An Experimental Study for

Yaw-Excitation Phenomena of 8MW-class FOWT in Waves

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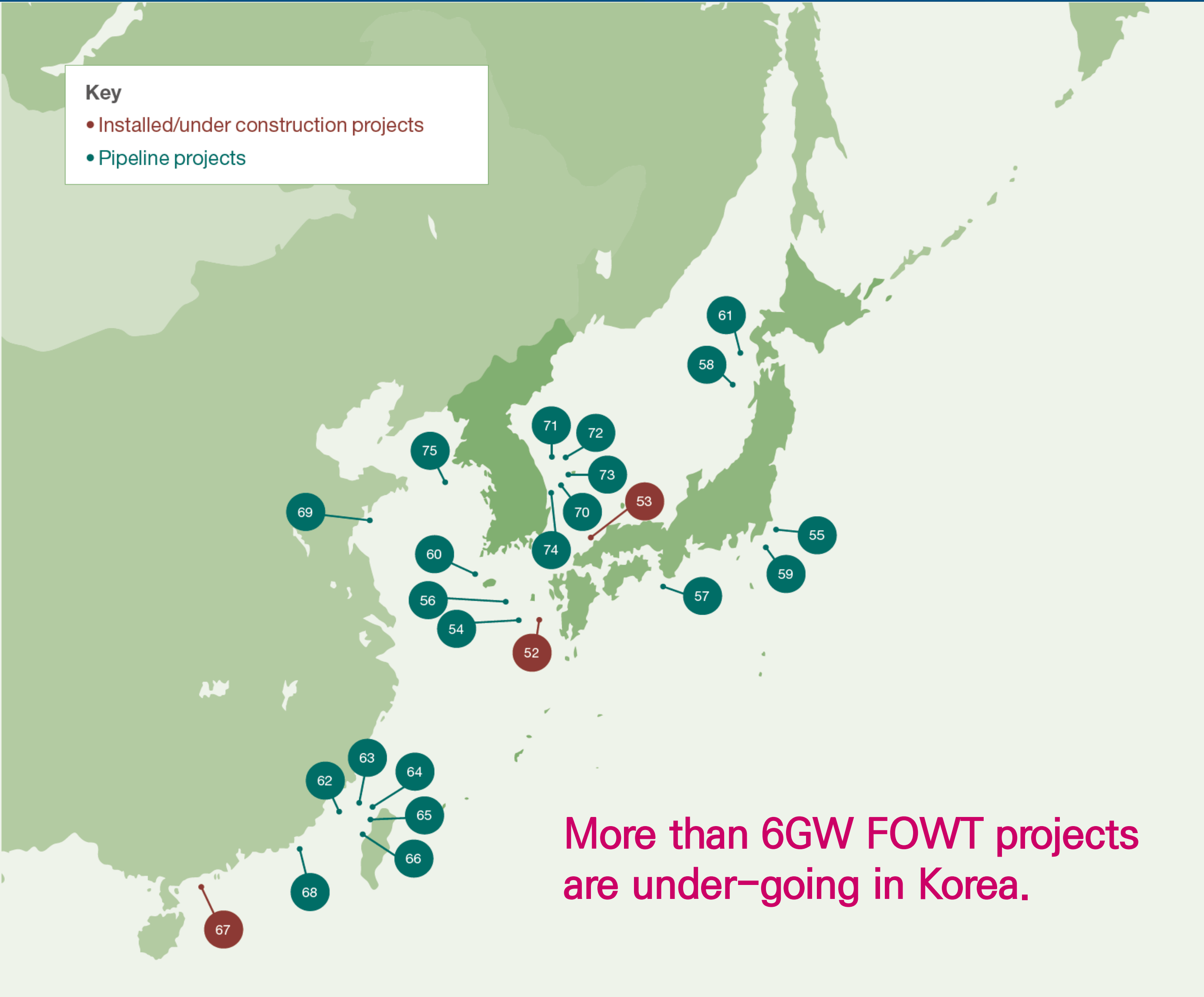
EERA DeepWind CONFERENCE 2025

Introduction



More than 6GW FOWT projects are under-going in Korea.

Japan	
52. Sakiyama	2
53. IDEOL Kitakyshu demo	3
54. Goto City	17
55. Sakura	520
56. Kyushu	1000
57. Kishuu	450
58. Toki Ⅰ & Ⅱ	1100
59. Progression Energy Floating	800
60. Goto Sakiyama Oki Oki	500
61. Seihoku-ouki	600
Taiwan	
62. Eolfi Taiwan	500–2000
63. Chu Tin Ⅰ & Ⅱ	1300
64. Huan Ya	1400
65. Laifeng	950
66. Hai Shuo	1350
China	
67. CTGNE Yangjiang Shapa	5.5
68. Longyuan Nari Island	4
69. Qingdao	2000
South Korea	
70. Ulsan Prototype	5
71. Donghae Sites	500–4500
72. Firefly	804
73. Munmu Baram	420–1500
74. Ulsan Floating	1000–2500
75. Incheon	1600

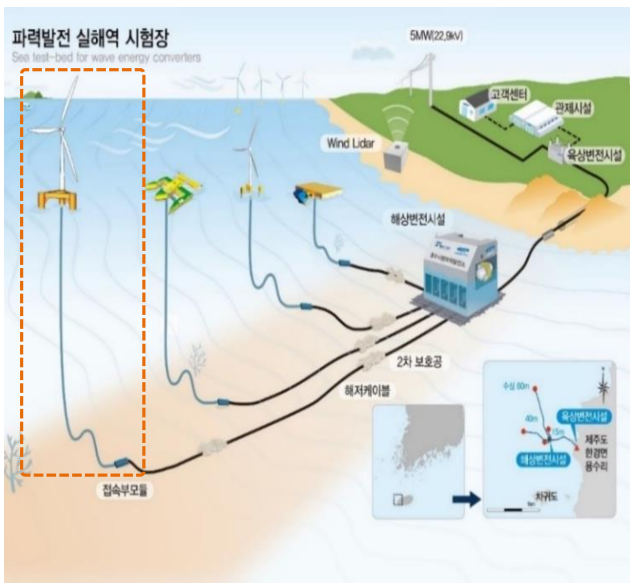
Ref : Carbon Trust(2022), Electric Power

Introduction

Government Funded Project (MOTIE)

Demonstration of 8MW FOWT (20~26)

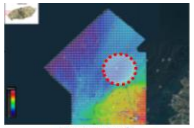
- Development and demonstration of 8MW class floating offshore wind turbine
- Consortium : Doosan, **KRISO**, IAE, Samgang M&T, KOMAC, Seho Eng., KOEN, Jejuenergy, GyeongnamTP, Jejudo, Gyeongnam



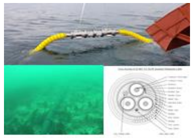
Real Sea Test Site
(West of Jeju Island)

Control Tower

Offshore Substation



Test Berth

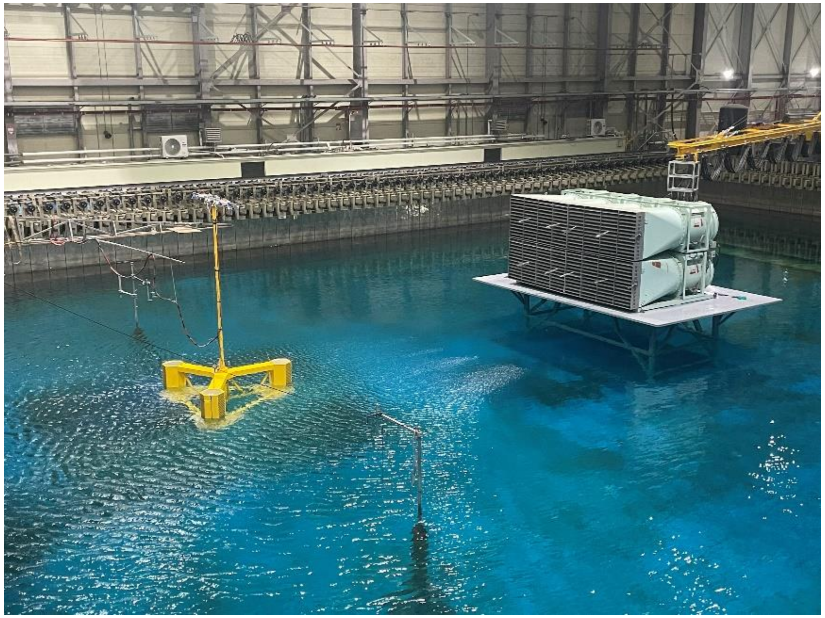


Subsea Cable/Connector

Experimental Campaign of FOWT

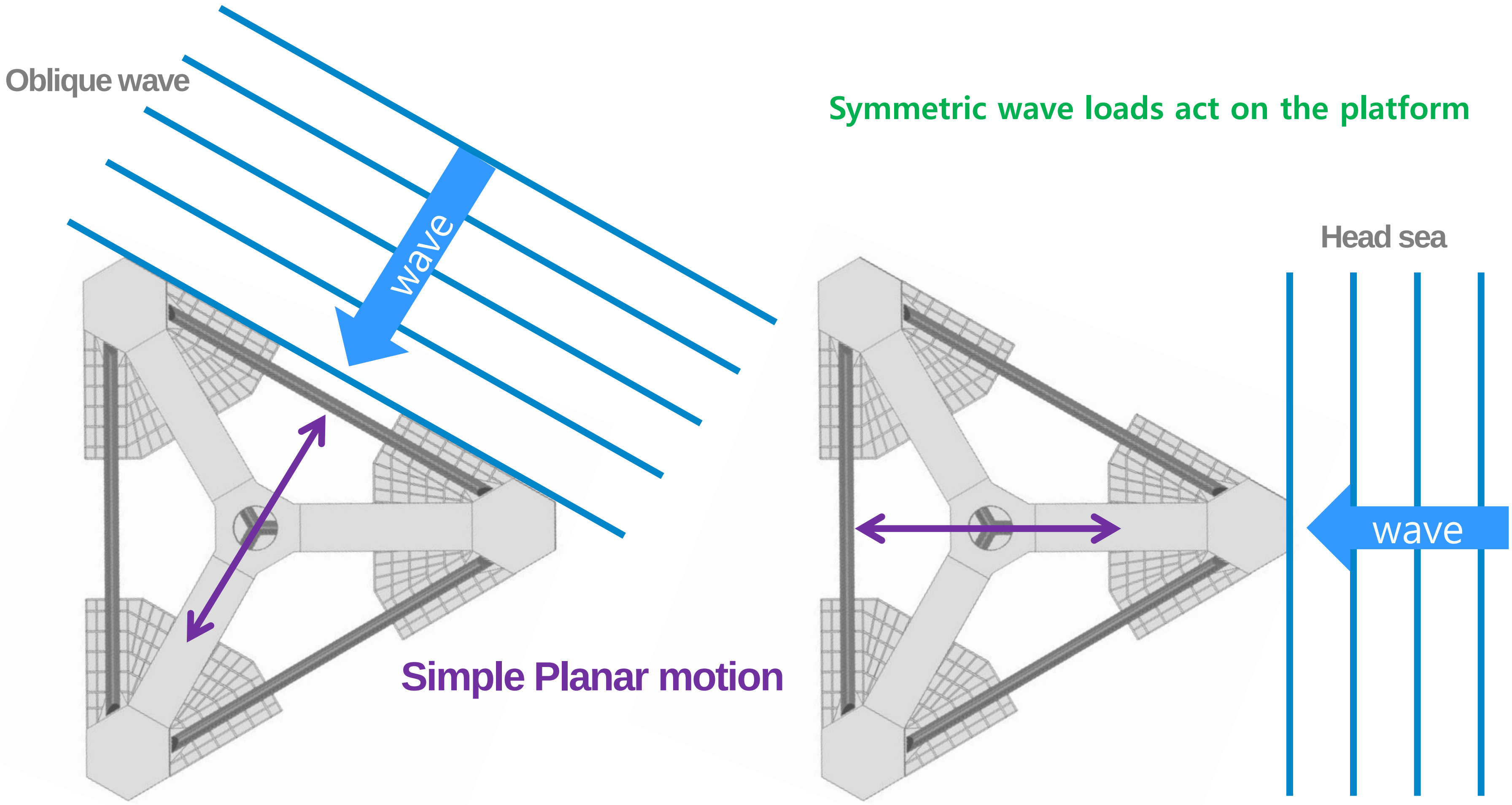
Validation of Numerical Model (8MW FOWT)

- Facility : Ocean Engineering Basin of KRISO (Daejeon, Korea)
- Test Program : DNV-RP-0286, Ch. 7.4
- Operation Condition : Real-time Hybrid Technique w/ Full-scale Simulation using Ducted-fan System



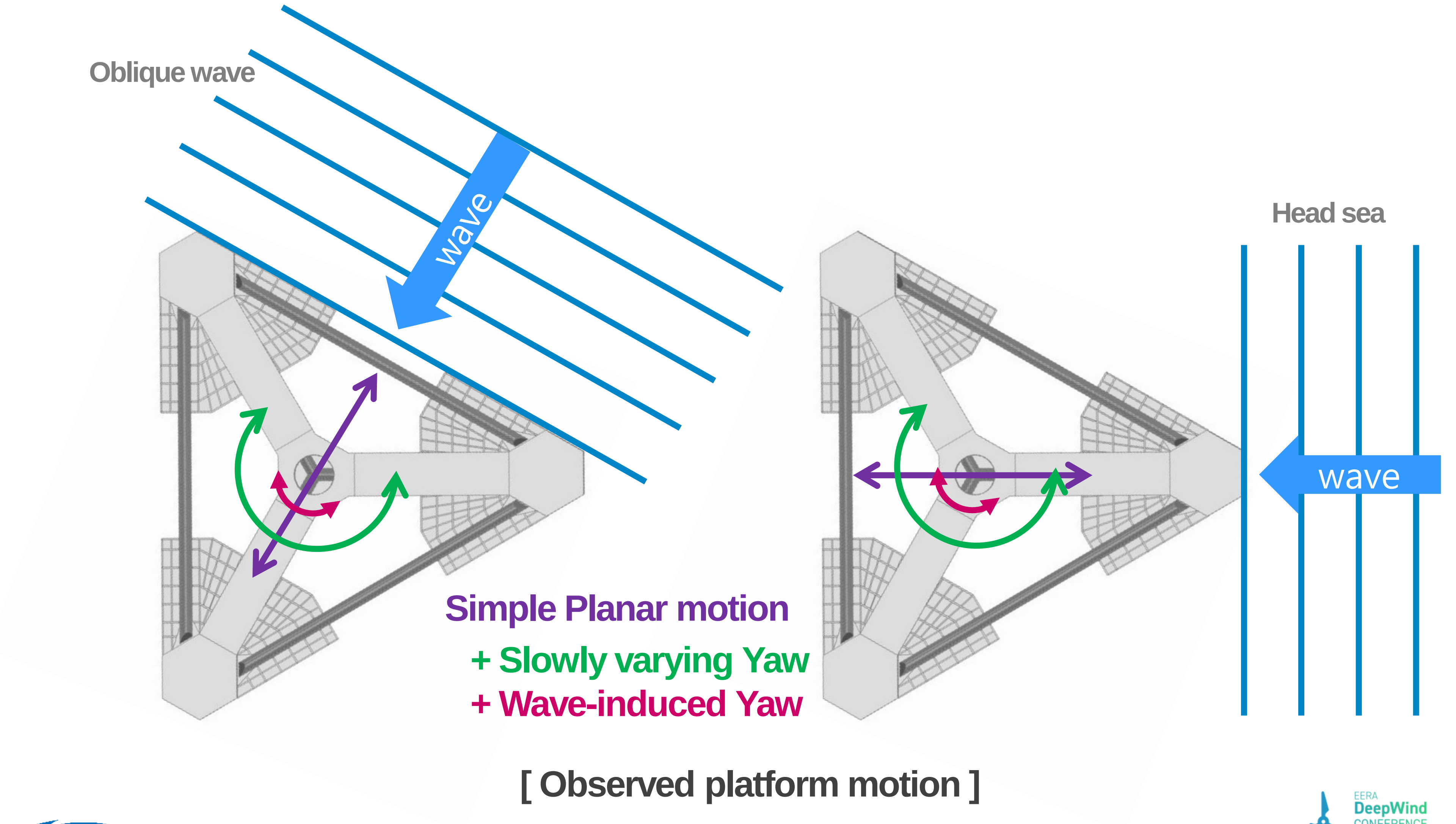
Introduction

- **Observation of Yaw Excitation Phenomena**



[Ideal platform motion]

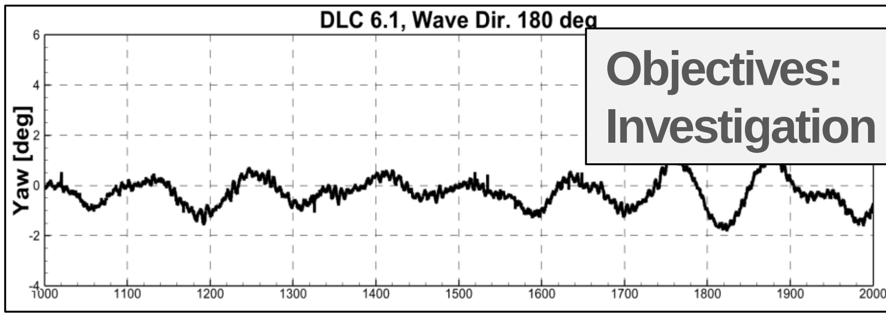
- **Observation of Yaw Excitation Phenomena**



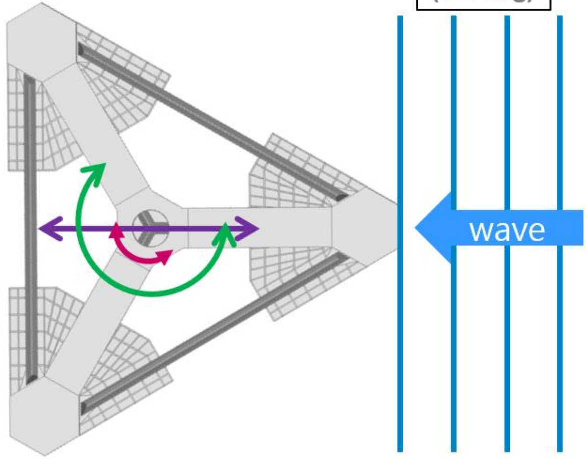
[Observed platform motion]

Observation of Yaw Excitation Phenomena

- Symmetric wave loading condition
- Minor disturbance & misaligned wave loading can induce the yaw motion



Objectives:
Investigation of wave-induced yaw motion & its effects



[Head sea]

https://education.nationalgeographic.org/resource/ocean/

[Ocean waves]

Design Load Cases

- DLC 1.6 – Operating condition
- DLC 5.1 – Operating condition (Transient case)
- DLC 6.1 – Parked condition

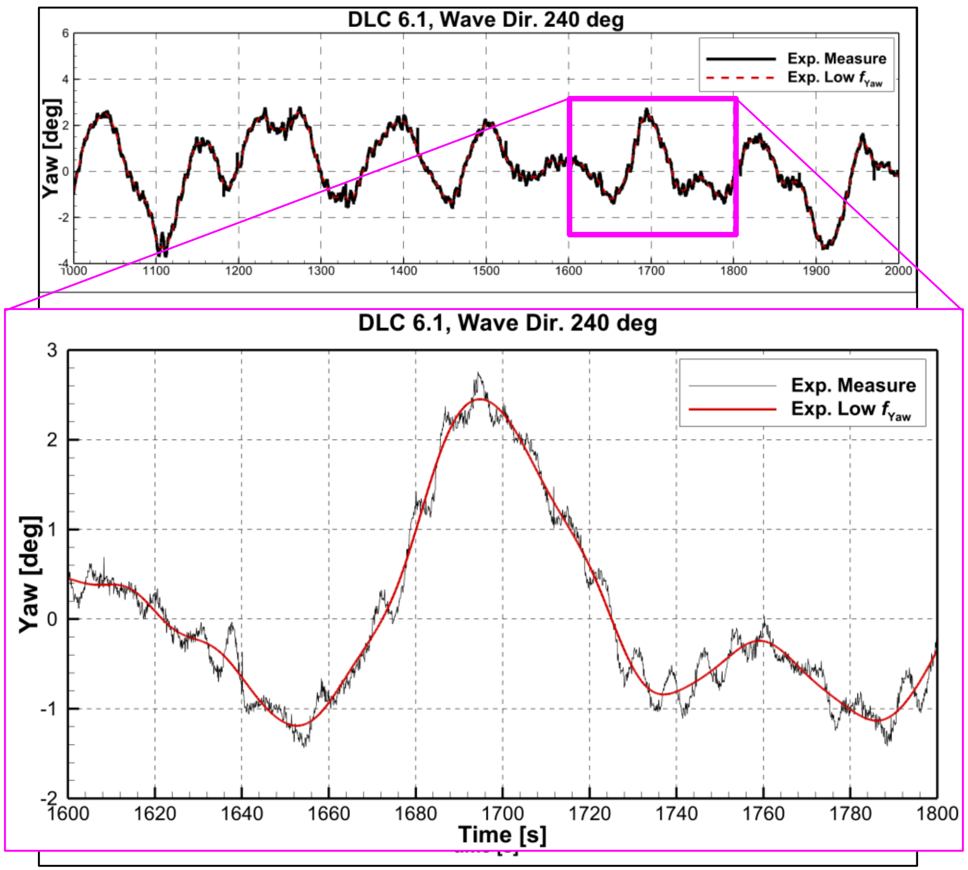
DLC	Duration	Wind [m/s]	Waves			Current [m/s]	Direction (deg.)		
			Hs [m]	Tp [s]	Gamma		Current	Wind	Wave
1.6	3-hour	-	3.63	9.0	1.37	-	-	-	180
		11.0	3.63	9.0	1.37	-	-	180	180
		11.0	3.63	9.0	1.37	0.41	180	180	180
5.1	3-hour	11.0	3.63	[illegible]	[illegible]	[illegible]	180	180	180
6.1	3-hour	-	5.7	10.3	1.33	-	-	-	180
		-	6.3	14.3	1.33	-	-	-	180
		-	6.2	12.7	1.33	-	-	-	180
		-	6.2	12.7	1.33	-	-	-	210
		-	6.2	12.7	1.33	-	-	-	240
		-	8.2	13.6	1.33	-	[illegible]	[illegible]	[illegible]
		-	6.2	12.7	1.33	1.64	180	-	180
		-	8.2	13.6	1.33	1.00	180	-	180
		42.5	8.2	13.6	1.33	-	-	180	180
		42.5	8.2	13.6	1.33	1.00	180	180	180

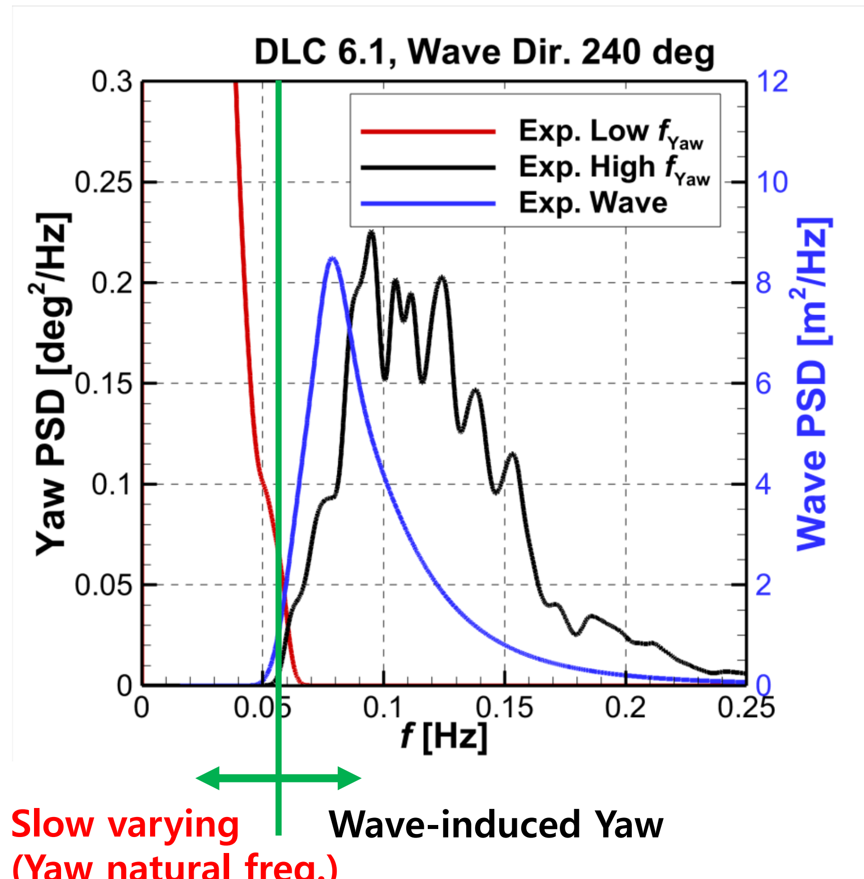
Effect of wave steepness

Effect of wave direction

Results and Discussion

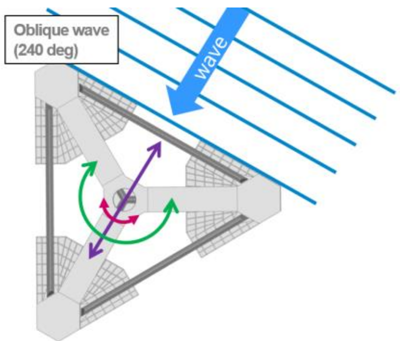
- **1) Yaw Motion in Irregular Waves**
  - DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

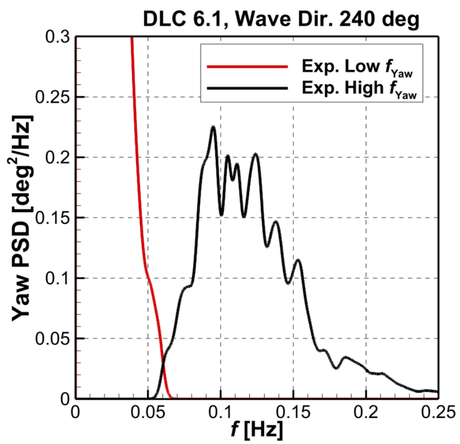


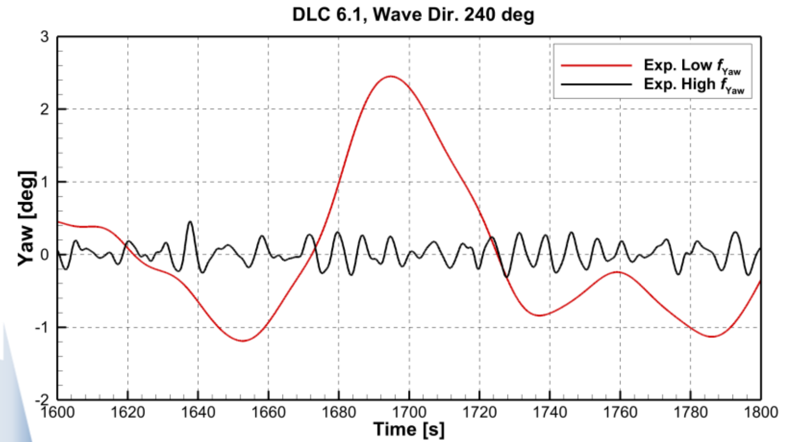


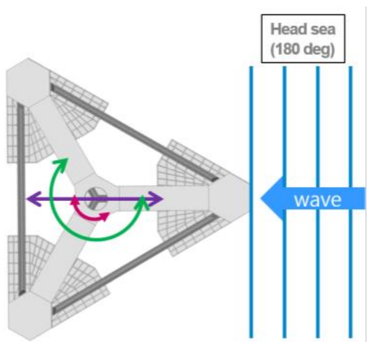
Results and Discussion

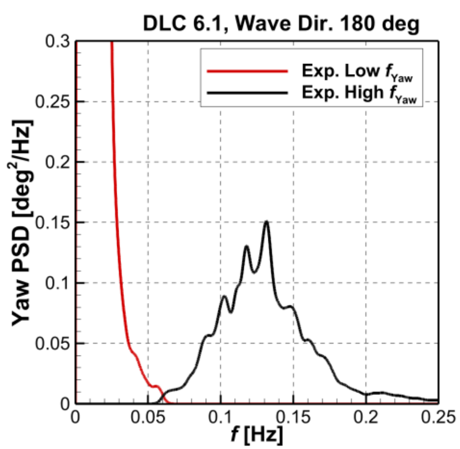
- **2) Effect of wave direction**
  - Yaw motion observed regardless of wave direction
  - Separation of frequency domain (natural & wave-induced yaw motion)

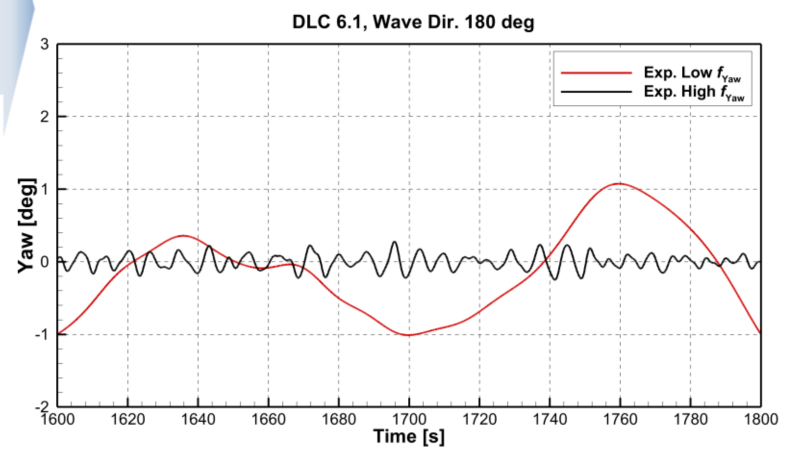








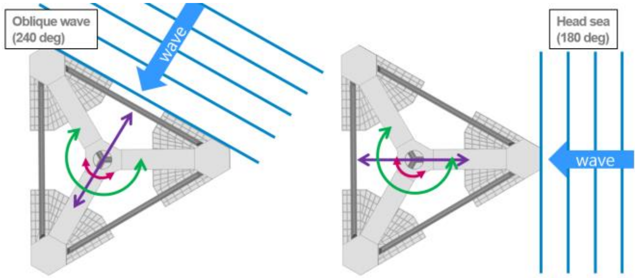


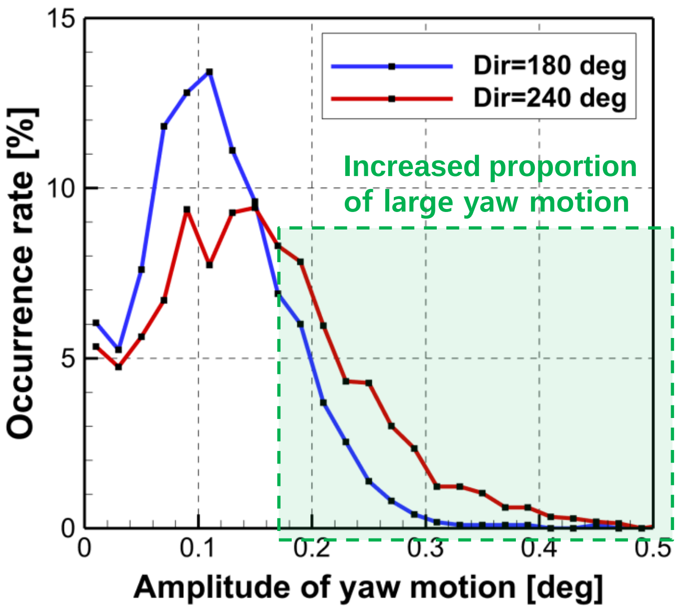


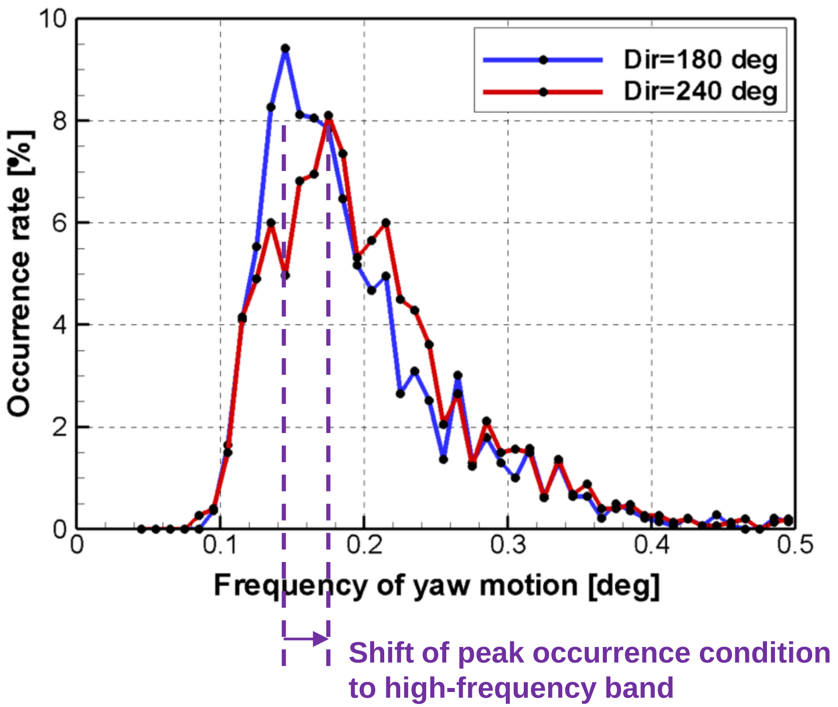
DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

Results and Discussion

- **2) Effect of Wave Direction**
  - Occurrence rate of yaw motion in oblique waves
    - Increase of proportion
      : large yaw motion, high-frequency yaw motion





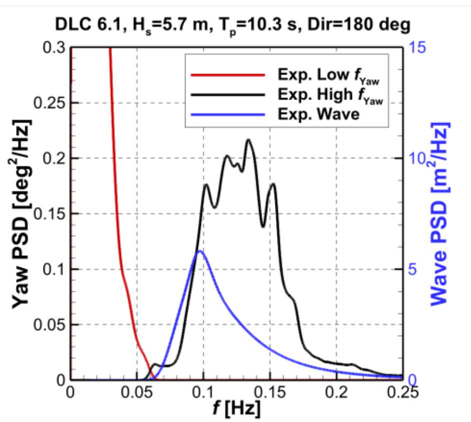


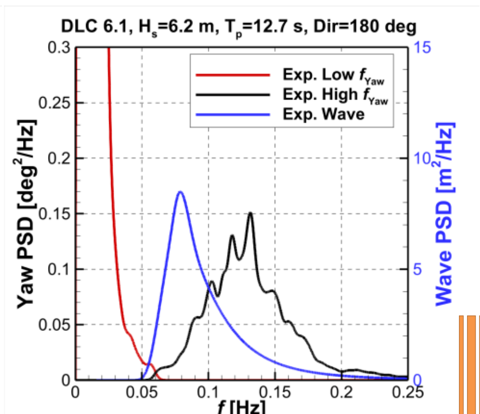
DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

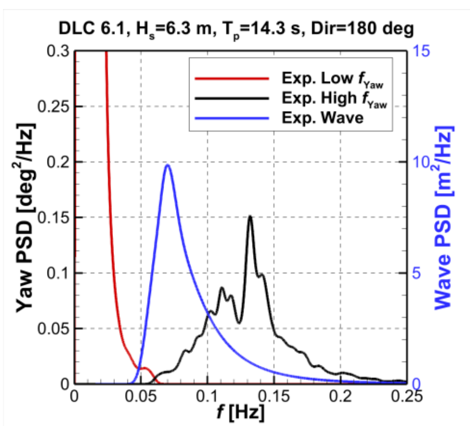
Results and Discussion

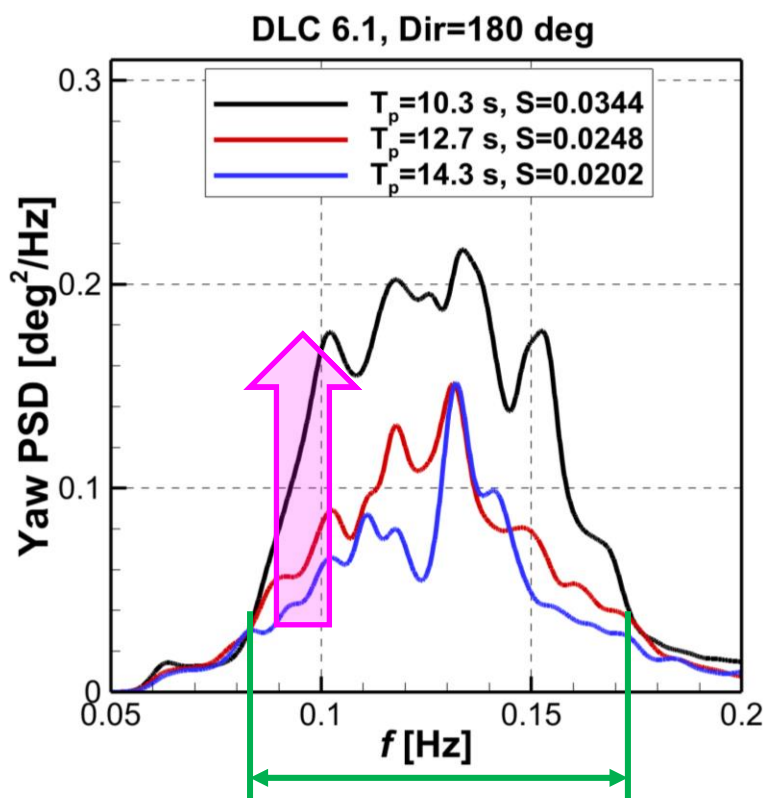
- **3) Effect of Wave Period & Steepness**
  - H_s= 5.7 m, T_p= 10.3 s, **S=0.0344**
  - H_s= 6.2 m, T_p= 12.7 s, **S=0.0248**
  - H_s= 6.3 m, T_p= 14.3 s, **S=0.0202**

Wave-induced Yaw ∝ Wave Steepness (S)





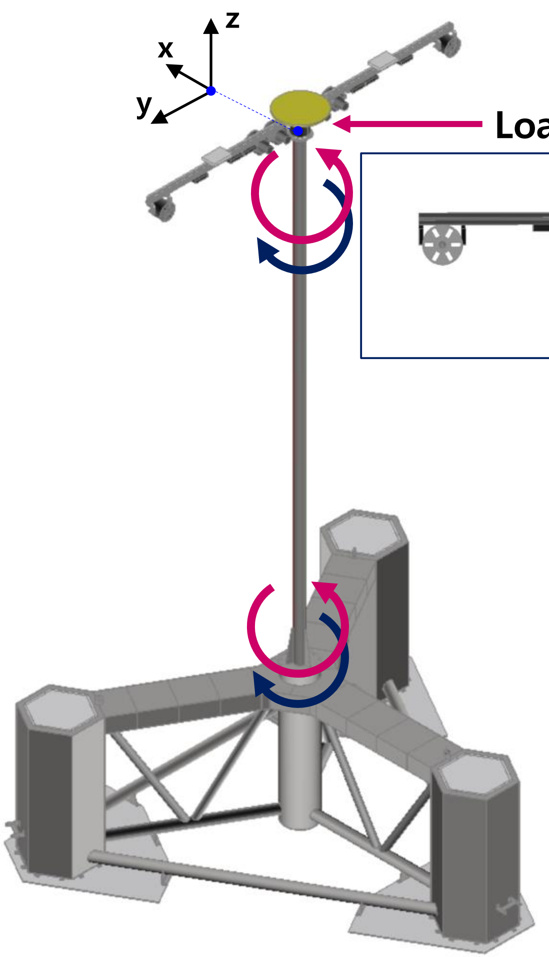


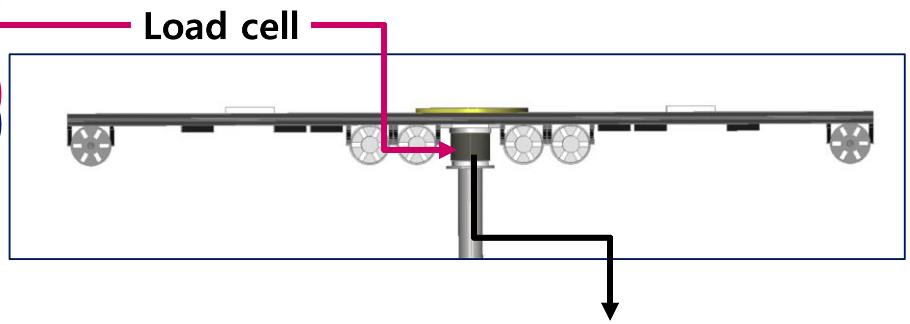


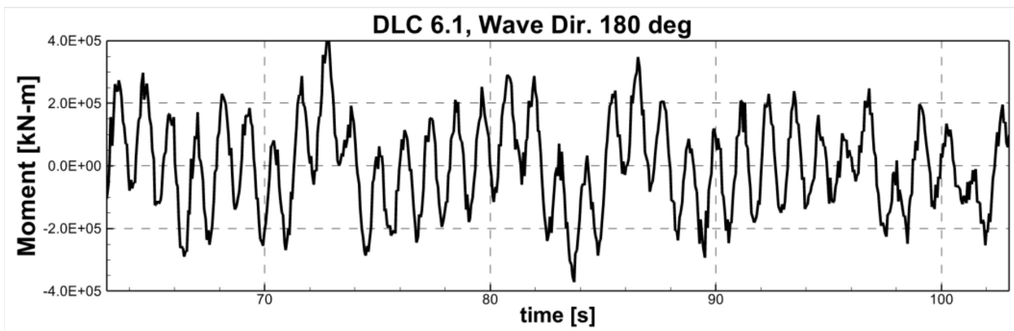
Frequency band of Wave-induced Yaw

Results and Discussion

- 4) Effect of Yaw Motion on Tower Response





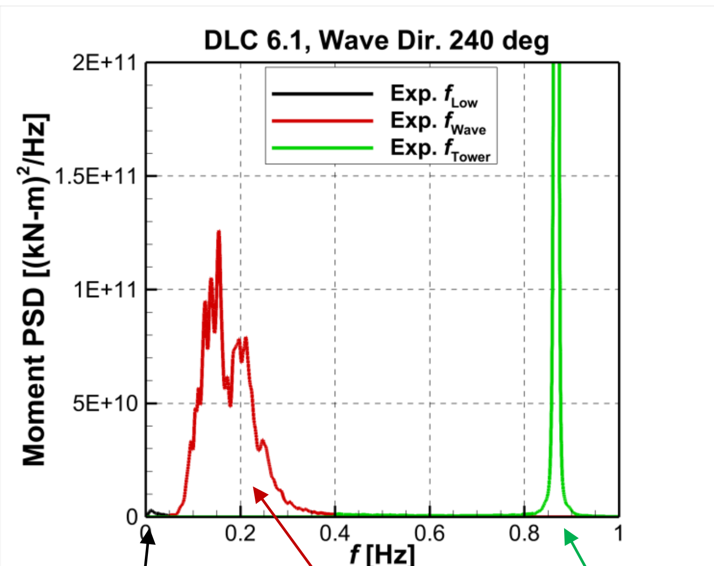


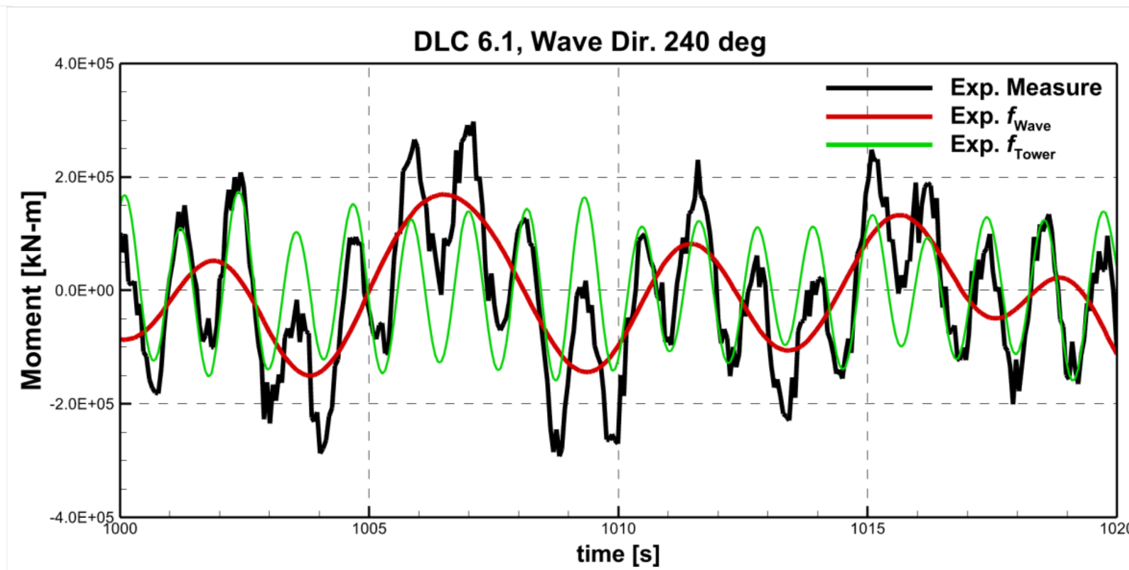
- Moment at top of the tower model
- Measured by 3-axis load cell (X, Y, Rz)

*Assume: rigid tower model (stiff fabrication)

Results and Discussion

- **4) Effect of Yaw Motion on Tower Response**
  - Response of tower moment : wave frequency band & tower natural frequency
  - No response at the low frequencies (slow varying yaw motion)





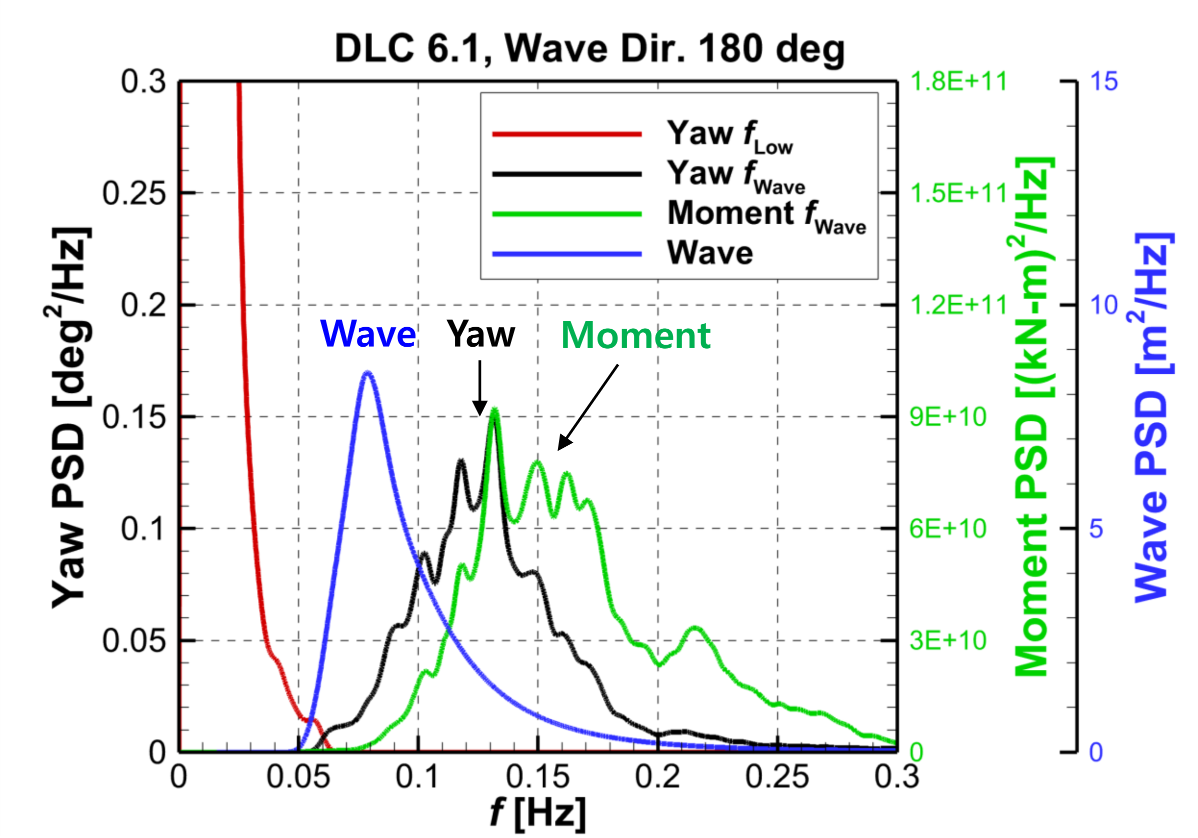
Yaw natural Freq. **Wave Freq.** **Tower Natural Freq.**

*Assume: rigid tower model (stiff fabrication)

DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

Results and Discussion

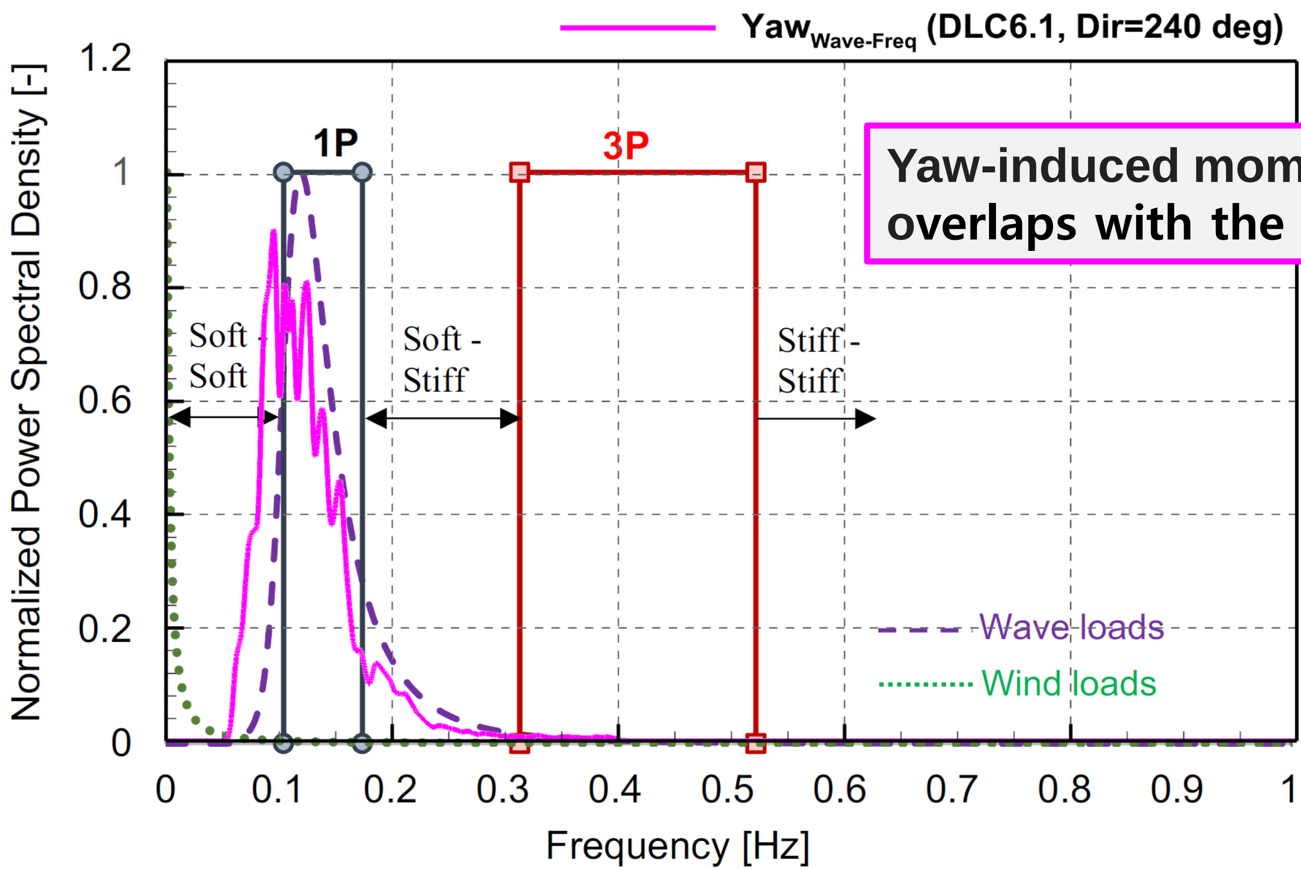
- **4) Effect of Yaw Motion on Tower Response**
  - Shift to higher frequency band in energy transfer process (wave, yaw motion, tower moment)
  - Effect of yaw-induced moment on the FOWT system need to be evaluated.



*Assume: rigid tower model (stiff fabrication)

DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

- **4) Effect of Yaw Motion on Tower Response**
  - Response of the 8MW wind turbine



Yaw-induced moment overlaps with the 1P region

Demirci, H. E., Jalbi, S., & Bhattacharya, S. (2022). Liquefaction effects on the fundamental frequency of monopile supported offshore wind turbines (OWTs). Bulletin of Earthquake Engineering, 20(7), 3359-3384.

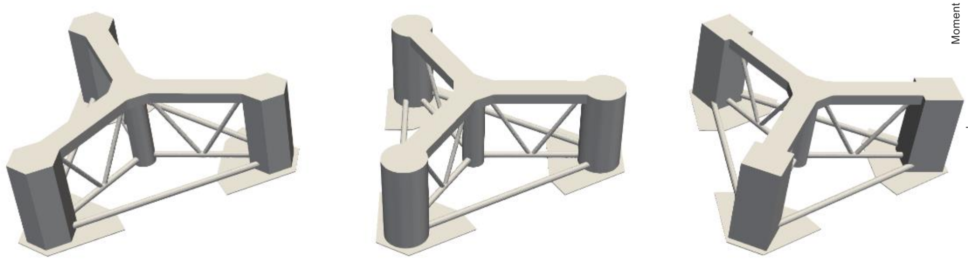
DLC 6.1 – Parked condition, H_s= 6.2 m, T_p= 12.7 s

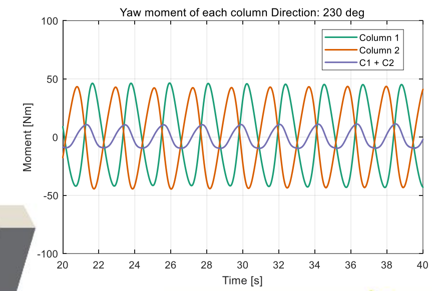
Summary & Conclusion

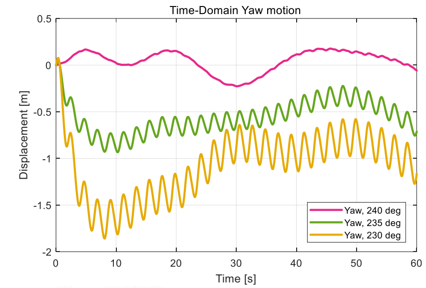
- **Analysis of Yaw excitation based on Experimental Observation**
  - Mechanism of Yaw excitation
    - Yaw excitation induced by waves regardless of wave direction.
    - Yaw motion mainly consists of the platform's natural periodic and wave-induced components.
    - Relative wave direction & steepness → increasing wave induced yaw amplitude
  - Effect of wave induced yaw excitation
    - Yaw excitation induces the torsional load of the tower
    - Tower moment was excited in the high-freq. band of the wave component.
    - Yaw-induced moment overlaps with the 1P region of the wind turbine.
  - An application of yaw-induced moment
    - Consideration in WT controller
    - Structural design of tower, RNA, and etc.
    - Method of load reduction & frequency band avoidance

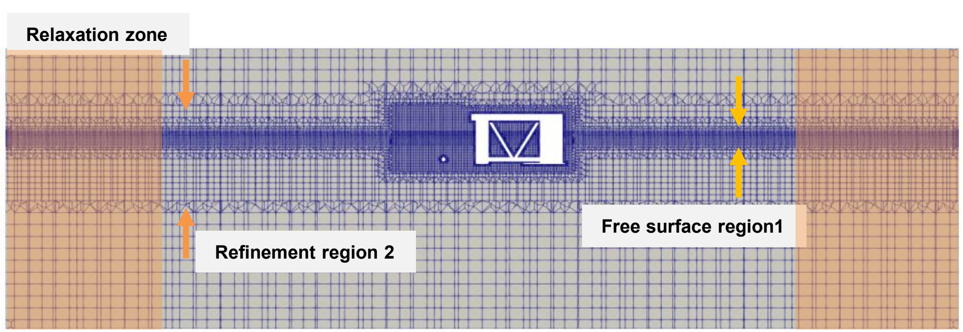
Future Research

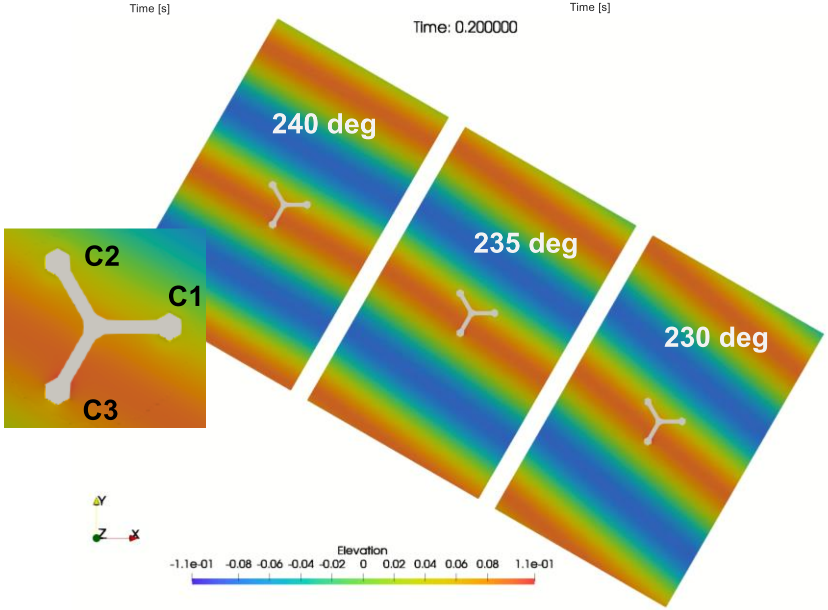
- **Analysis of Yaw Excitation Mechanism based on CFD Simulation**
  - Decomposition of wave loading component inducing yaw motion
  - Correlation between wave loading and platform's geometry (configuration, shape, and etc.)











"Thank you"

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