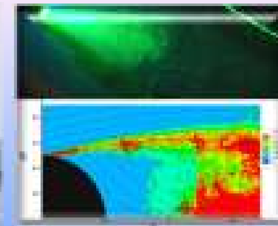

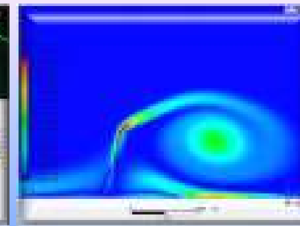

Desarrollo de Tecnología en Ingeniería Costa-Afuera para Aguas Profundas en el Golfo de Mexico

2da Asamblea de la Red Global MX Capitulo Corea
12 de Diciembre de 2017

Cristobal Santiago[1],

[1]Korea Research Institute of Ships and Ocean Engineering (KRISO)
Offshore Plant Research Division,

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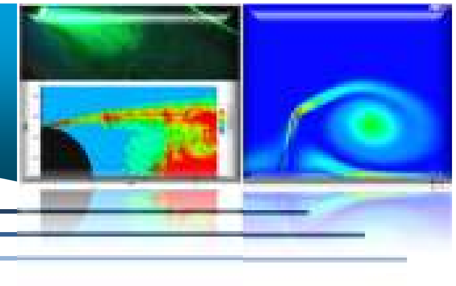
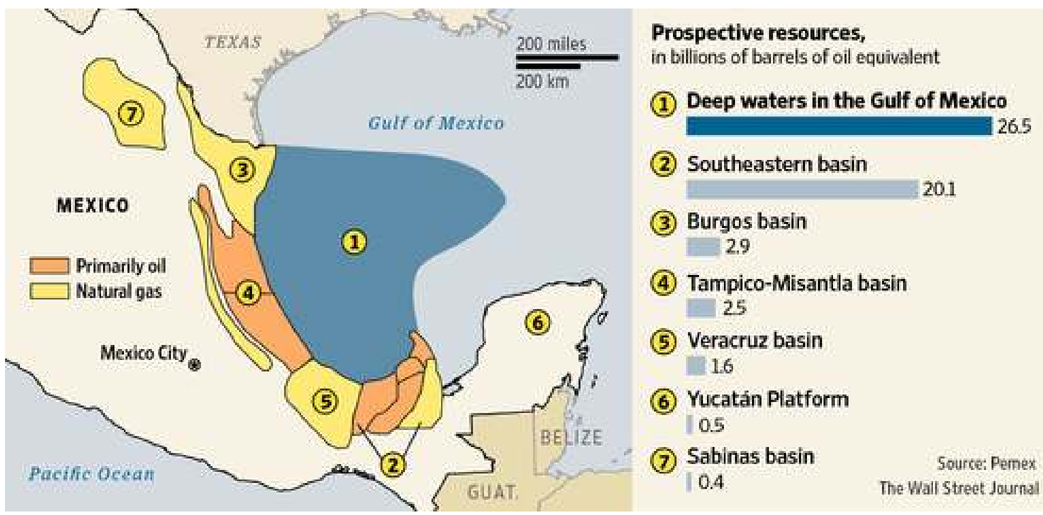


Introduction

❑ Hydrocarbons Fields in Deep Water

1. Exploration and Exploitation of Oil and Gas Fields in:
   - ✓ Deep water: 500-1500 m
   - ✓ Ultra-Deep Water: >1500 m
2. Opportunities and Challenges that Companies will Face in:
   - ✓ Upstream (Exploration and Production);
   - ✓ Midstream (Oil and Gas Transportation).



Prospective Resources in the Gulf of Mexico

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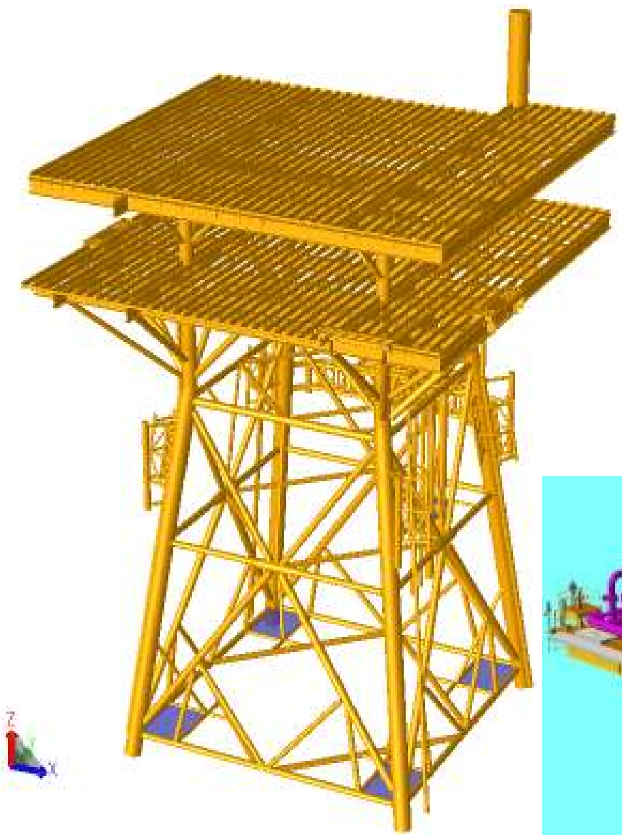
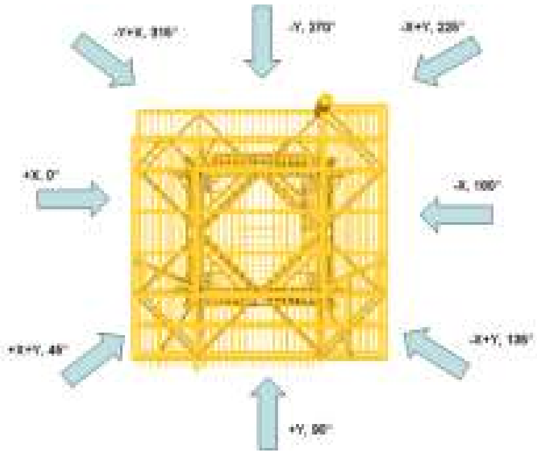
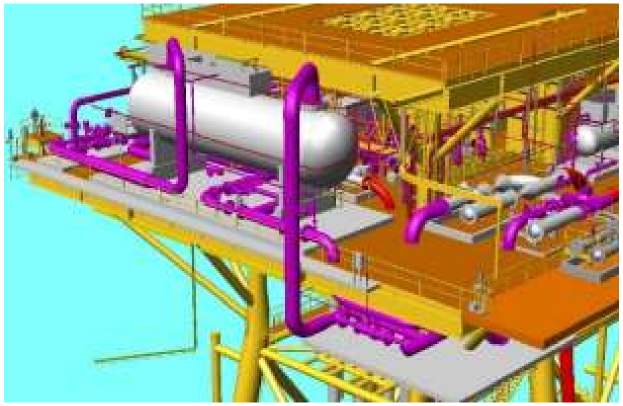
State of the Art

❑ Operation and Storm Condition Analysis (In Situ)

✓ Offshore Production Platform.– PB-LIT-T







Water Depth: 26.20 m.

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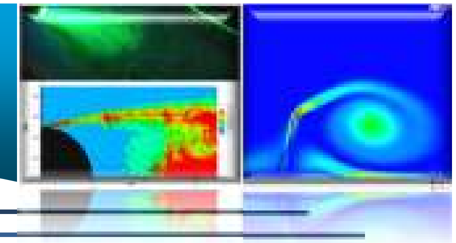
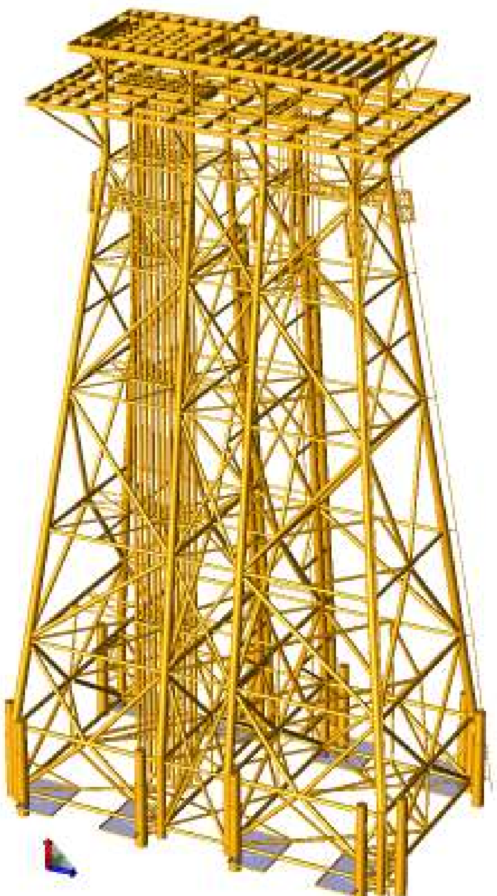
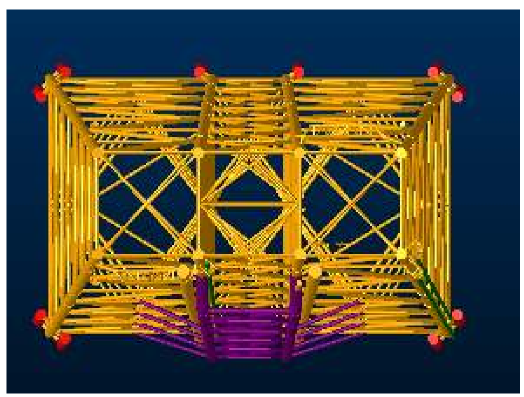
State of the Art



❑ Jacket Platform Dockyard

✓ Offshore Drilling Platform.– Ayatsil-D





Water Depth: 115.950 m.

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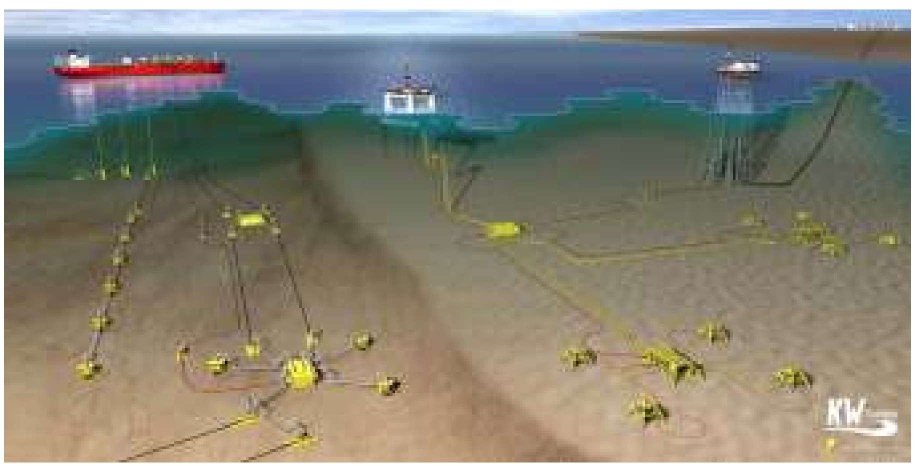
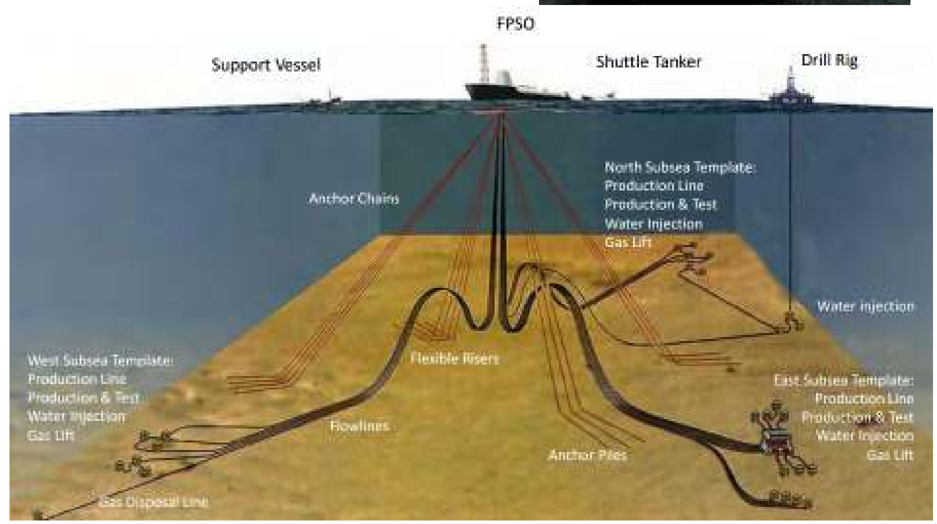
State of the Art

❑ Floating Systems in Deep Water Oil Fields

1. Engineering and Economic Perspective
   - ✓ Cost-Effective Steel-Jacket Structures are Difficult ($)
2. Industry has Developed Concepts to Overcome Deep Water Challenges
   - ✓ Floating Production Systems and Offloading (FPSOs) for water depth up to 2500 m



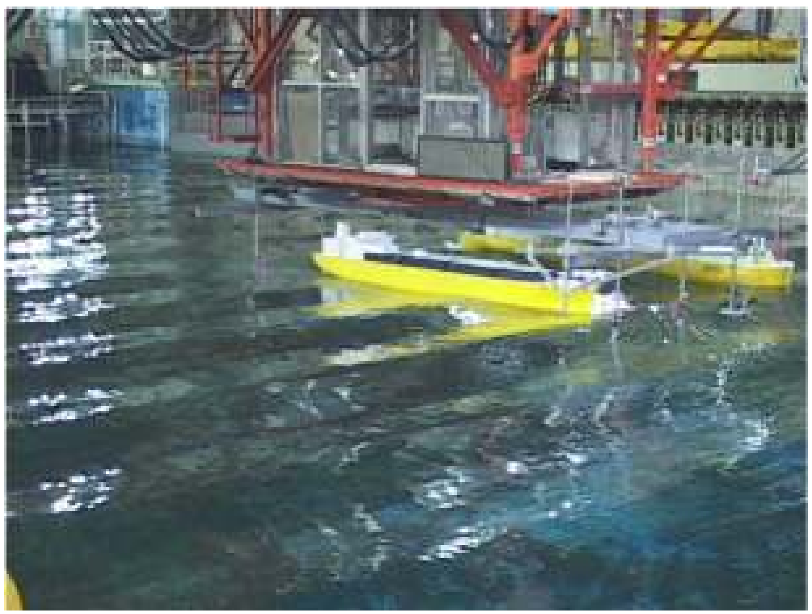


Contents

Methodology

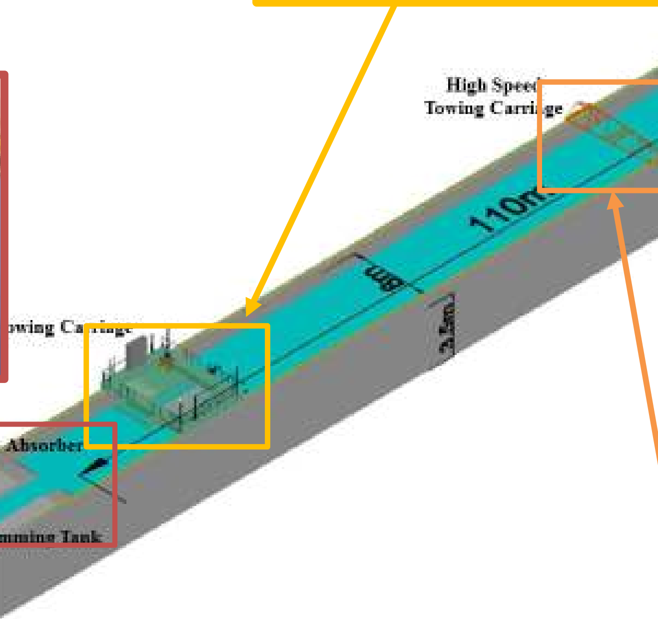
❑ Korea Research Institute of Ships and Ocean Engineering

1. Evaluate and Design Ships and Maritime Structures
   - ✓ Length: 56 m
   - ✓ Width: 30 m
   - ✓ Depth: 4.5 m



❑ Seoul National University Towing Tank

1. Propulsion Test
   - ✓ Length: 110 m
   - ✓ Width: 8 m
   - ✓ Depth: 3.5 m



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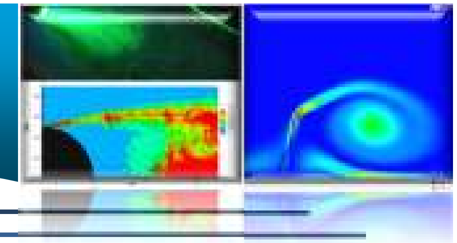
Methodology



❑ Time Domain Eq. – Mooring System

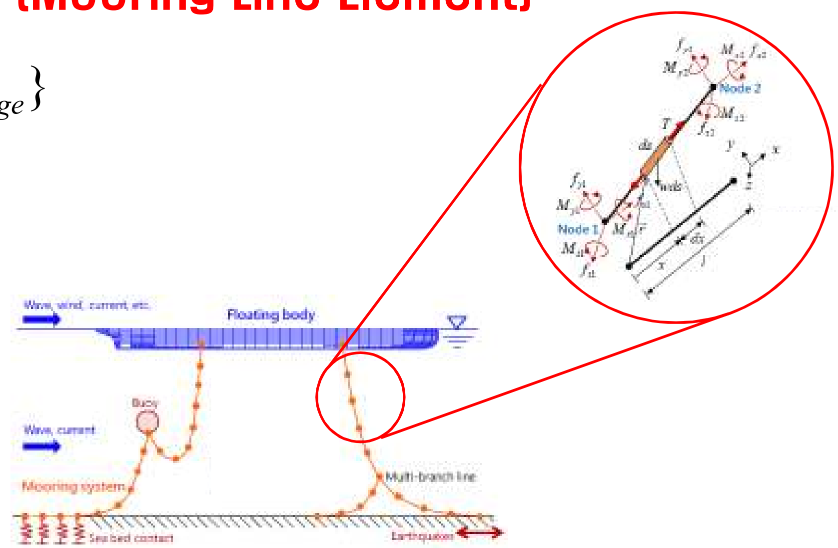
1. Time Domain Eq.–Global Coordinates (Mooring Line Element)

$$[M_{ge}]\{\ddot{u}_{ge}\}+[K_{ge}]\{u_{ge}\}+\{B_g\}\lambda=-\{f_{we}\}+\{f_{ge}\}$$

- Where:

$$\{B_g\}^T\{u_{ge}\}=s-l \qquad s=s_0\left(1+\frac{T}{EA}\right)$$

$[M_{ge}]$: Geometric Non-Linear Mass Matrix (Mooring Elem)
$[K_{ge}]$: Geometric Non-Linear Stiffness Matrix (Mooring Elem)
$\{u_{ge}\}$: Nodal Displacements Vector (Global Coordinates)
$\{f_{ge}\}$: Section Forces Vector (Global Coordinates)
s_0: Unstretched Length
λ: Lagrange Multiplier
EA: Axial Stiffness



Time Domain Solution: Generalized Newmark-Alpha Method

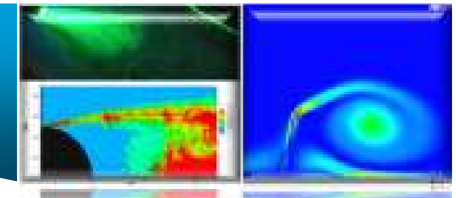
2. Time Domain Eq.–Total Mooring System

$$[M]\{\ddot{u}\}+[C]\{\dot{u}\}+[K]\{u\}=\{f_n\}+\{f\}$$

Non-Linear Eq.

$[M]$: Mass Matrix of the Total Mooring System
$[C]$: Damping Matrix of the Total Mooring System
$[K]$: Stiffness Matrix of the Total Mooring System
$\{f\}$: Force Vector-External Forces (Drag Force)
$\{f_n\}$: Force Vector-Catenary Weight
$\{u\}$: Nodal Displacements Vector

Contents



Research Results

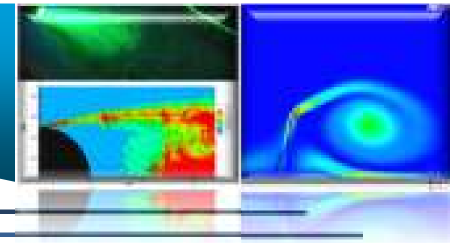
❑ Towing Tank Test

1. Experimental Fluid Dynamics
   - ✓ 6DOF Response of the Model Ship.
   - ✓ Moored System Condition.
   - ✓ Evaluate Intact and Damaged Condition Ship Responses.

Intact Condition λ/H = 1.0

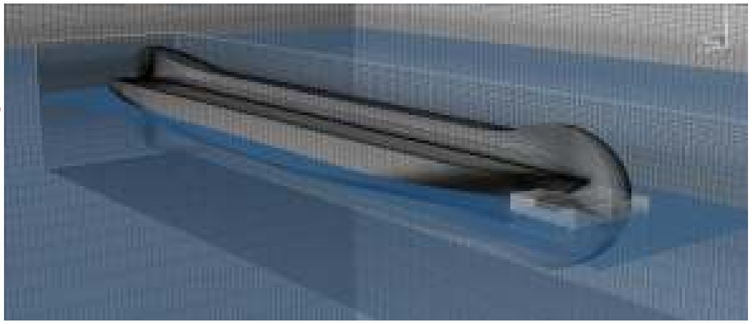
Damaged Condition λ/H = 1.0

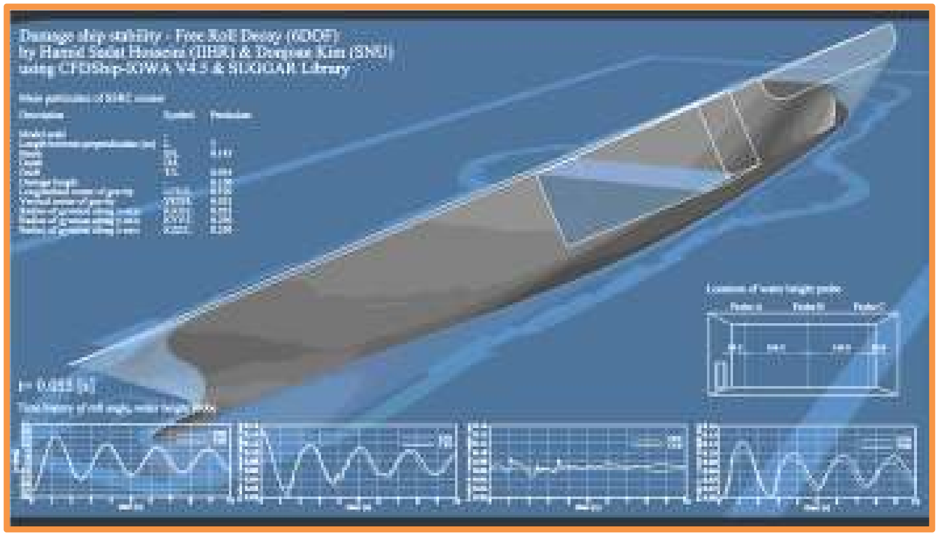
Research Results

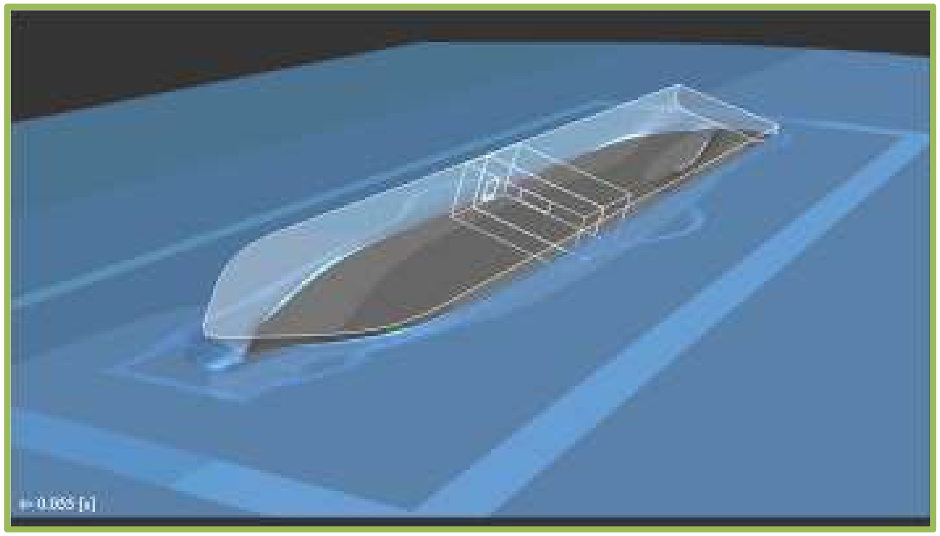


❑ CFD analysis: Damaged Ship Stability

1. Analyzed by CFDShip-IOWA Solver
   - ✓ Free Roll Decay in Calm Water
   - ✓ 3DOF Motion Response in Regular Waves
   - ✓ Compared with Experimental Results







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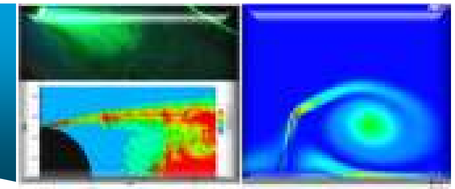
Research Results

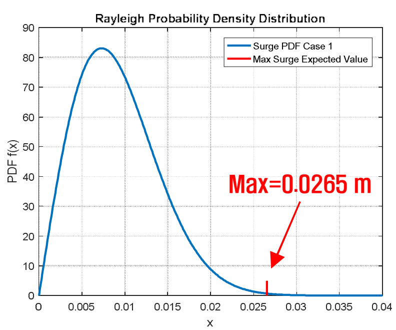


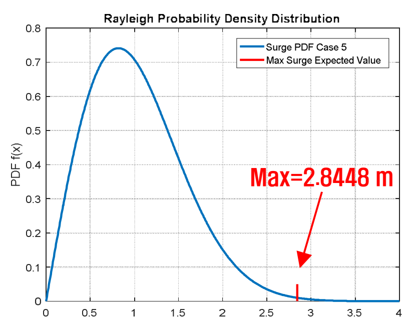
❑ Surge

1. Drifting Time–Around 2000 seconds
2. Surge Motion Comparison
   - Min=0.02 m (H_s=0.30m; T_p=6.30s)
   - Max=2.84 m (H_s=5.00m; T_p=12.40s)

Case Number	Max Surge[1] (m)	Max Surge[2] (m)	Abs Error Value (%)	Probability of Exceeding Max Value (%)
1	0.02974	0.02653	12.10	0.14
2	0.22138	0.17529	26.29	0.24
3	0.75939	0.64919	16.98	0.24
4	2.18065	1.77595	22.79	0.24
5	3.02180	2.84488	6.22	0.24

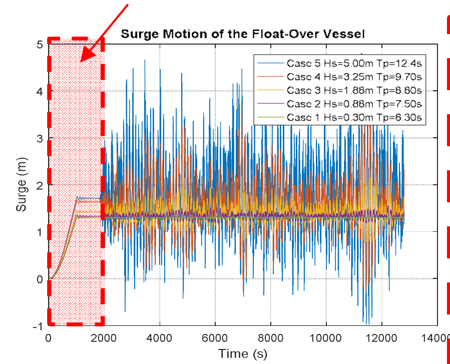
Maximum Surge Motion Results



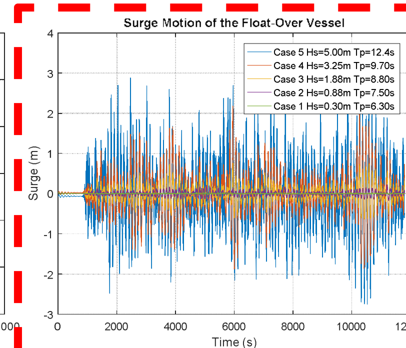


Rayleigh PDF – Case 1 & 5 Comparison

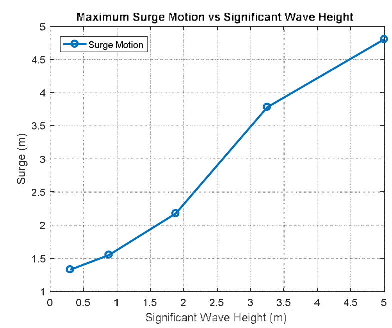
Drifting Time Zone



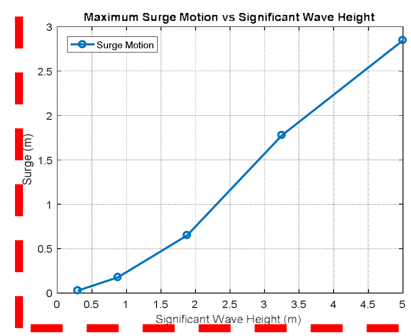
Surge W/Drifting Time



Surge W/O Drifting Time



Maximum Surge Motion Comparison



Maximum Surge Motion Comparison

[1]Direct Method; [2]Statistical Method

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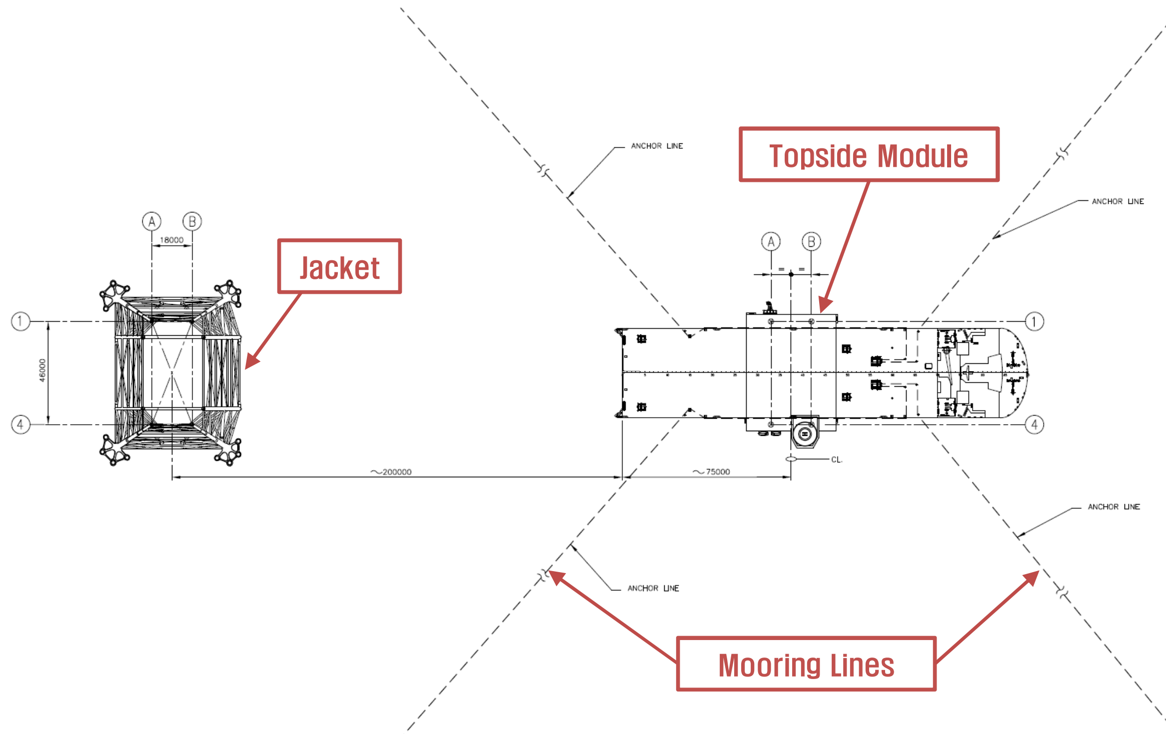
❑ Float-Over Installation Recommended Procedure (4 Phases)

1. Standoff (Standby):
   1. Vessel Moored Near the Jacket. (Approx. 200 m.)
   2. Float-Over Preparation and Weather Window (Up to 72 hours).
2. Entry (Docking)
3. Mating
4. Exit (Undocking)

Float-Over Standoff Phase.
HZ25-8 DP-South China Sea



Float-Over Installation Procedure-Standoff

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Future Research Plan

❑ Future Research Plan and Development in Mexico

Marine Hydrodynamic Lab

Ocean Basin & Water Channel

Cluster IPN Headquarters

Future Research Plan

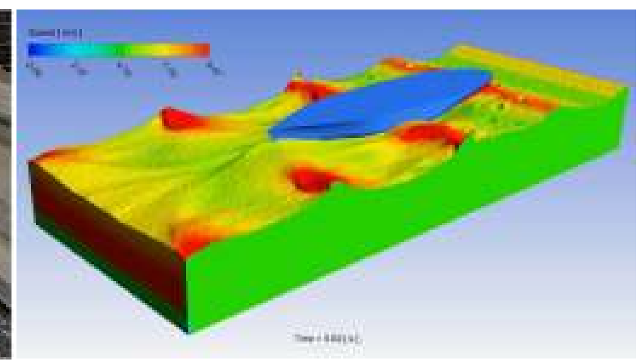
❑ Offshore Engineering Future Projects

1. Numerical Simulation and Experimental Research
   - ✓ Wave Breaking Dynamics
   - ✓ Port Maneuvering
   - ✓ Renewable Energies
   - ✓ Ships Performance in Waves
   - ✓ Applied Control Systems

Wind Turbines Performance

Control System Model Test

Wave Generator



Numerical Simulation-Ships on Waves

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Gracias!
Q&A

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