Dead-Water Phenomenon

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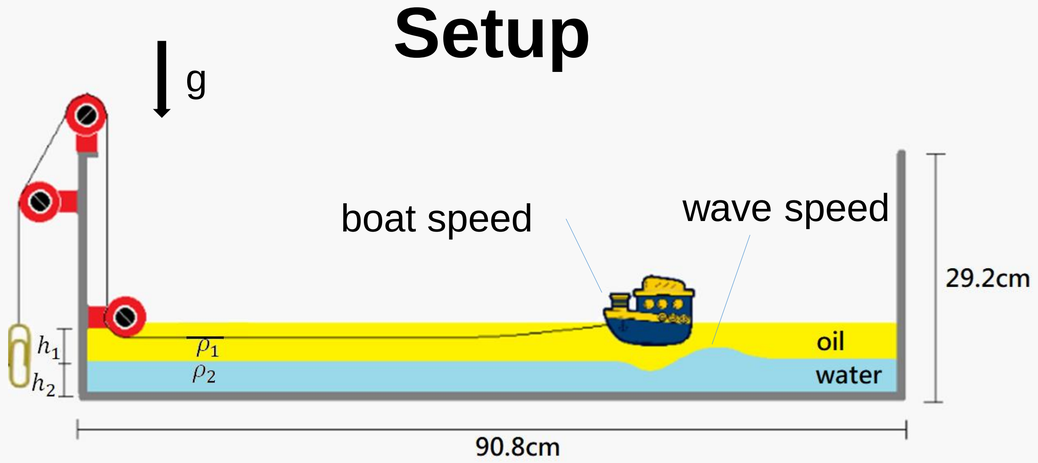
Introduction

Dead-Water Phenomenon

In the past, the dead-water phenomenon is well-known for sailors. What is dead-water-phenomenon? Because of the different salinity in two layers, it make a interface between them.

When a boat exists on a interface, it may feel an extra drag because the internal wave is generated between layers.

Setup



- Use oil and water to simulate two-layer fluid.
- Use clips to drag the boat.

Method

- Internal wave speed for two layer liquid

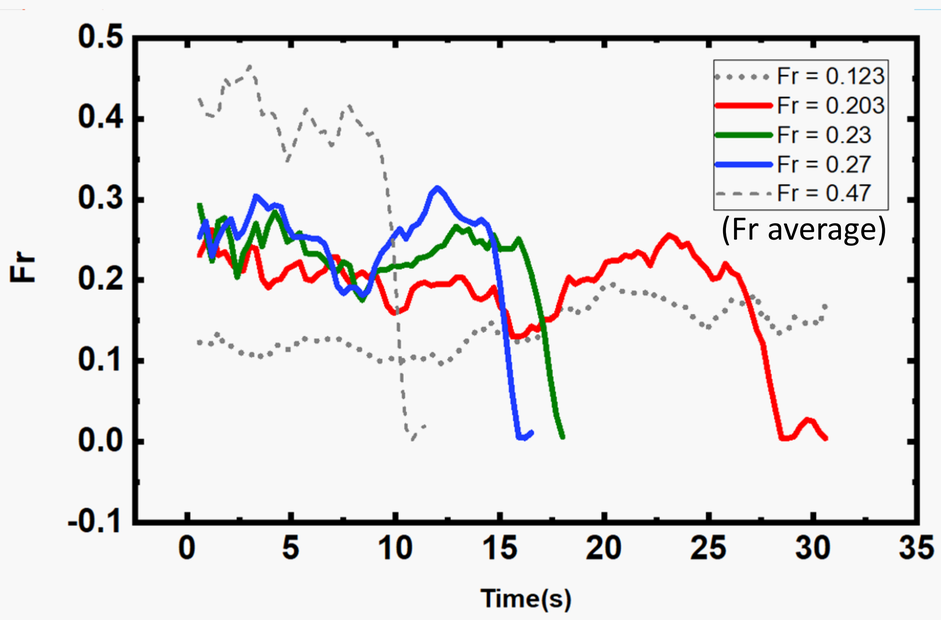
$$V_{wave} = \sqrt{g\frac{\rho_2 - \rho_1}{\rho_2}\frac{h_1 h_2}{h_1 + h_2}}$$

- Froude number (dimensionless)

$$F_r = V_{boat}/V_{wave}$$

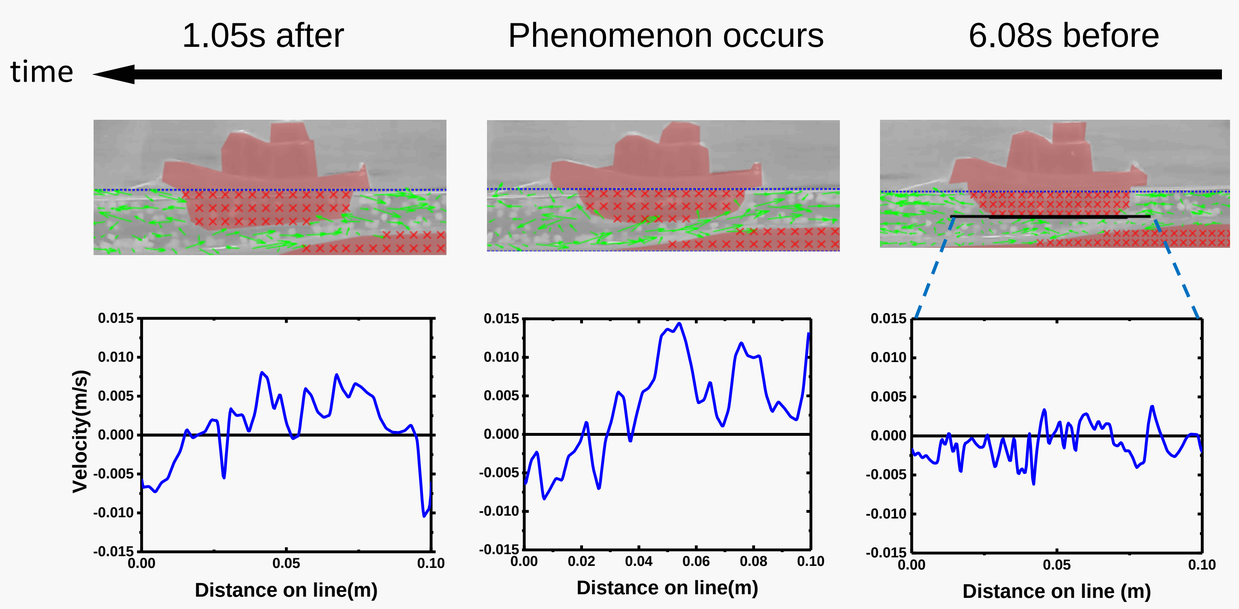
Result

Froude number(Fr)



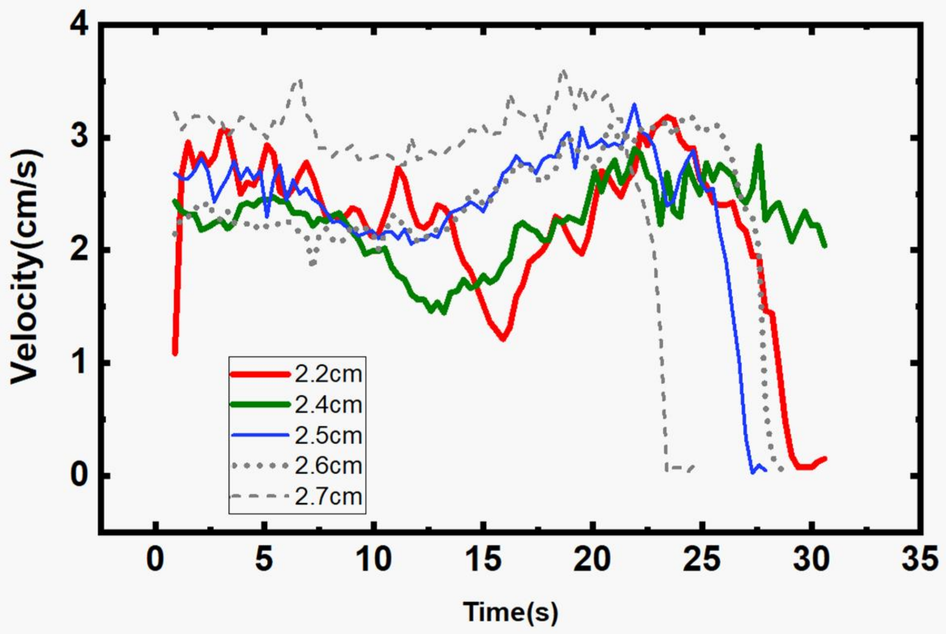
- Oil depth is fixed in 2.2 cm
- When the phenomenon occurs, there's a significant sink in velocity curve.
- Phenomenon happens in the range of Fr ~ 0.2 to 0.27

Field

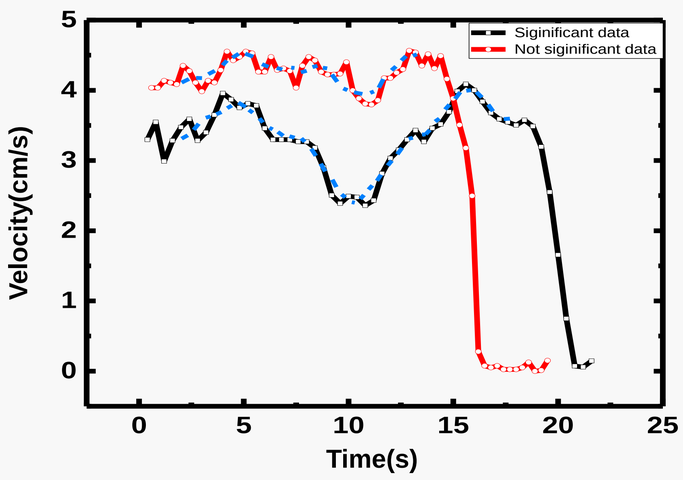


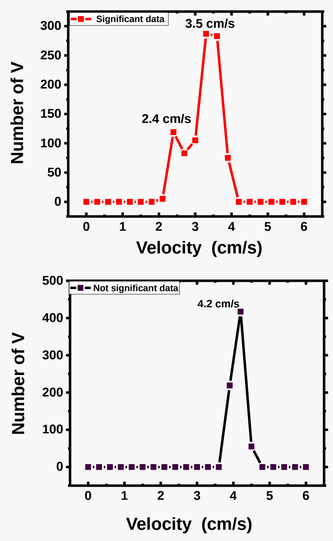
Here, we observe the velocity of fluid under the boat when time goes. When the boat moves slower, it get a drag force which is produced by the flow under the boat.

Change depth of oil



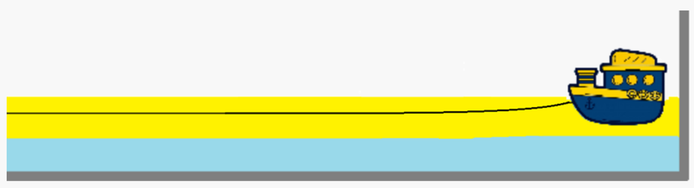
- Change oil depth with fixed Fr around 0.25
- When oil depth is above 2.5cm, the phenomenon is so weak.



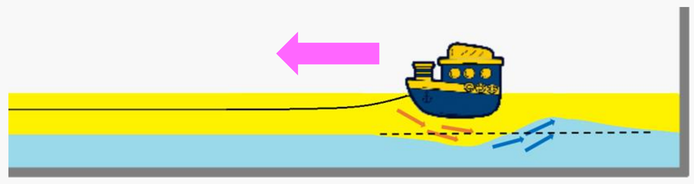


- The difference of two conditions.
- If phenomenon happens, the distribution of velocity has two peaks.

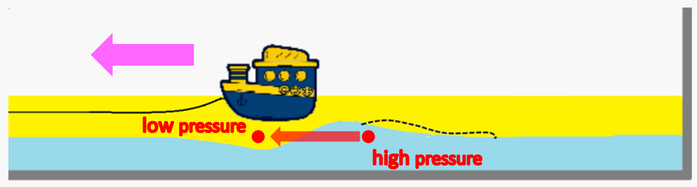
Model



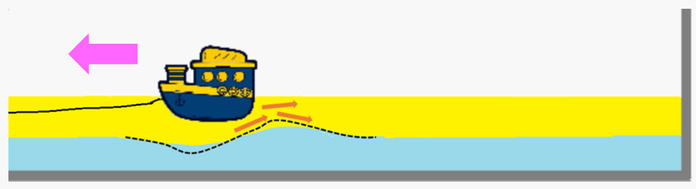
- Initial situation



- The boat starts moving, which extrudes the oil, and creates the internal wave.



- The wave approaches to the bottom of boat owing to the gradient of pressure.



- To make up the vacancy behind internal wave , the countercurrent of oil through the bottom of boat, which makes the boat decelerate.
- The amplitude of wave becomes smaller.

Conclusion

1. In our system, the dead-water phenomenon happens in Fr ~ 0.2 to 0.27.
2. Thin oil layer improves the dead-water phenomenon happens.
3. The oil pass through the button of the boat makes our boat decelerate, and it is the origin of the dead water phenomenon.

Reference

M. J. Mercier1,*, R. Vasseur1,**, and T. Dauxois1:Resurrecting dead-water phenomenon, 2011