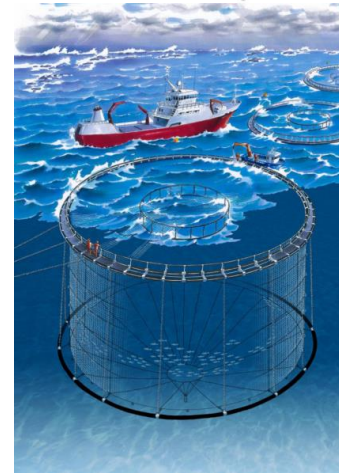



# Simulations of well boats at fish farms in waves and current

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**Co-supervisors:** Prof. Odd Magnus Faltinsen  
Adjunct Prof. Arne Fredheim



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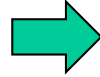
# Outline:

- Introduction
- Objective and scope
- Numerical modelling
- Results and discussions
- Conclusions
- Ongoing and Future work

# Introduction

## ■ Fish farm system?

- Floating collar fish farm



Floating collars

## ■ Well boat?

- Important for fish welfare

## ■ Wellboat operations?

- Approaching fish farms
- At fish farms (harvesting)
- Leaving fish farms

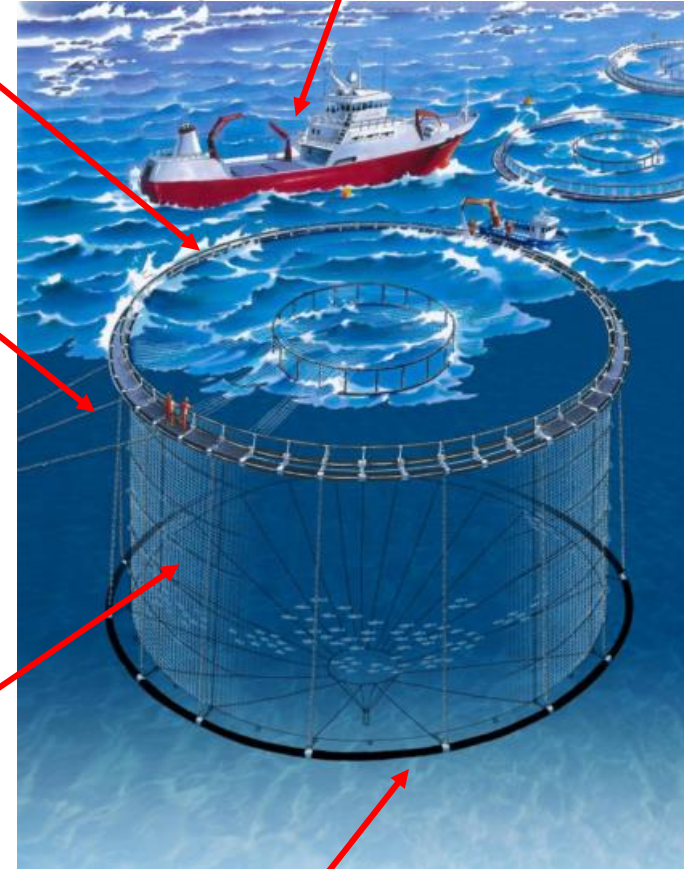


Mooring

Net cage

Bottom ring

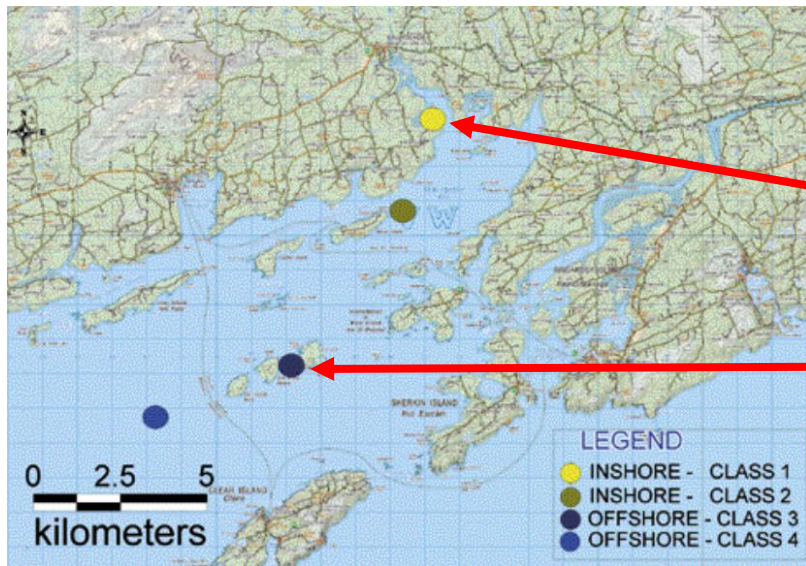
Well boat





# ■ Why?

## Introduction



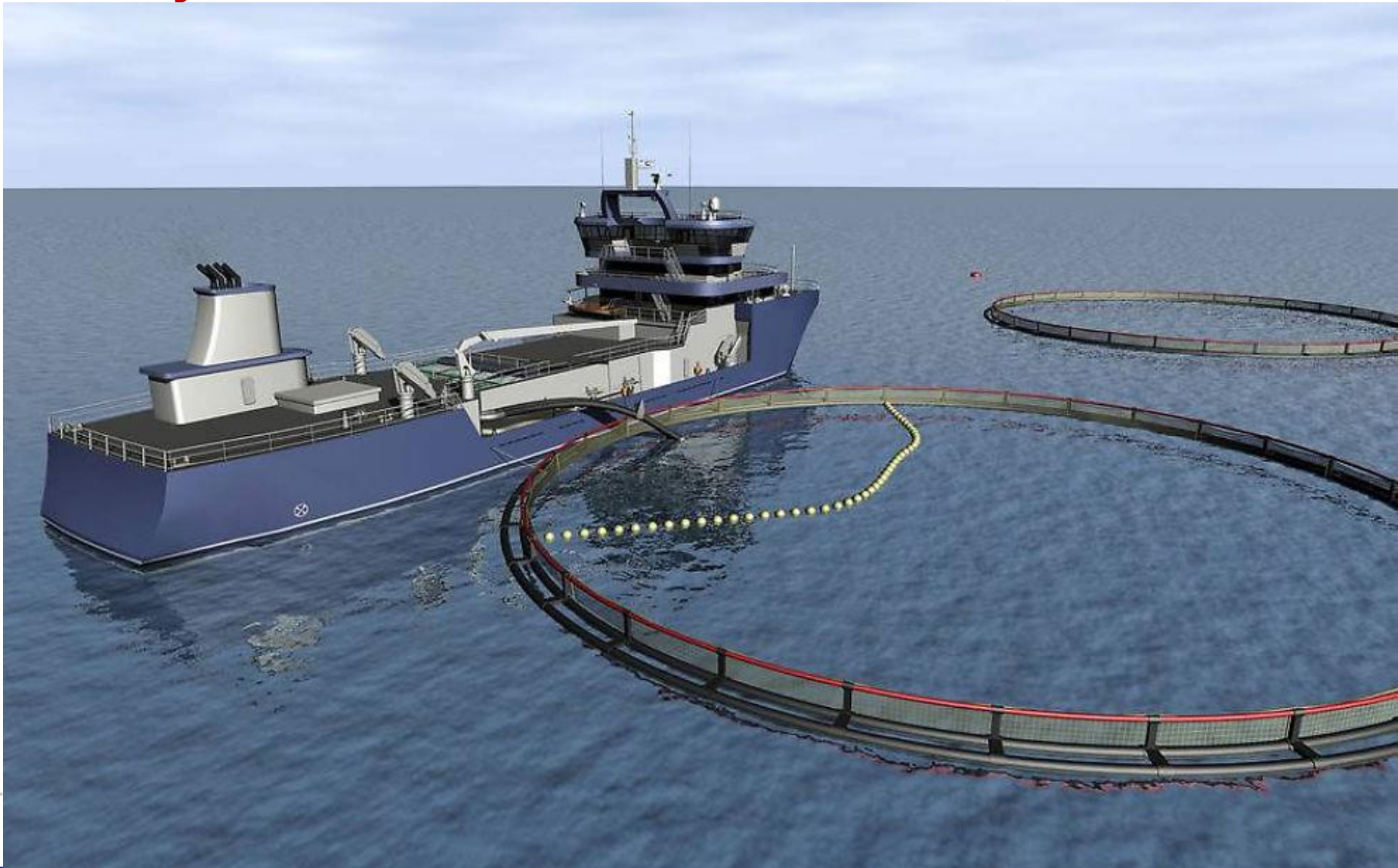
(Ryan 2005)

Table 1: Standard Norge,2003

Class	$H_s$ [m]	$T_p$ [s]	$U_c$ [m/s]	Exposure
1	0.0-0.5	0.0-2.0	0.0-0.3	Small
2	0.5-1.0	1.6-3.2	0.3-0.5	Moderate
3	1.0-2.0	2.5-5.1	0.5-1.0	Heavy
4	2.0-3.0	4.0-6.7	1.0-1.5	High
5	>3.0	5.3-18.0	>1.5	Extreme

# Introduction

## ■ Why?



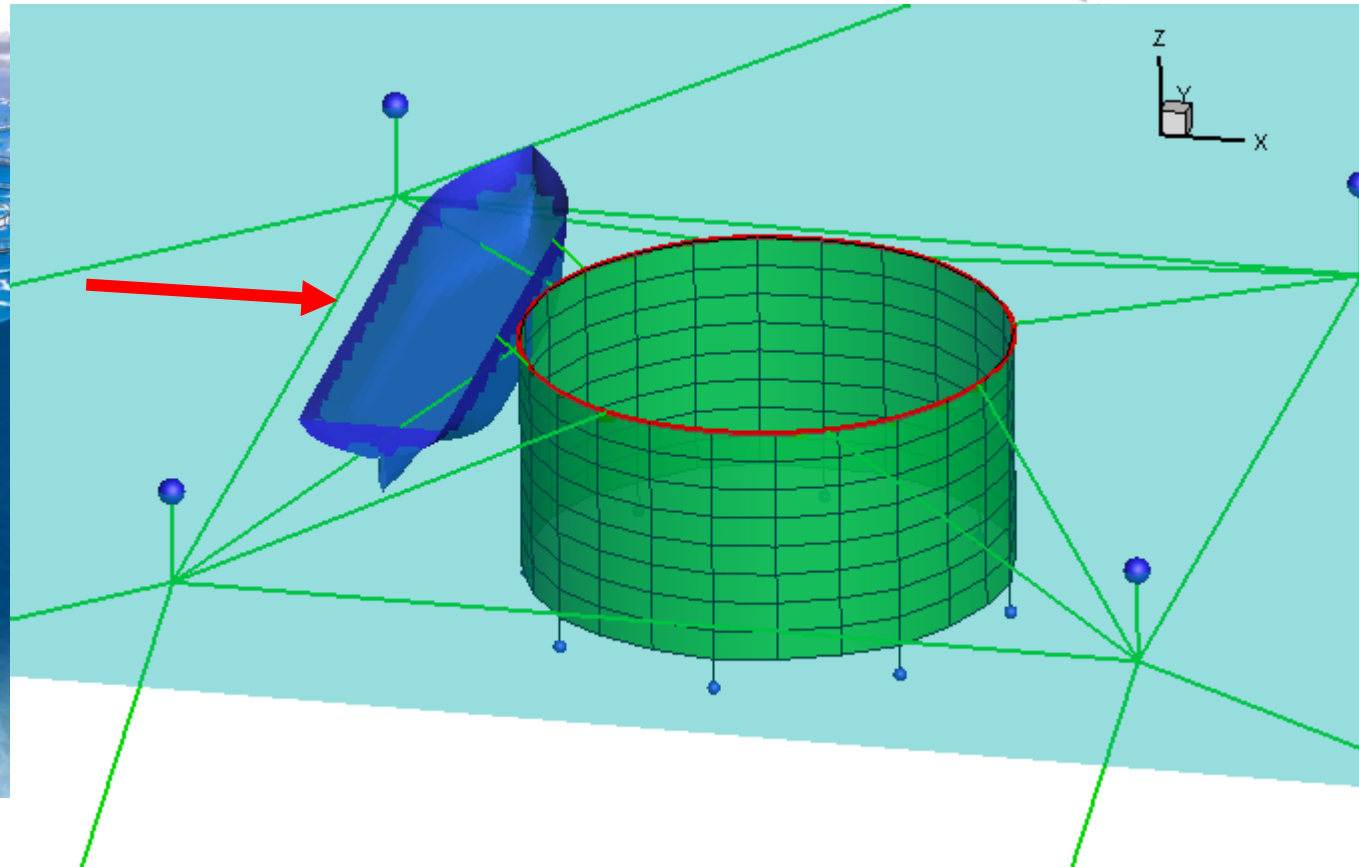


# Objective and scope

## ■ Objective

- Coupling between well boat and fish farm system in regular waves and current.

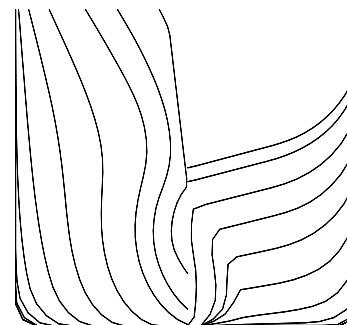
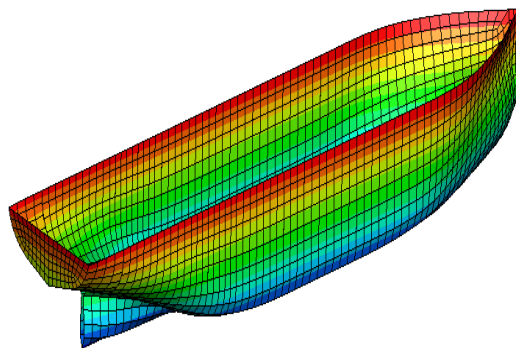
## ■ Scope



# Numerical modelling

## ■ The well boat

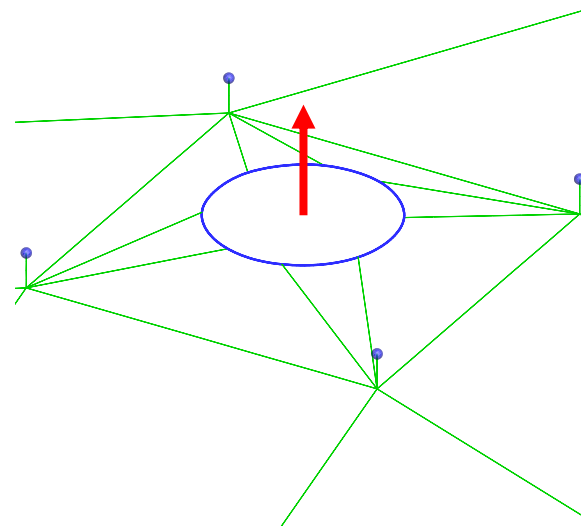
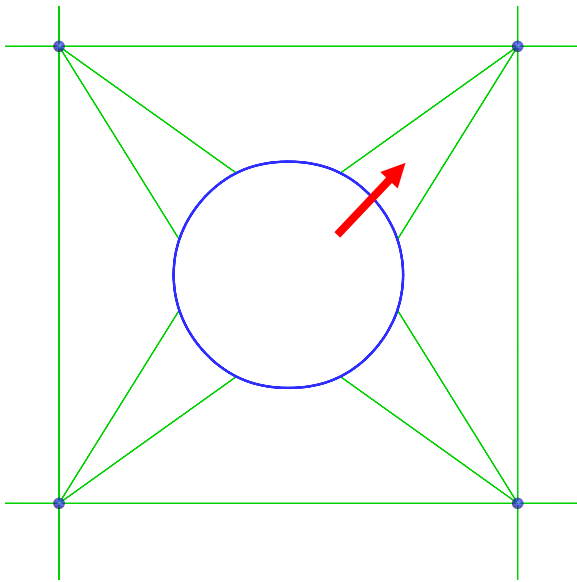
Displacement	5273.6 ton
Length overall (L)	71.8 m
Length between perpendiculars	70 m
Breadth	15 m
Draft	6.7 m
Radius of gyration in roll	5.25 m
Radius of gyration in pitch/yaw	19.6 m
Center of gravity (COG)	(0m,0m,-1.7m)
Center of buoyancy (COB)	(0m,0m,-3.11m)
Length from COG to stern	37.147m



# Numerical modelling

## ■ The elastic floater

Curved beam equations with axial tension effect are adopted, refer to Li et al. (2014)

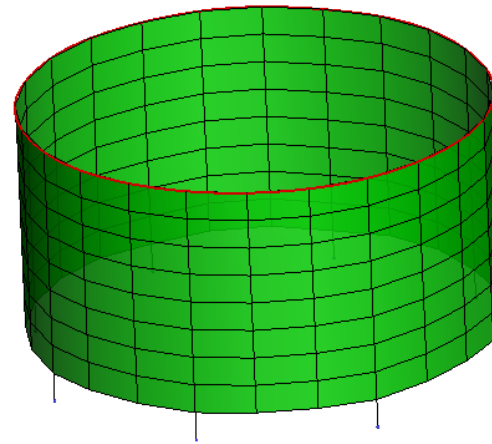
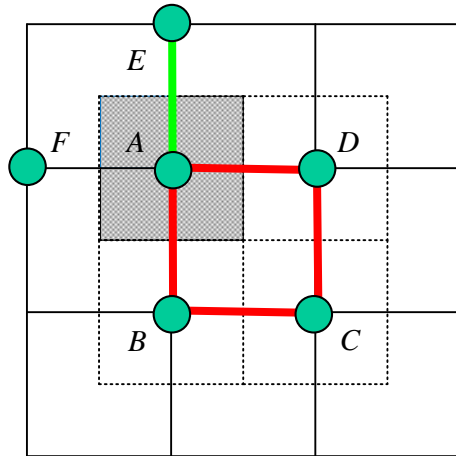




# Numerical modelling

## ■ The net cage

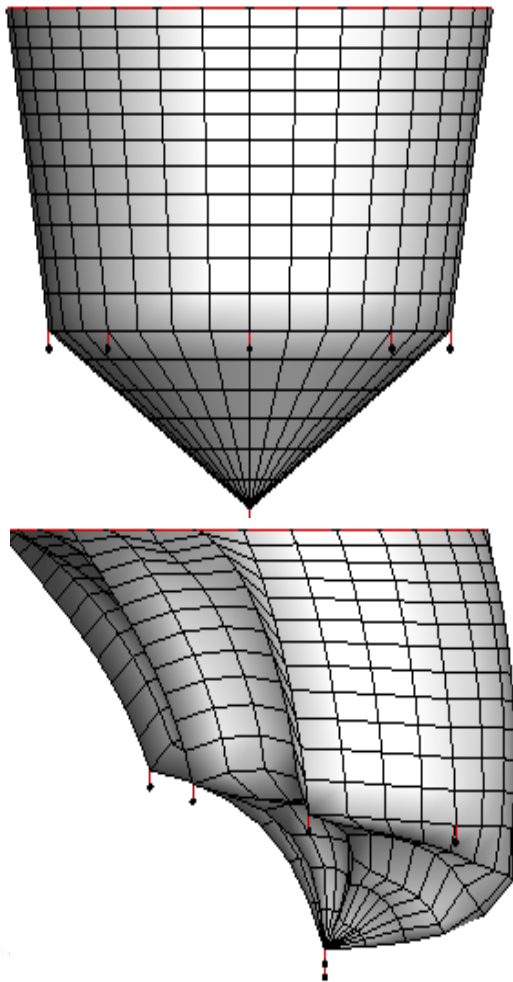
- **Structure model:** The net twine is represented by **elastic truss**
- **Hydrodynamic model:** **screen model**



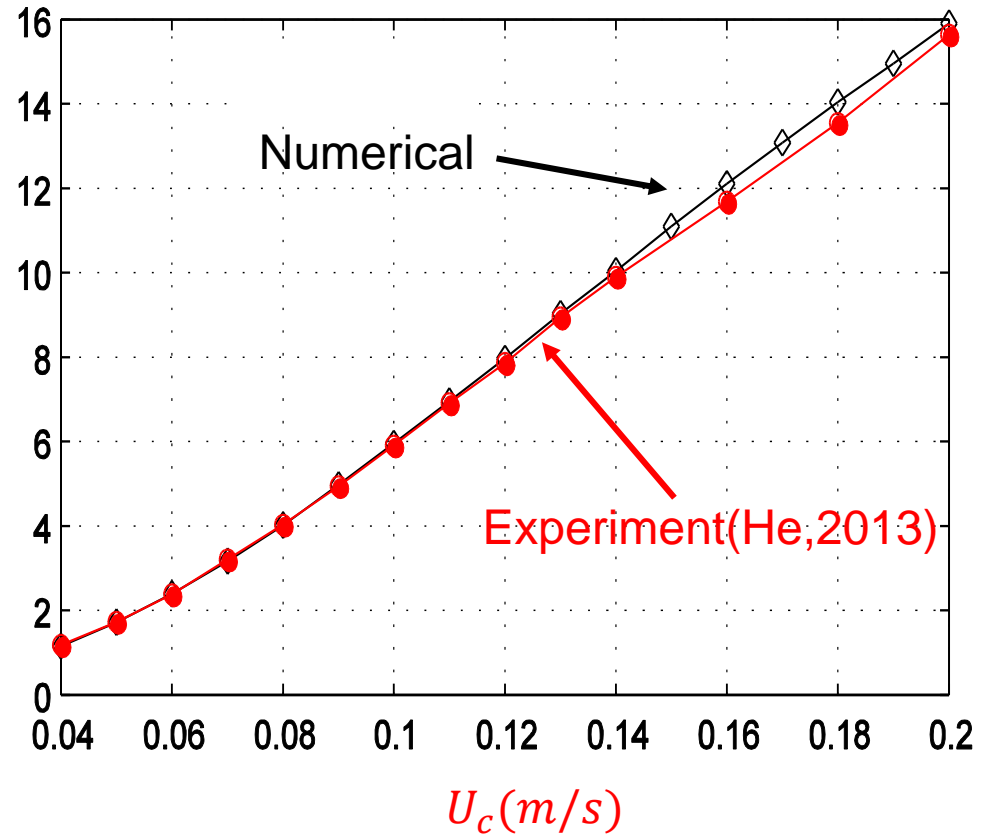
# Numerical modelling

## ■ The net cage

- Drag forces of a flexible net cage in current



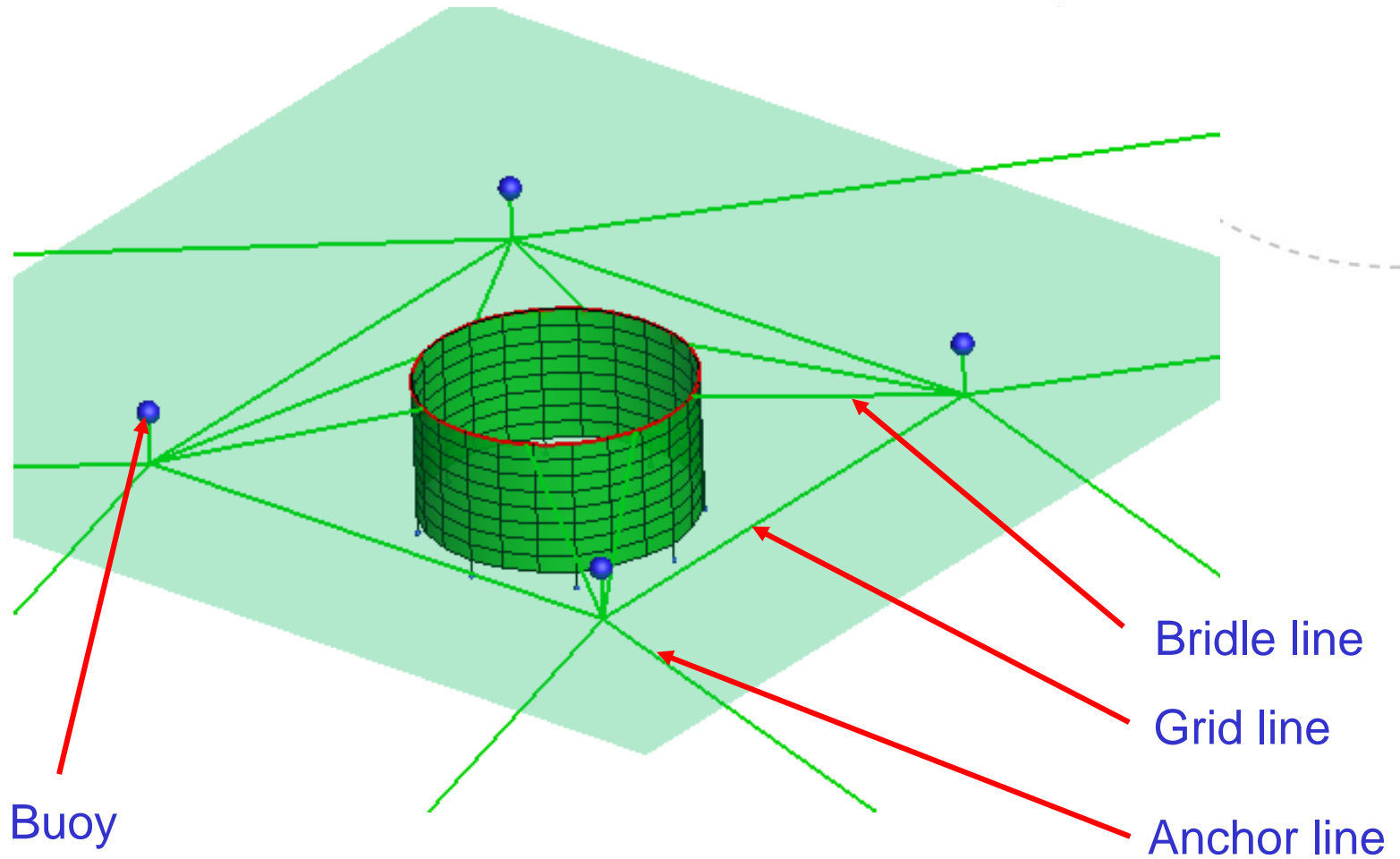
$F_D(N)$



The mean drag force in current only.

# Numerical modelling

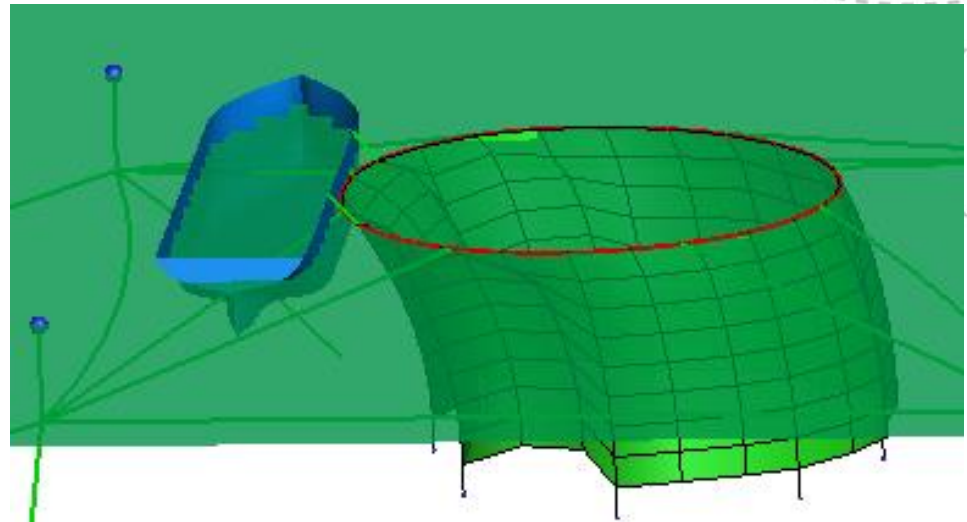
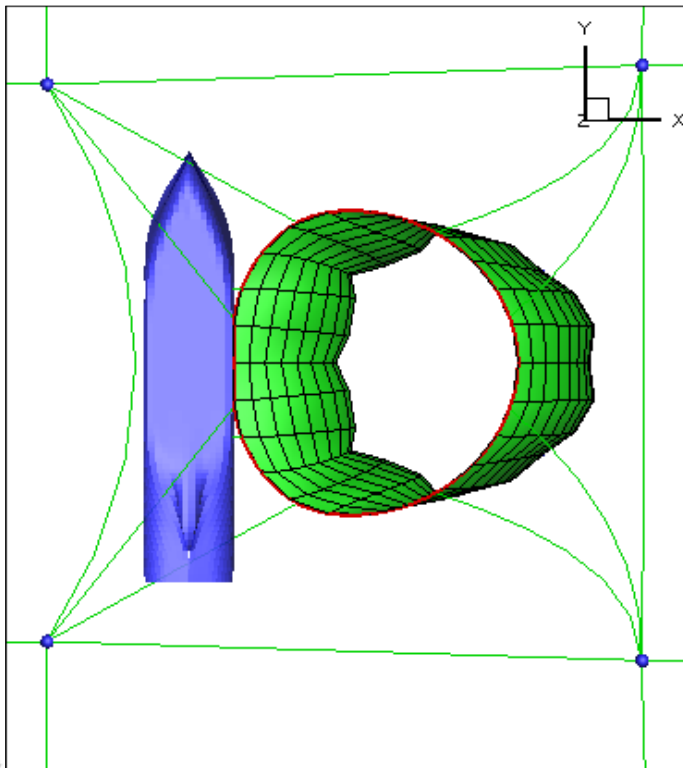
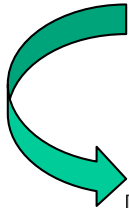
## ▪ The mooring system



# Numerical modelling

## ▪ Coupled well boat – fish farm system

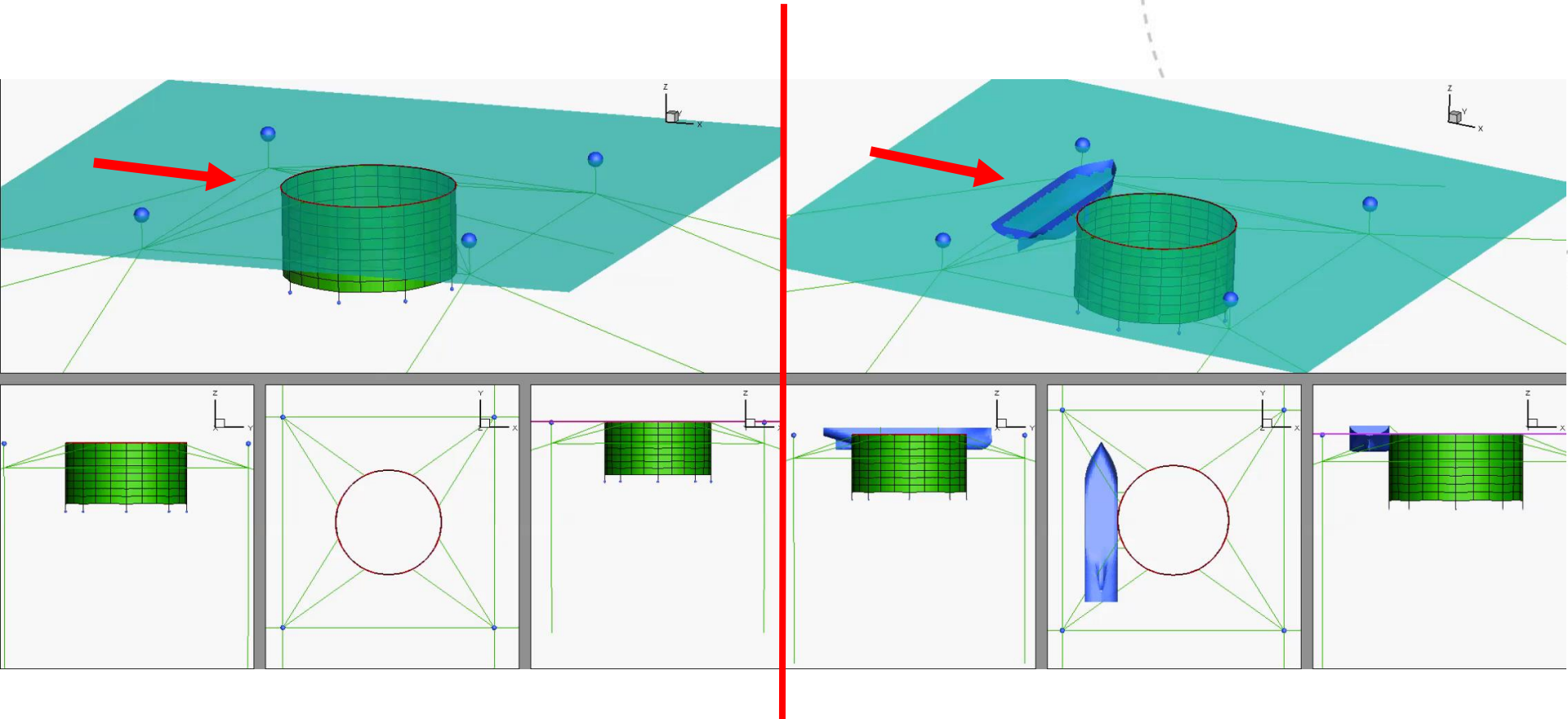
- Connecting ropes
- Contact
- ~~Hydrodynamic interaction~~





# Results and discussions

## ■ Current



**No boat**

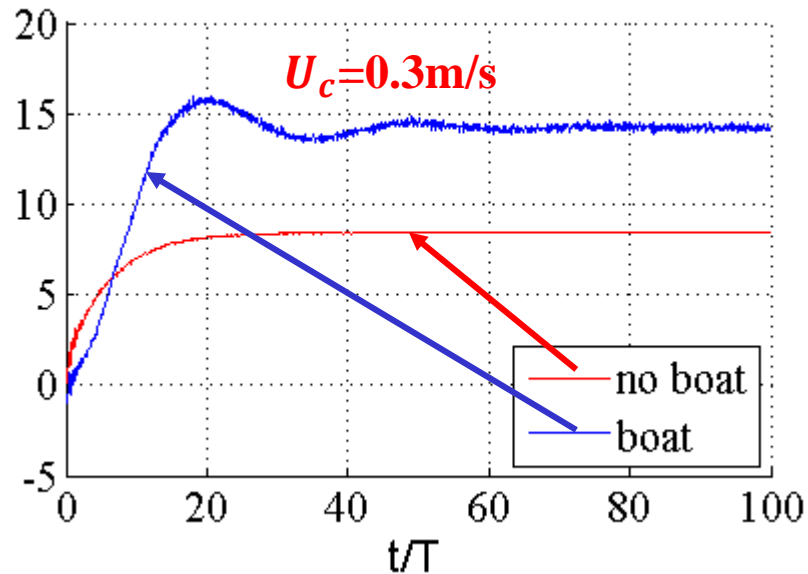
$(U_c = 0.3 \text{ m/s})$

**With boat**

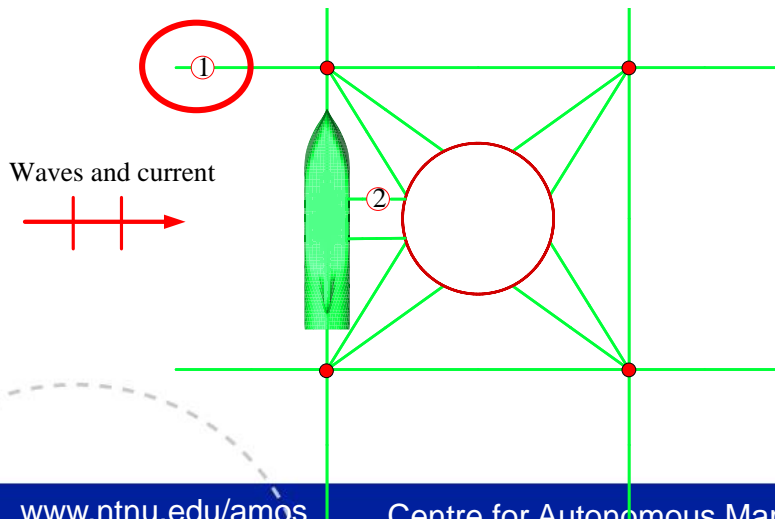
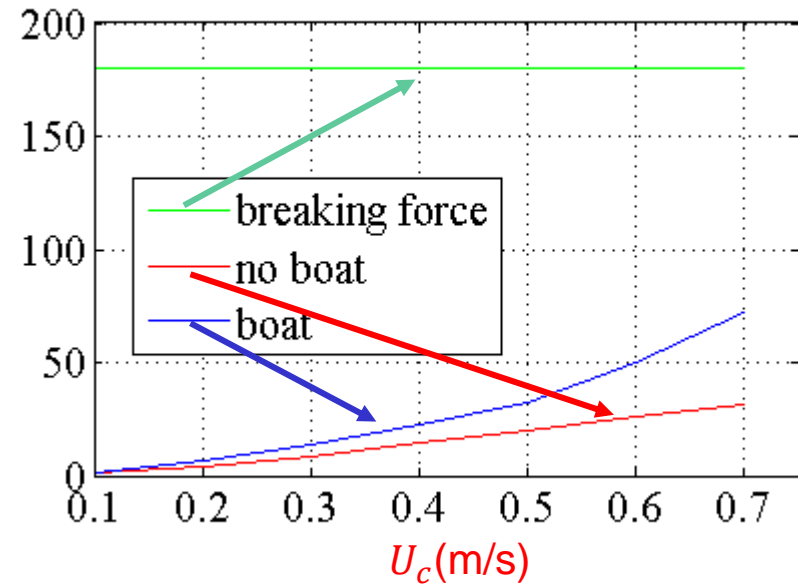
# Results and discussions

## Current

Mooring force-1 [kN]



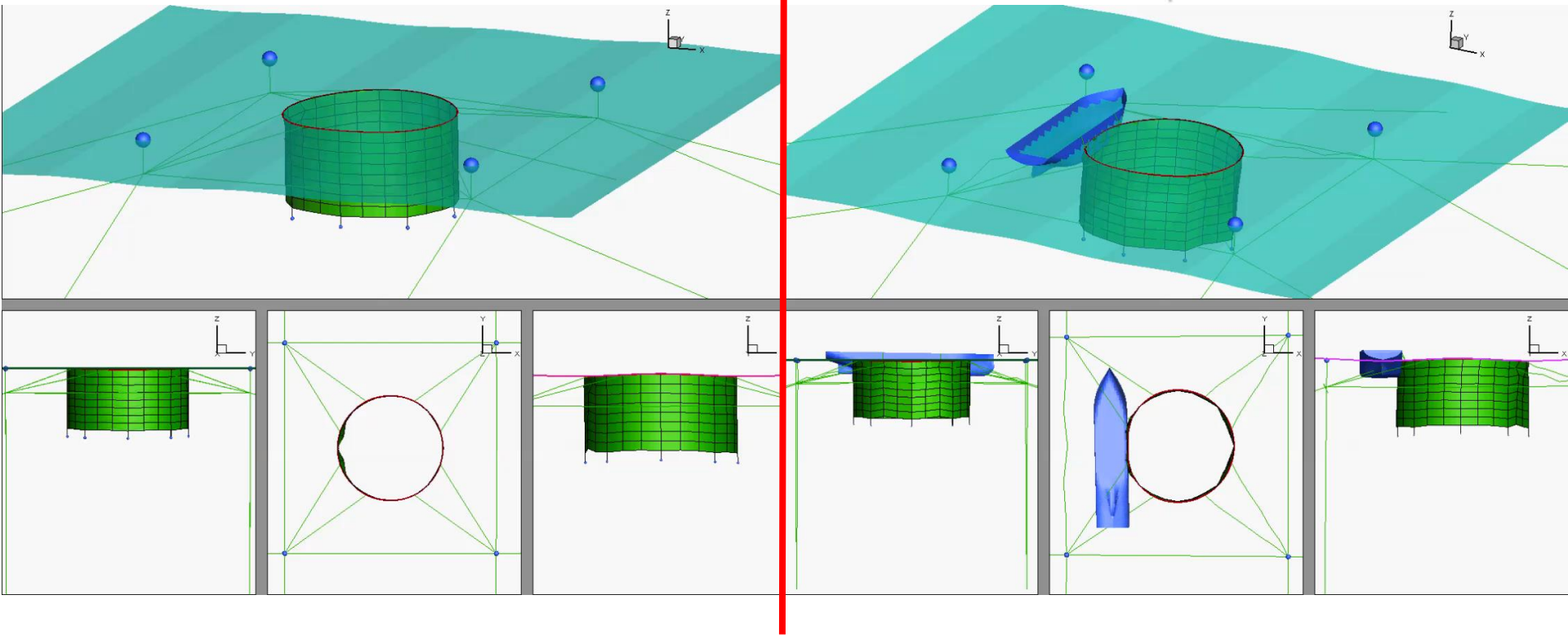
Steady mooring force-1 [kN]



Class	$U_c$ [m/s]	Exposure
1	0.0-0.3	Small
2	0.3-0.5	Moderate
3	0.5-1.0	Heavy
4	1.0-1.5	High
5	>1.5	Extreme

# Results and discussions

## ■ Wave



**No boat**

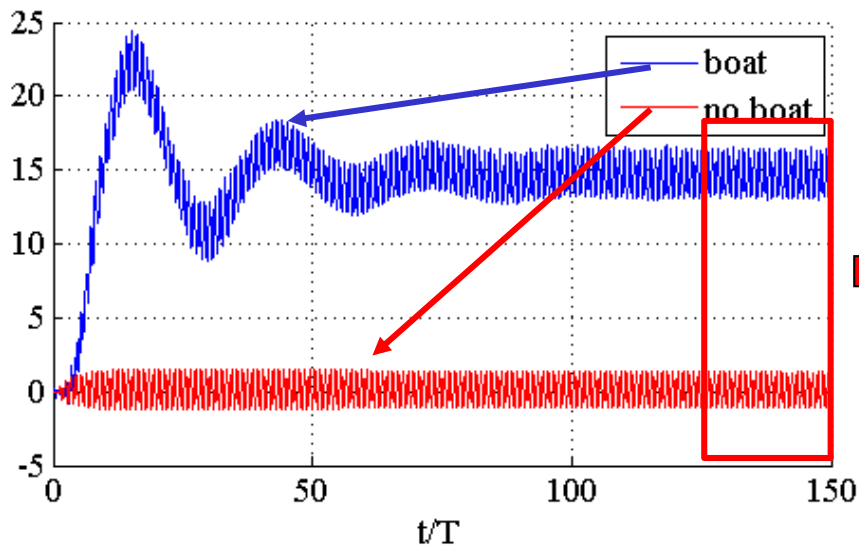
$(T=6s, H/\lambda=1/60)$

**With boat**

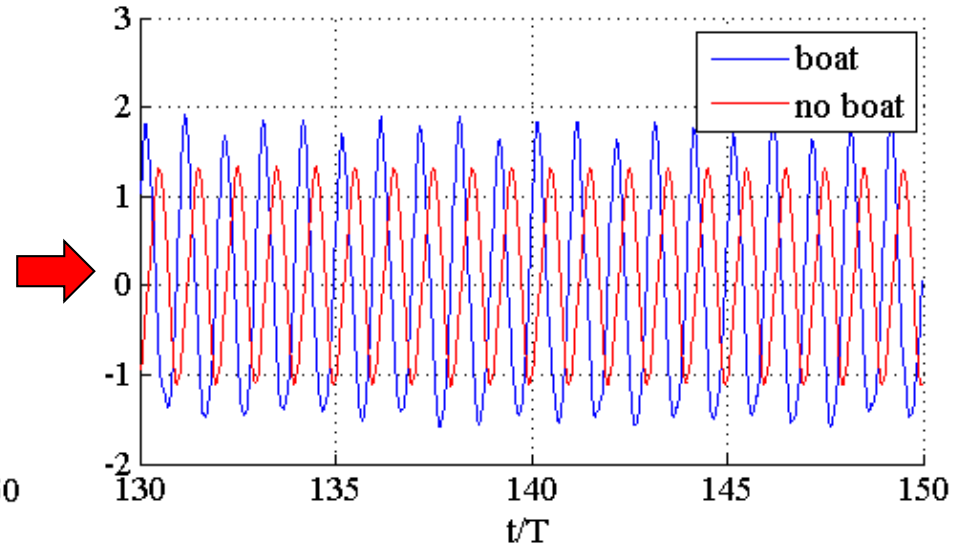
# Results and discussions

## ■ Wave

Mooring force-1 [kN]



Mooring force-1 [kN], avoid mean value

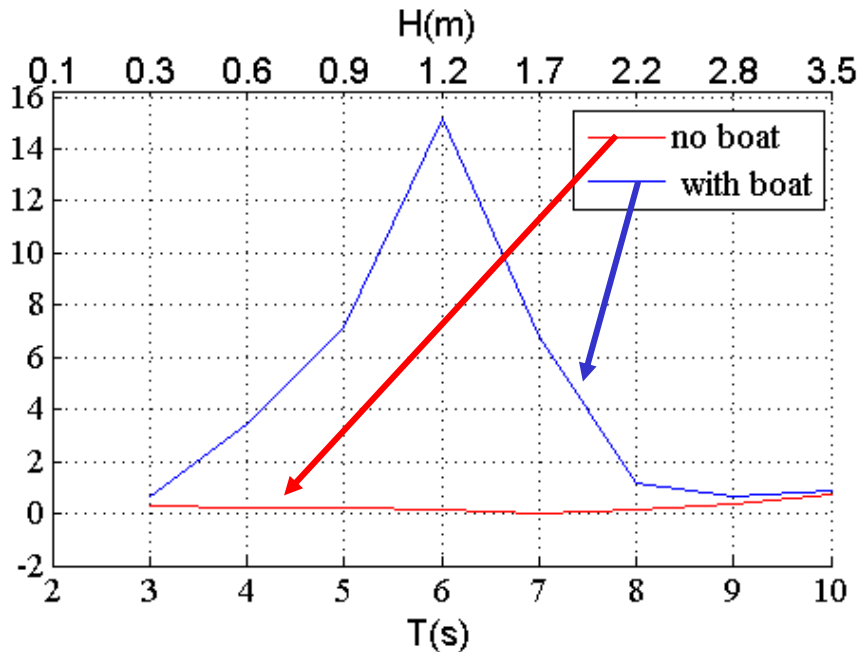




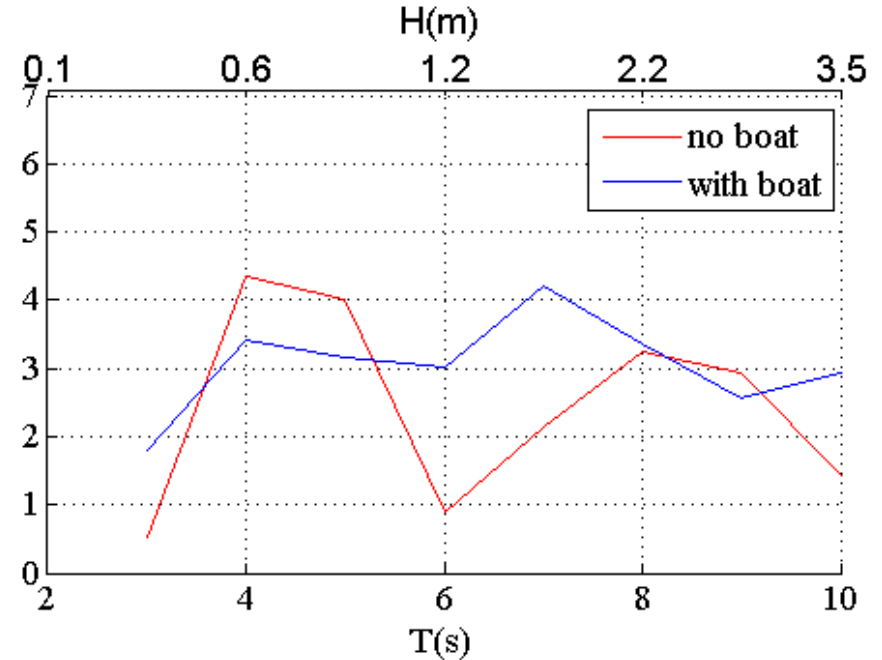
# Results and discussions

## Wave

Mean value [kN]



Amplitude[kN]

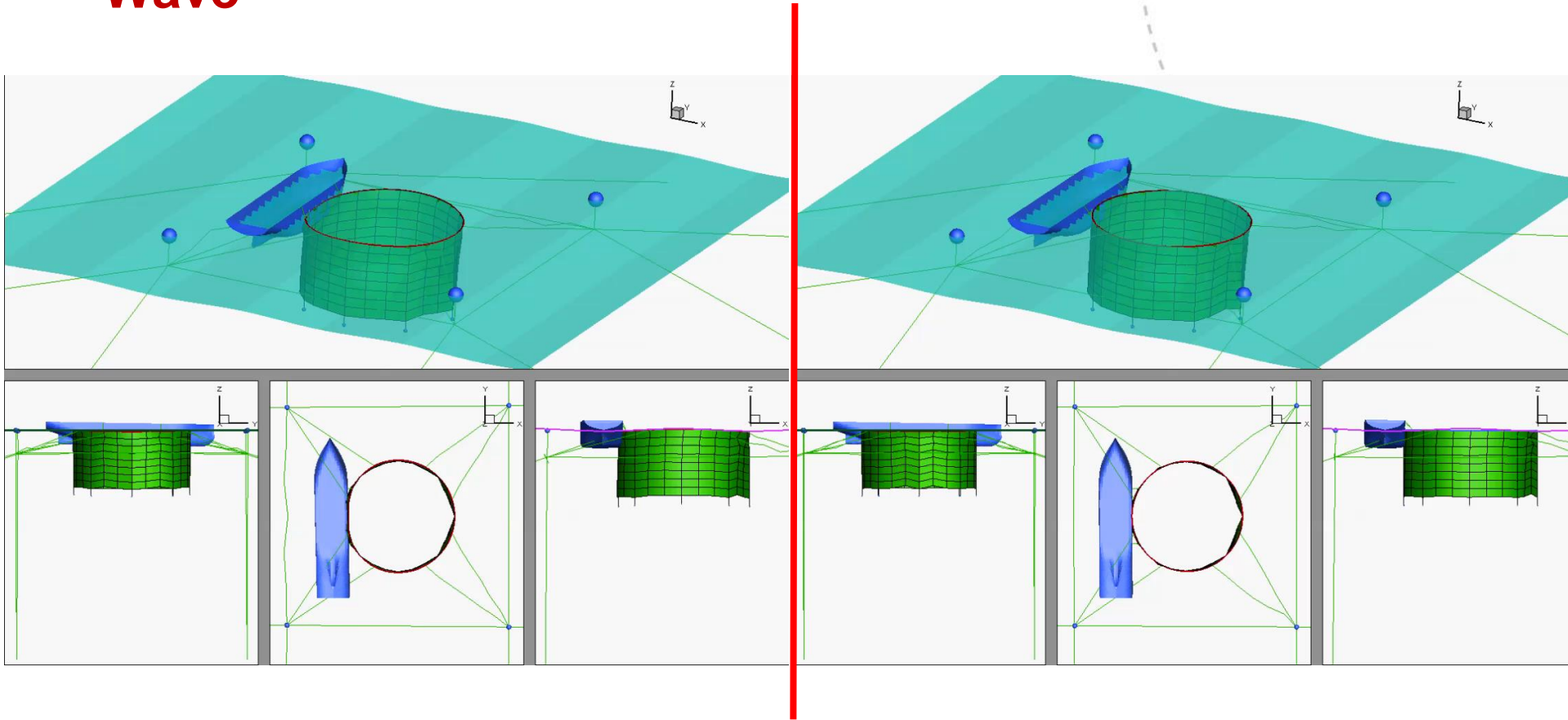


$$H/\lambda=1/60$$

Class	$H_s$ [m]	$T_p$ [s]	Exposure
1	0.0-0.5	0.0-2.0	Small
2	0.5-1.0	1.6-3.2	Moderate
3	1.0-2.0	2.5-5.1	Heavy
4	2.0-3.0	4.0-6.7	High
5	>3.0	5.3-18.0	Extreme

# Results and discussions

## ■ Wave



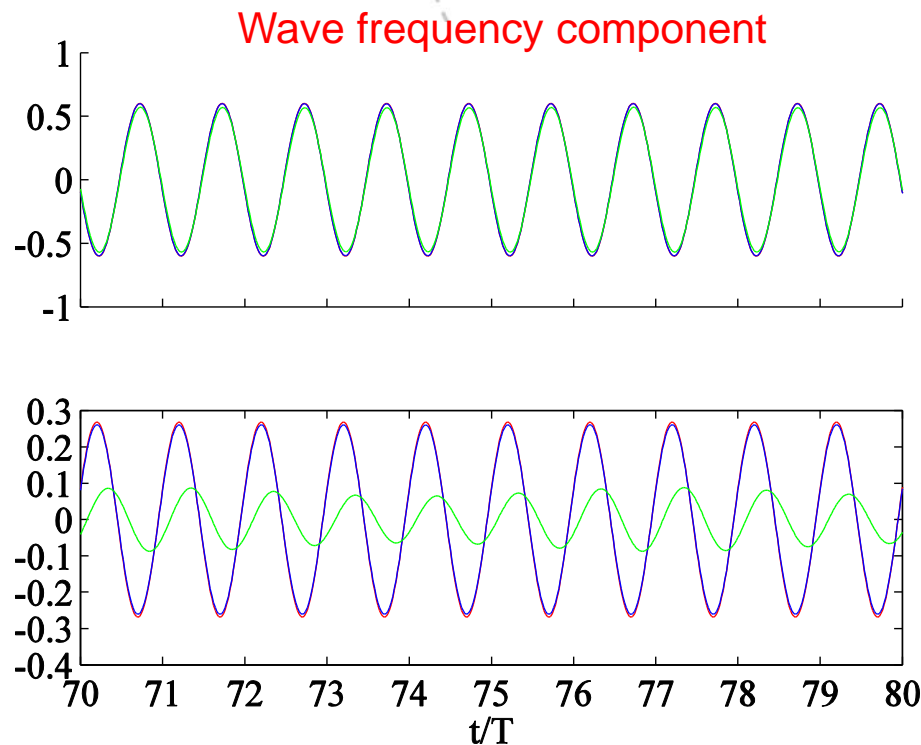
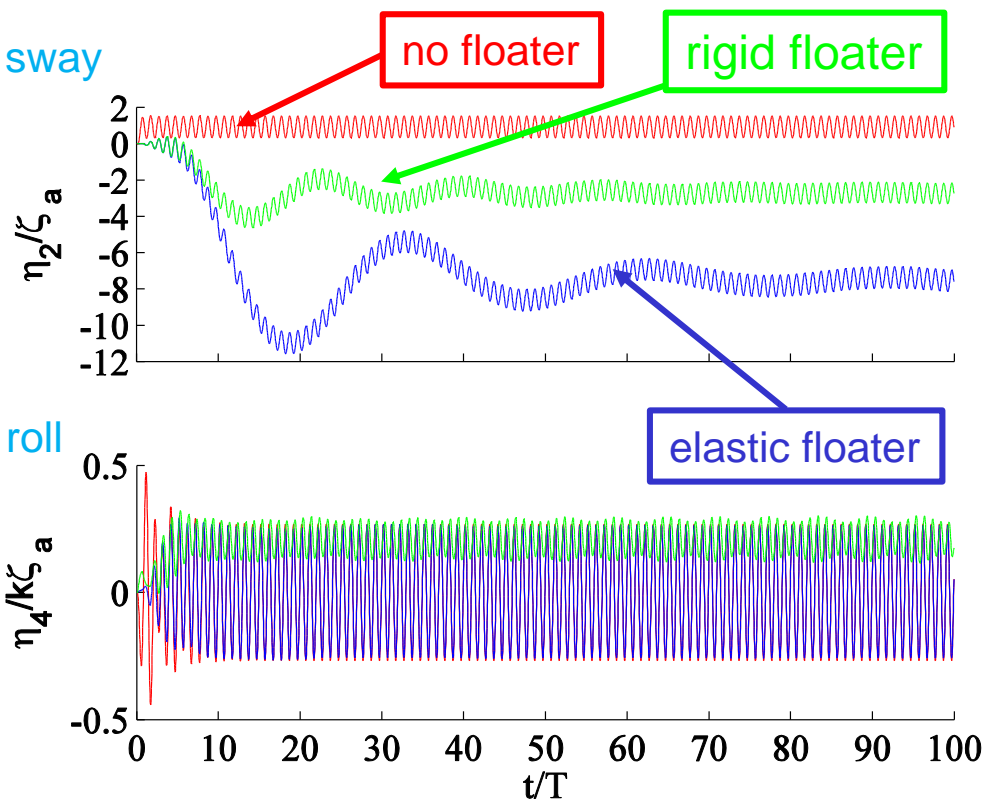
**Elastic floater**

$(T=6s, H/\lambda=1/60)$

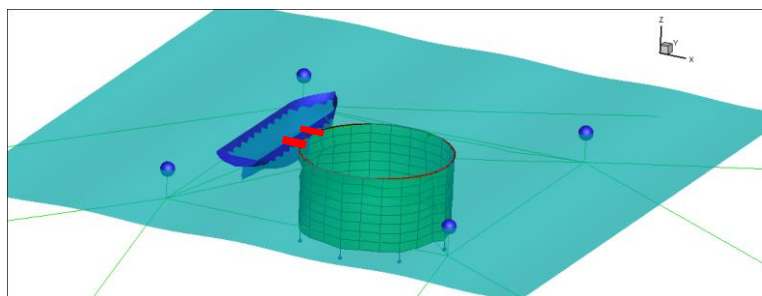
**Rigid floater**

# Results and discussions

## Wave

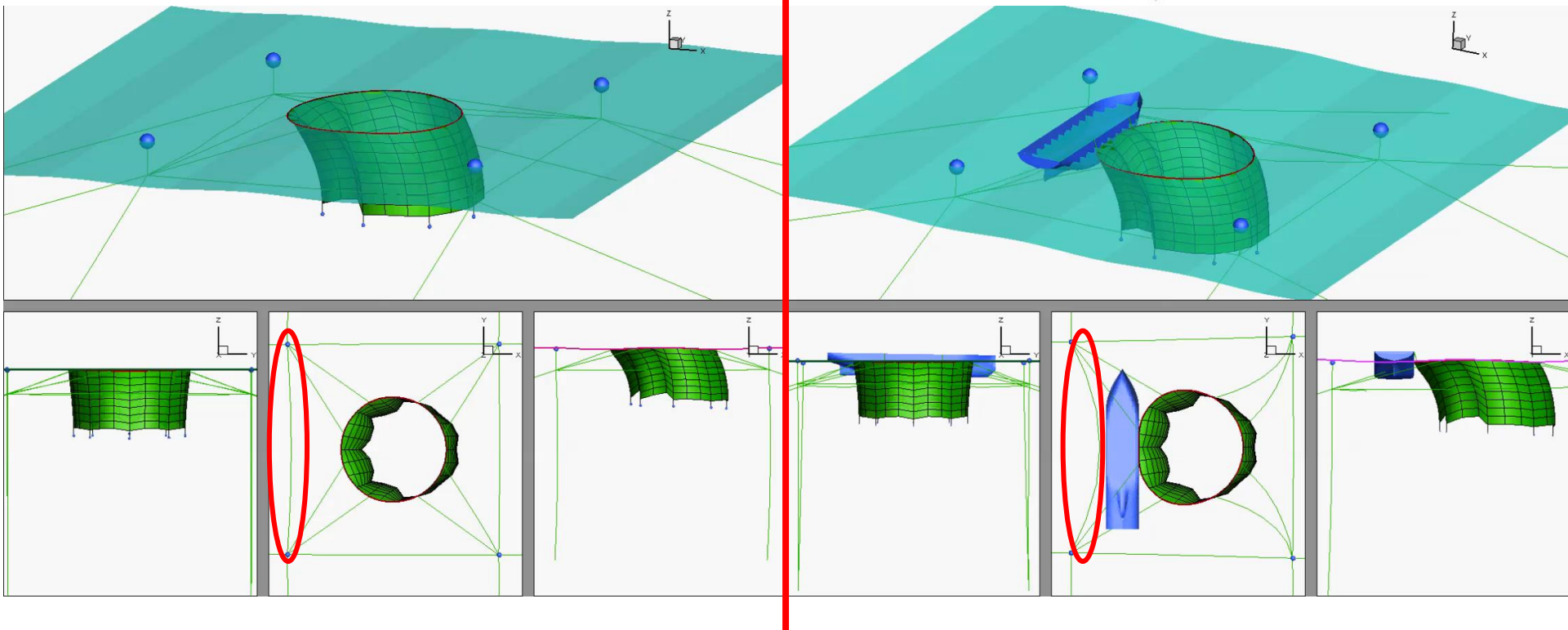


## Well boat motions



# Results and discussions

## Waves and current



**No boat**

$(U_c = 0.3 \text{ m/s}, T = 6 \text{ s}, H/\lambda = 1/60)$

**With boat**

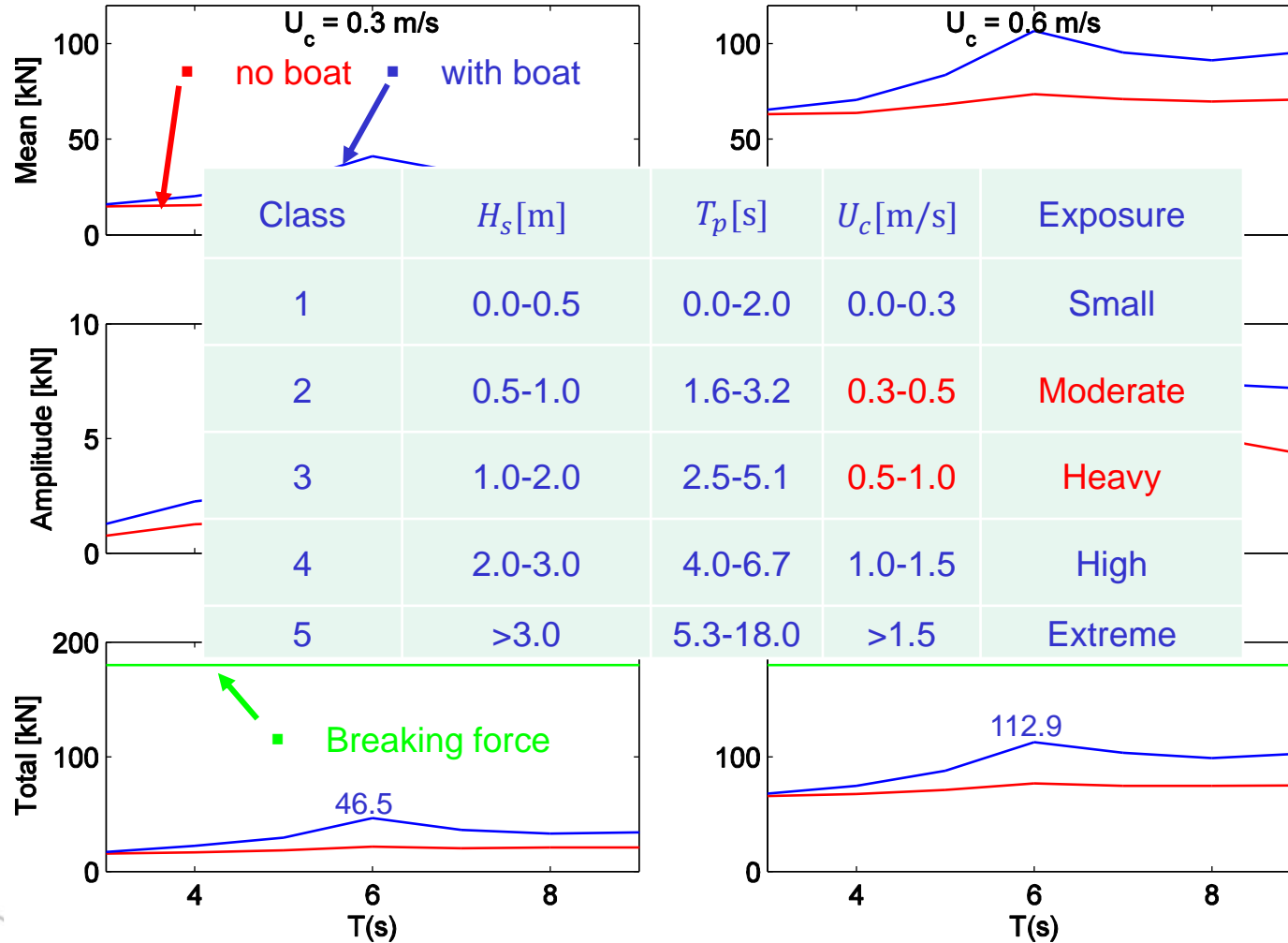


# Results and discussions

## Waves and current

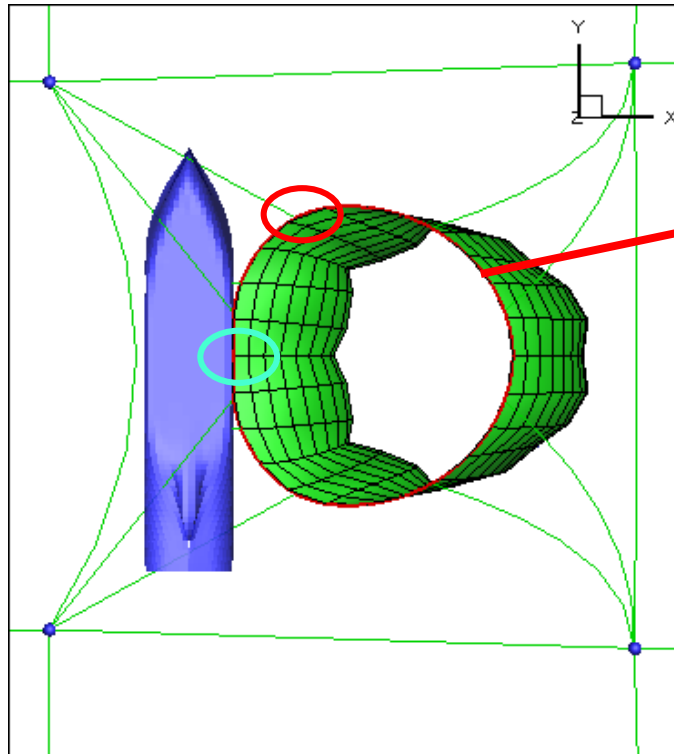
Mooring force-1 [kN]

$H/\lambda=1/60$



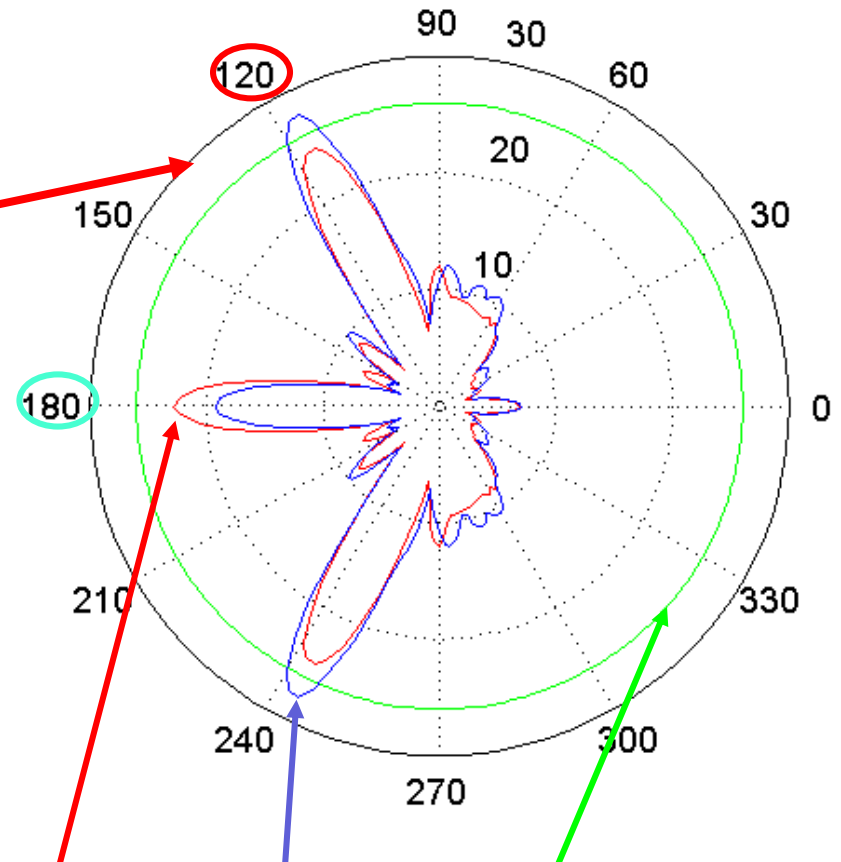
# Results and discussions

## Waves and current



$U_c = 0.6 \text{ m/s}$ ,  $H/\lambda = 1/60$

Stress distribution along the floater



■  $T = 6 \text{ s}$

■  $T = 9 \text{ s}$

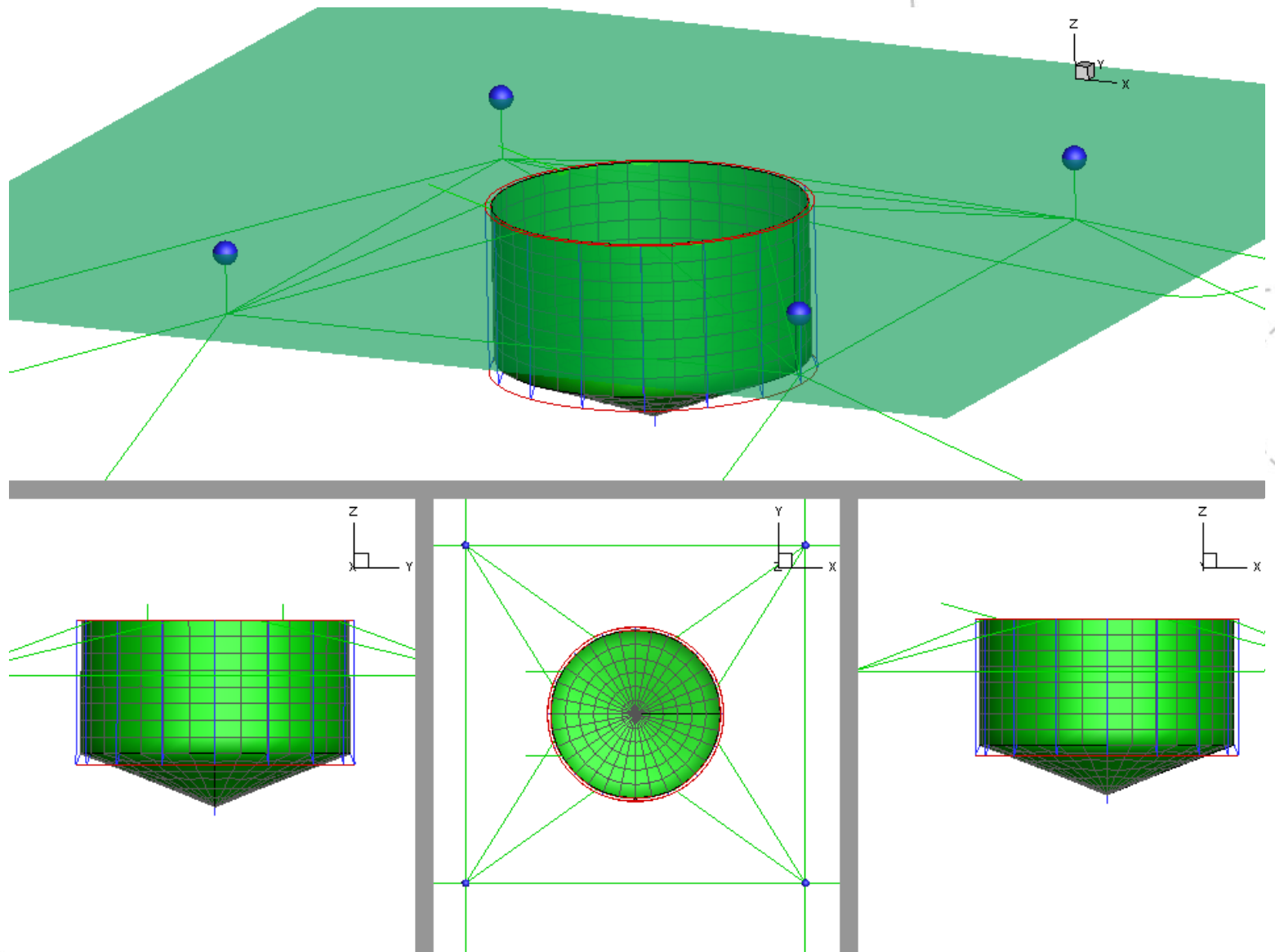
■ yield stress

# Conclusions

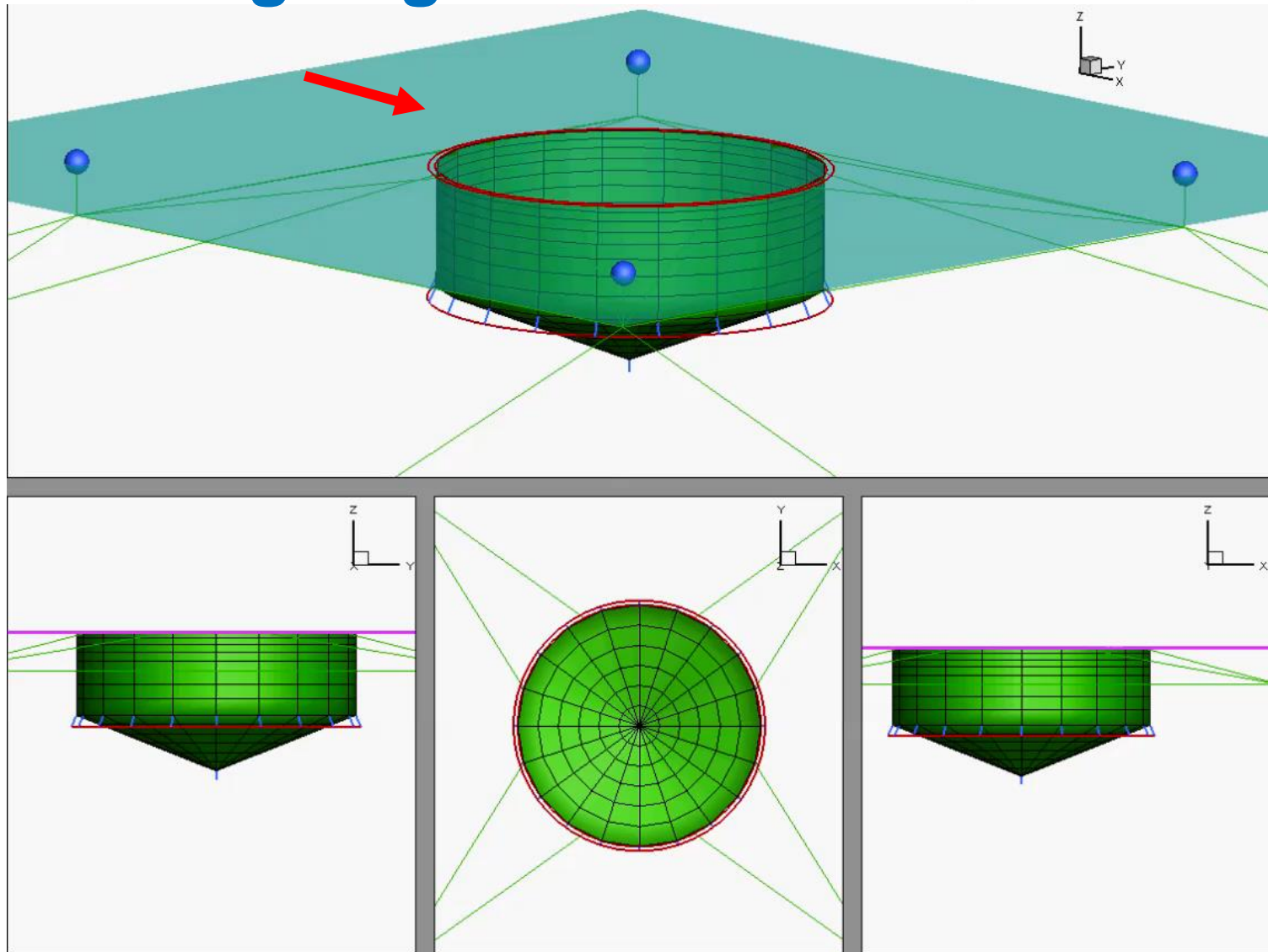
- Well boat will increase both the mean and amplitude of the mooring loads
- Well boat may threaten the structural integrity of the fish farm system even in not so severe sea states.

**Shen, Y. G., Greco, M., and Faltinsen, O. M., 2016. “Numerical Study of a Coupled Well Boat-fish Farm System in Waves and Current during Loading Operations ”. In Proceedings of 12th International Conference on Hydrodynamics, No.98.**

# Ongoing and Future work



# Ongoing and Future work

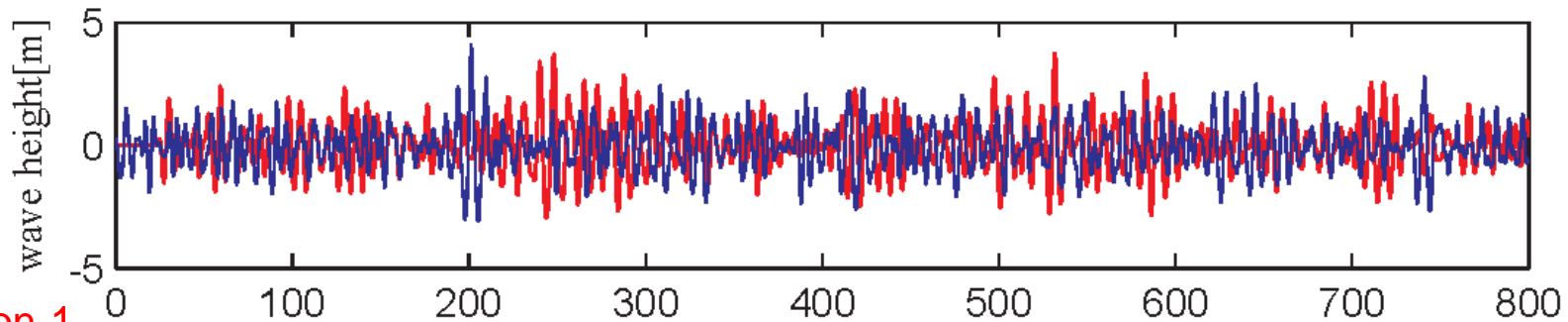


**$(U_c=0.5\text{m/s}, H_s=4\text{m}, T_p=8\text{s}, \text{storm})$**

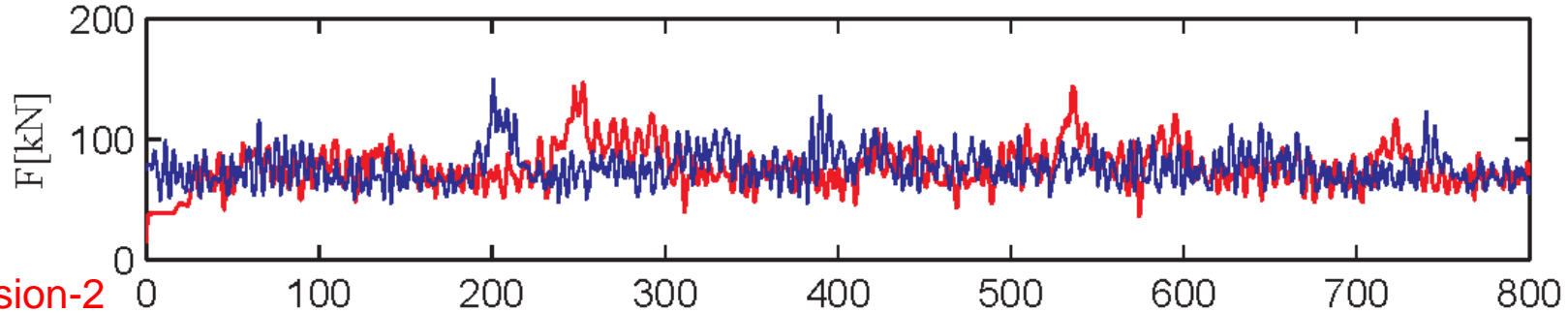


# Ongoing and Future work

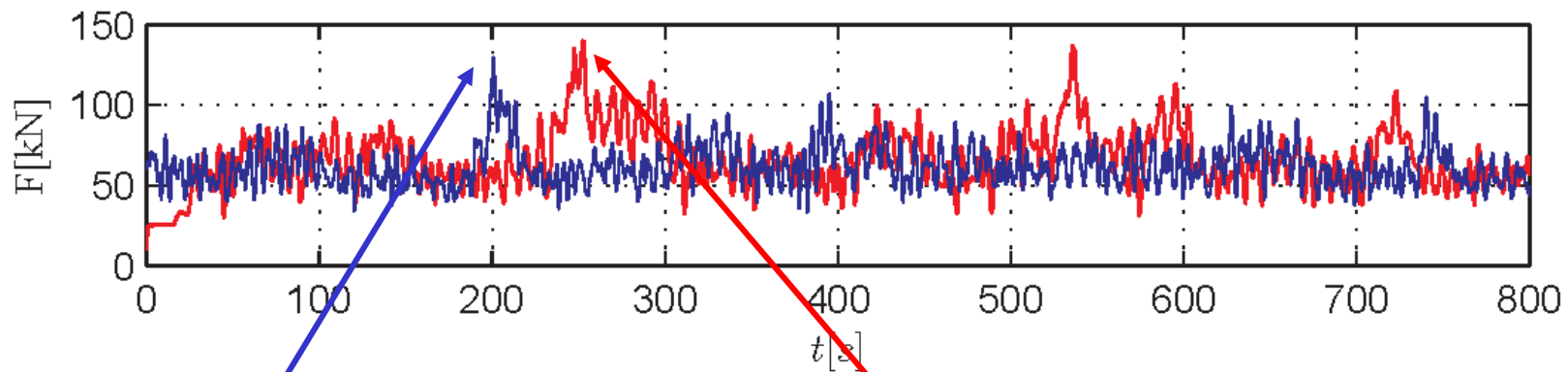
Wave history



Mooring tension-1



Mooring tension-2



Experiment, Nygaard(2013)

Numerical

- **Thank you for your attention!**

**Questions?**

