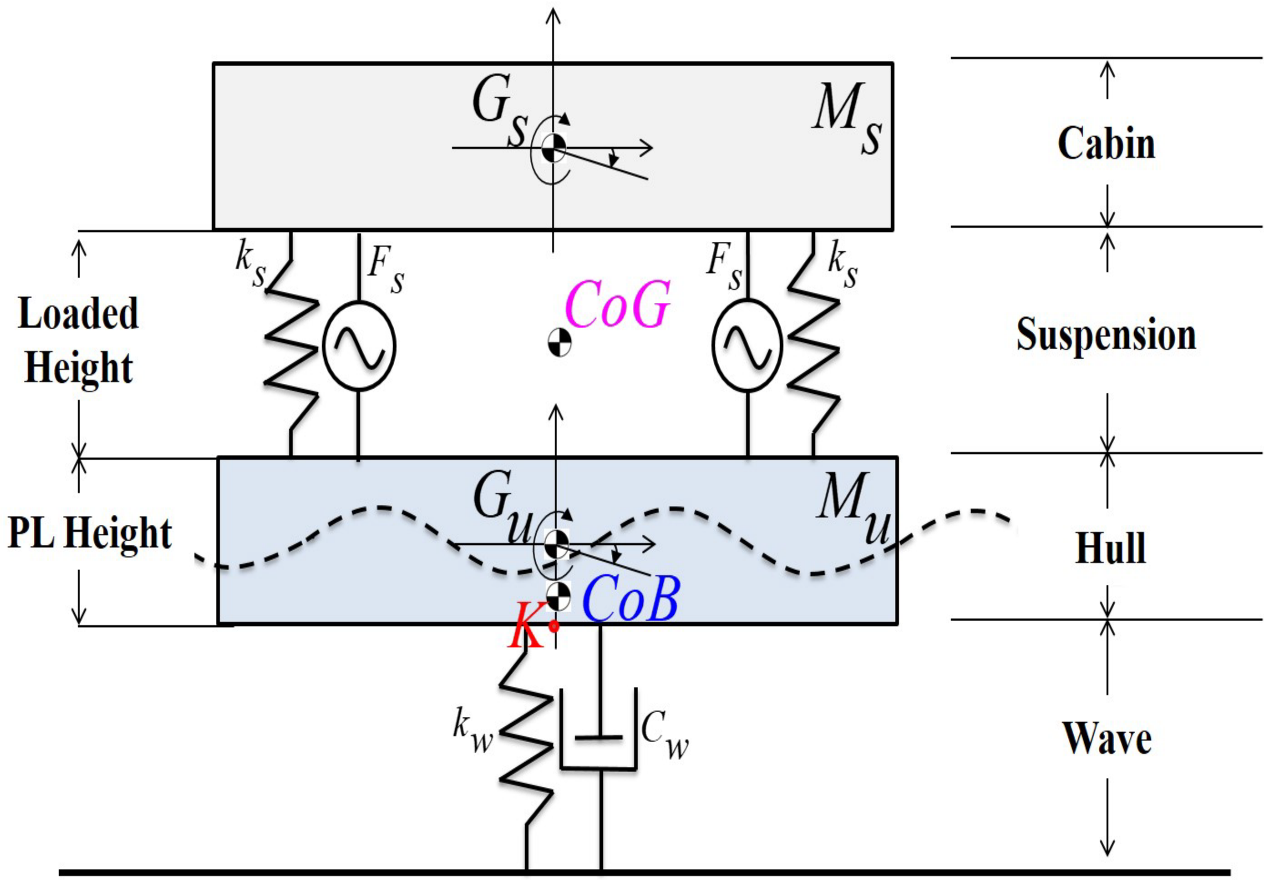


Fig.1 Structure diagram of suspension ships.

- **Dynamic Mass ratio**:

$$q = \frac{M_s}{M_u}$$

Ms: Sprung mass; *Mu*: Unsprung mass

- **Static Mass ratio**:

$$p' = \frac{M_{cabin}}{M_{hull}}$$

M_{cabin}: mass of cabin; M_{chull}: mass of hull;

- **Loaded Height**:

$$H_L(k_s, L_f, M_s)$$

k_s: spring stiffness; L_f: free length of spring

- **Placement Location Height**:

$$H_{PL}$$

- **Beam of Ship**:

$$B_{hull}, BoA$$

Initial Transverse Stability (GM)

Table 1. Design specifications of a suspension model

Item	Value
mass of cabin M_1	2.5 kg
mass of suspension M_3	2.6 kg
mass of hull M_2	1.3 kg
spring stiffness k_s	235 N/m
free length of spring L_f	0.22 m
Diameter of spring	0.05 m
Dimension of cabin L_1, H_1, B_1	L0.5 m H0.20 m B0.15 m
Dimension of hull L_2, H_2, B_2	L0.5 m H0.15 m B0.15 m

Metacentric height GM:

$$GM = KB + BM - KG$$

where, $KB = \frac{d}{2}, BM = \frac{I_L}{\nabla}, KG = \frac{M_1 KG_1 + M_2 KG_2 + M_3 KG_3}{M_1 + M_2 + M_3}$

$GM = -0.2387 < 0$ **unstable!**

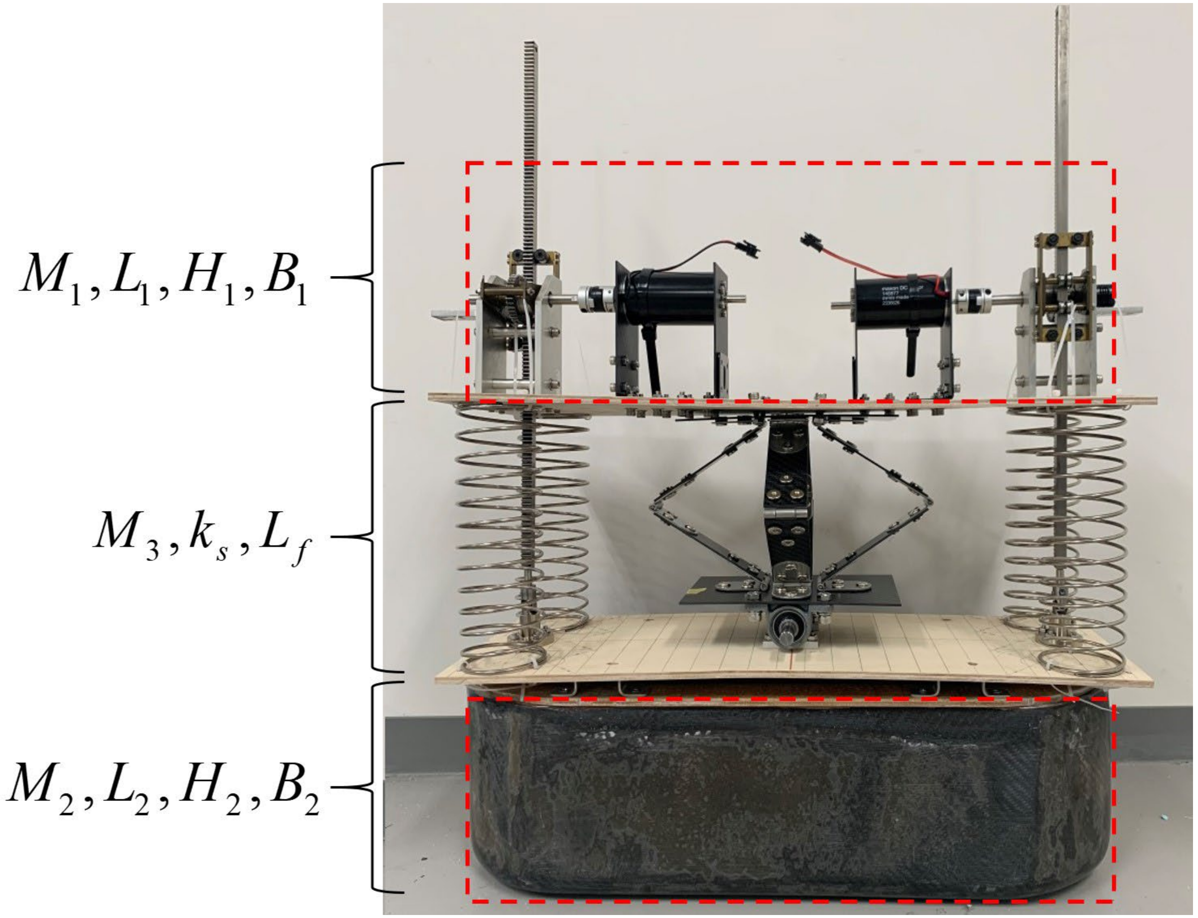
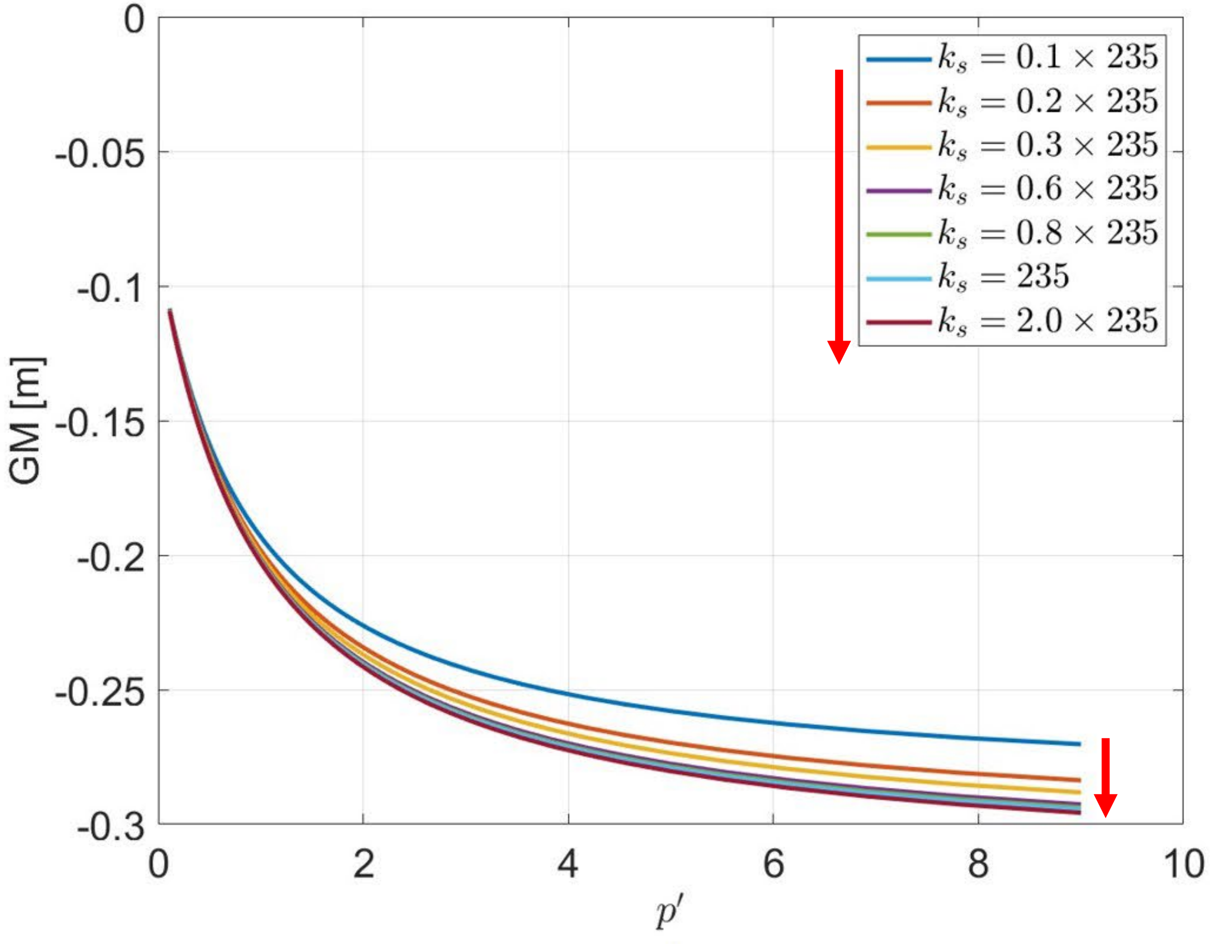
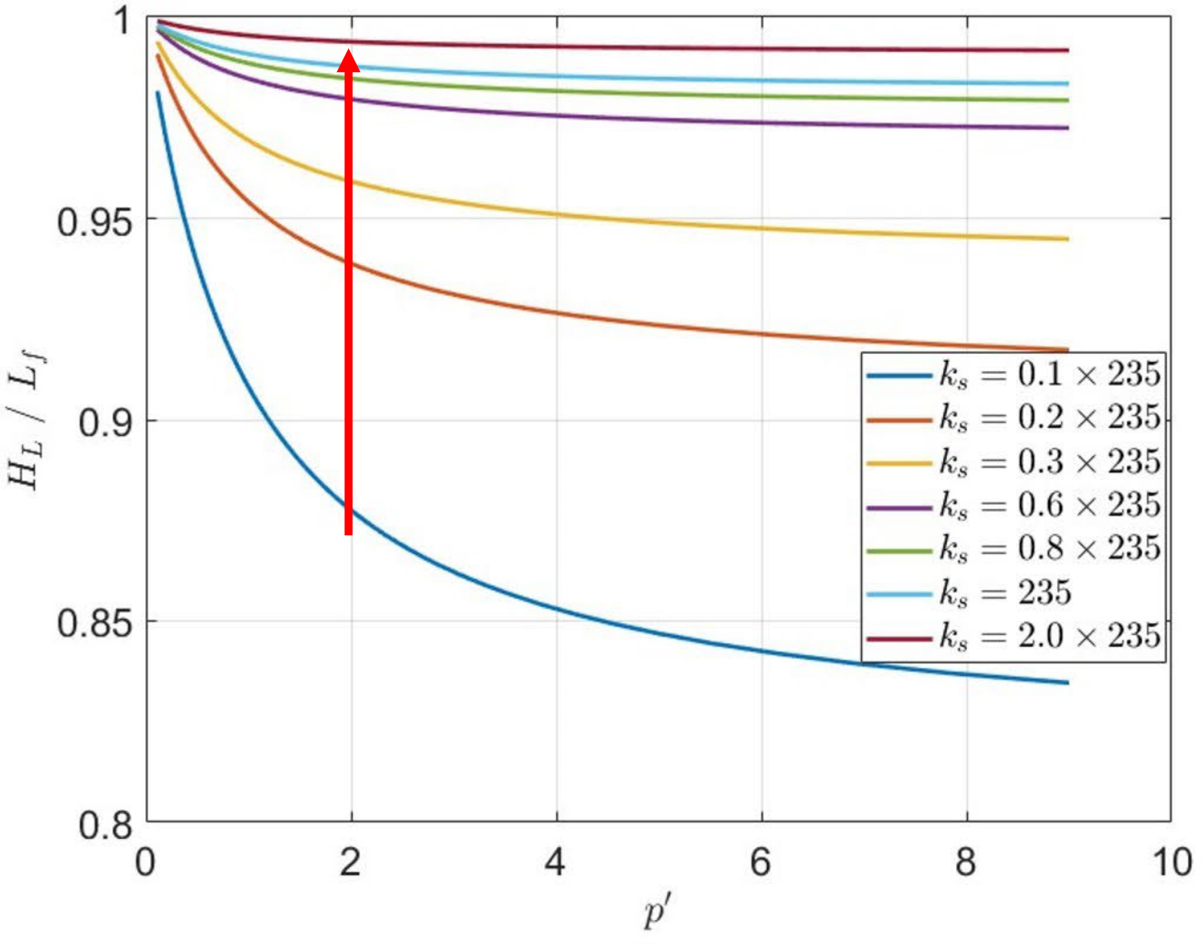


Fig.2 A prototype of suspension ship.

Parametric Study (k_s, M_{cabin}/M_{hull})

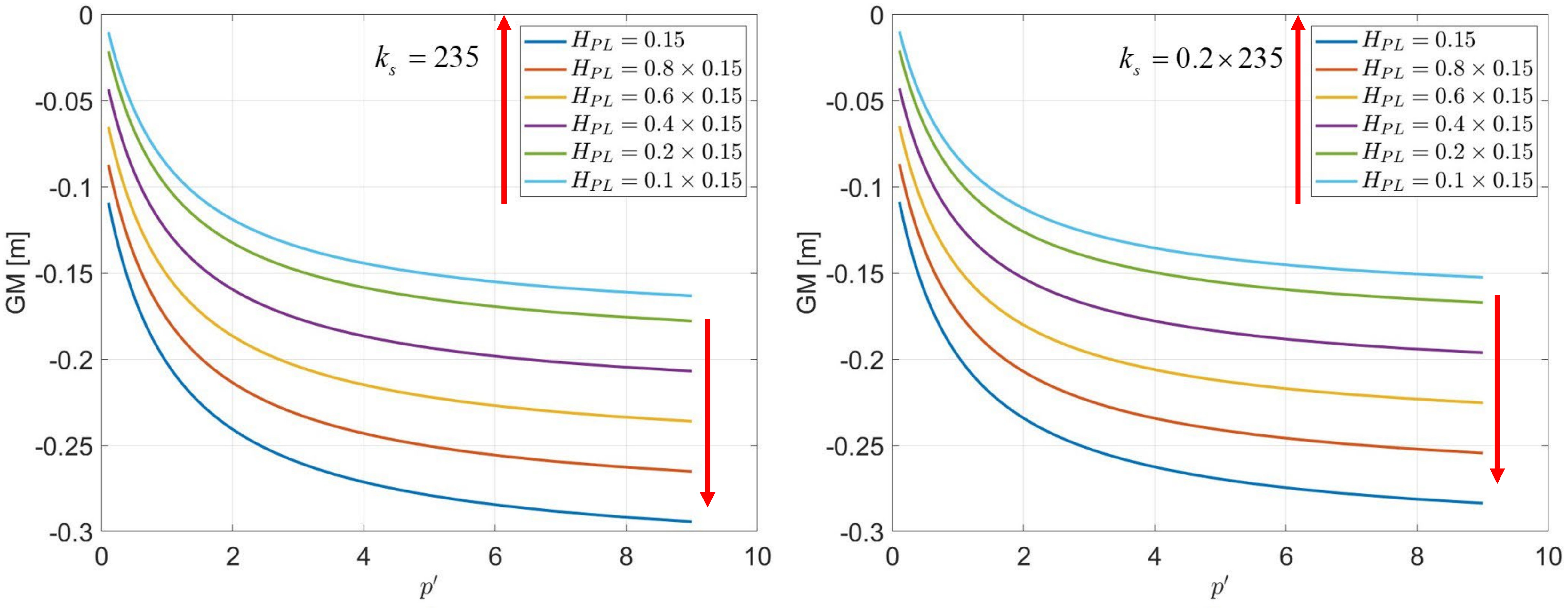


(A)



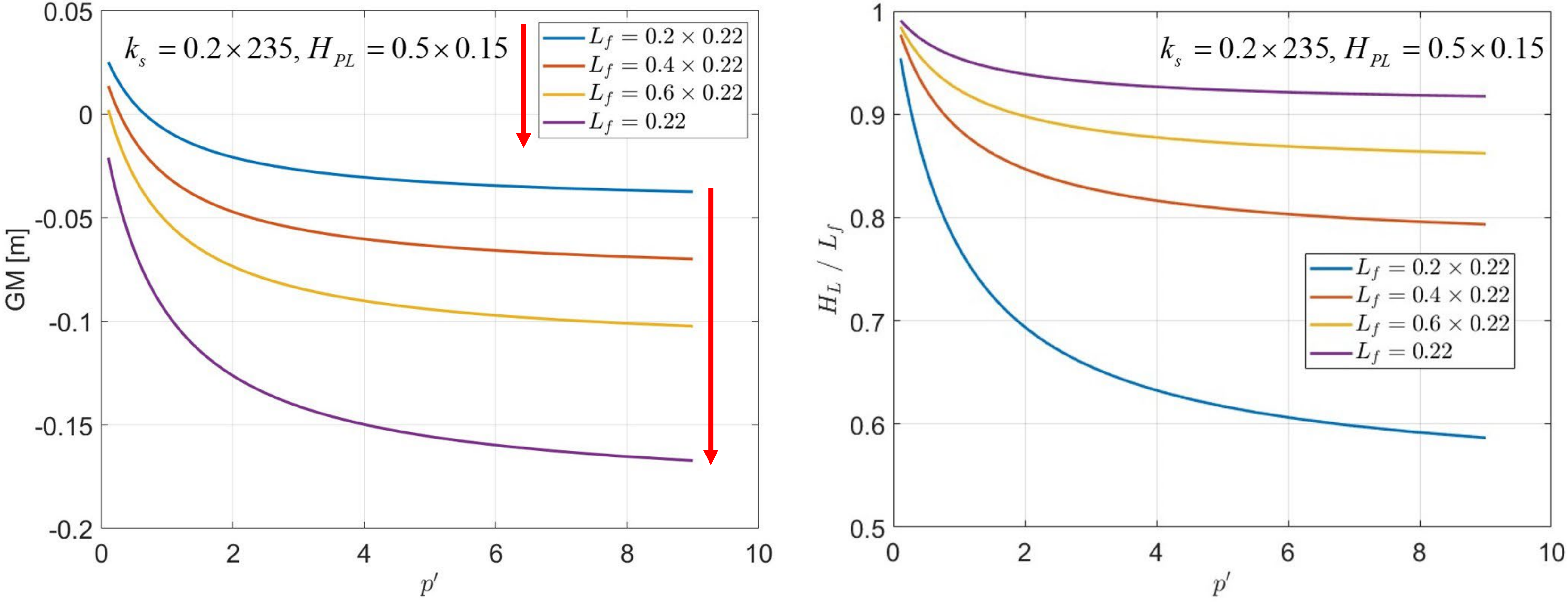
(B)

Parametric Study (H_{PL}, k_s, M_{cabin}/M_{hull})



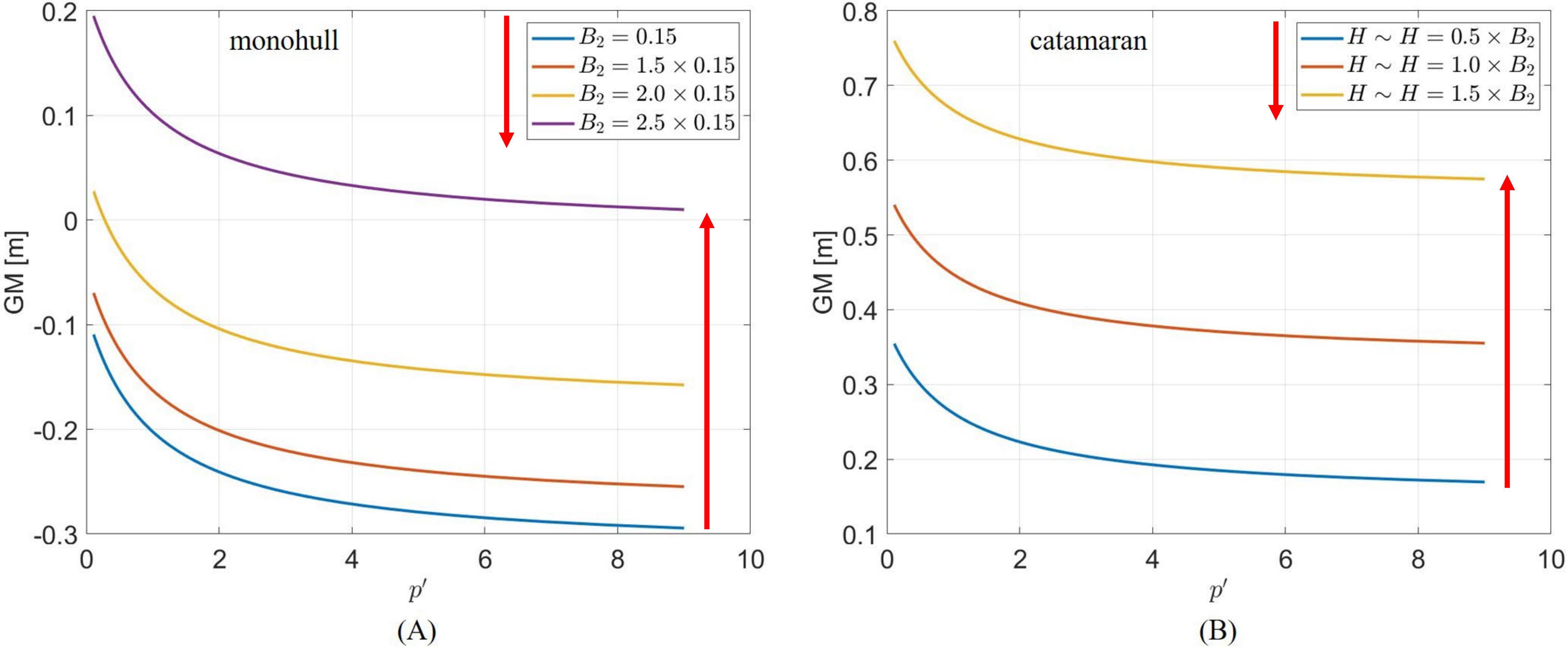
(A) (B)

Parametric Study (L_f, M_{cabin}/M_{hull})



(A) (B)

Parametric Study (Beam of ship)



Conclusions:

1. A reduced mass ratio results in an increased GM. The initial transverse stability displays significant variation when the mass ratio of the cabin and hull is **less than 2**. It is imperative to pay close attention if the static mass ratio falls within this range;

2. A **shorter** loaded height is preferable for a larger GM. However, the allowable travel distance must be taken into account to prevent bottom out. If springs are utilized, the spring stiffness and free length must be carefully balanced.

3. A **lower** placement location height results in a larger GM. Although, the impact becomes weaker with the reduced static mass ratio, it exerts more impact compared to the spring stiffness.

4. A **larger** beam produces a larger GM. The beam of the hull for a monohull and the overall beam of a catamaran are the dominating parameters that influence the initial transverse stability.

Thank you for your attention!

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