Digitalization in Marine Hydrodynamics

– Focusing on Introduction to KRISO Activities

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CONTENTS

Ship Hydrodynamics

Virtual Towing Tank

Big Data : Full scale performance

DB & ML : Power prediction & Hull form design improvement

WEB-based Design Platform : Hull, Propeller & ESD

DB & ML : Cavitation & Noise

AI & Big Data : ICE

Ocean Engineering

Virtual Ocean Engineering Basin based on High Fidelity CFD Simulation

Digital Twin for Model Tests

Ocean Renewable Energy

Simulation-based Design of Ocean Renewable Energy

Digital Twin for OWC Wave Energy Converter

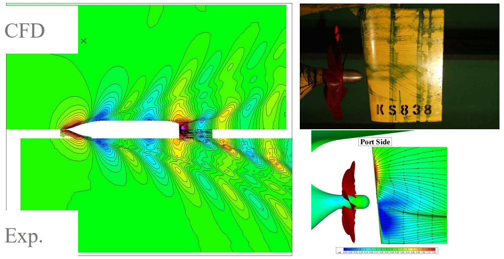
CFD / FEA can be an alternative approach for design validation?

Virtual Towing Tank

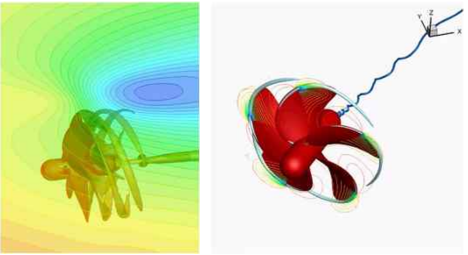
KRISO in-house Code WAVIS

Pre & Post Processor for
WAVIS 2.X
Wave and VIScous flow analysis system for hull form development
WAVIS2 Launcher

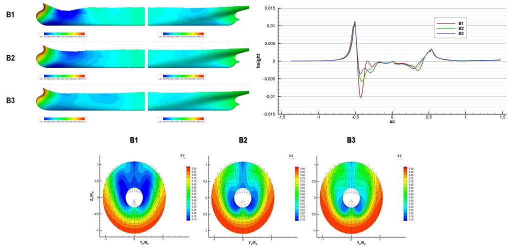
Resistance/Propulsion


CFD
Exp.
KS838
Port Side

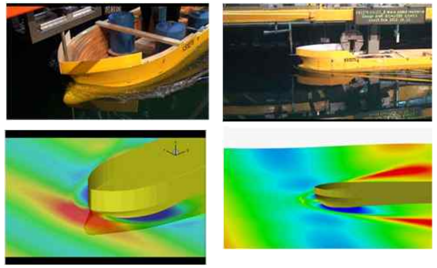
Propeller Open Water test



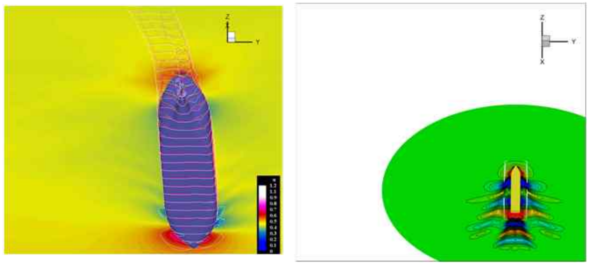
Hull form design evaluation



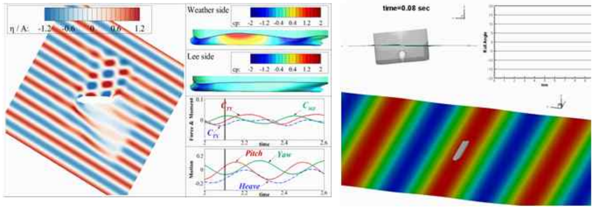
Added Resistance in waves



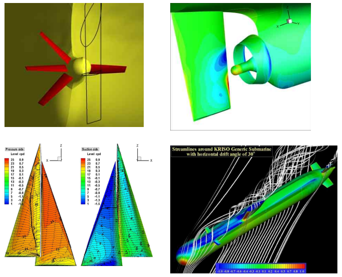
Maneuvering



Seakeeping

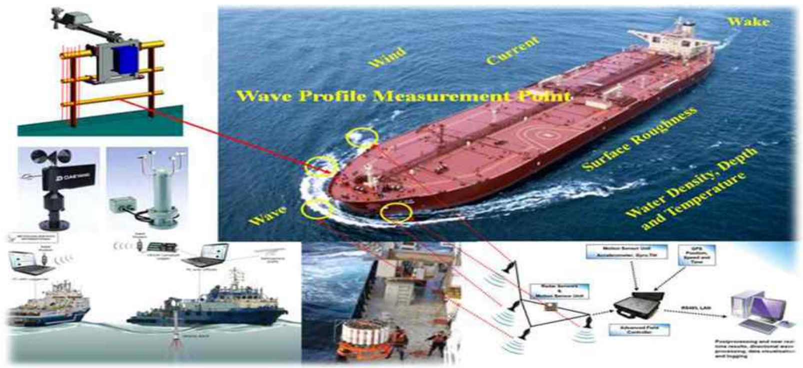

η / A: -1.2 -0.6 0 0.6 1.2
Weather side
Lee side
Pitch
Yaw
Heave
time=0.08 sec

Misc.


Streamlines around KRISO Generic Submarine with horizontal drift angle of 30°

Big DATA : Full scale performance

Operational Seas

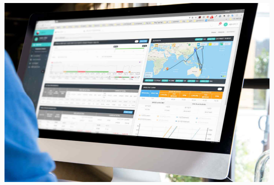

Wake
Wind
Current
Wave Profile Measurement Point
Surface Roughness
Water Density, Depth and Temperature
Wave

Metocean Services International 제공

Taekwang Electronics Corporation 제공

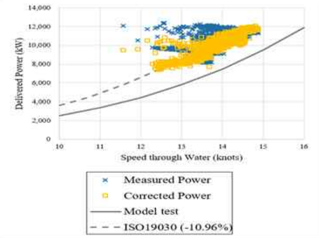
Real time performance monitoring

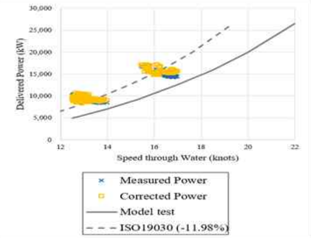
- ✓ Data collected onboard is aggregated and sent to onshore monitoring centre.
- ✓ Data is used for analytics such as current performance, trends and custom KPI



Full scale performance verification

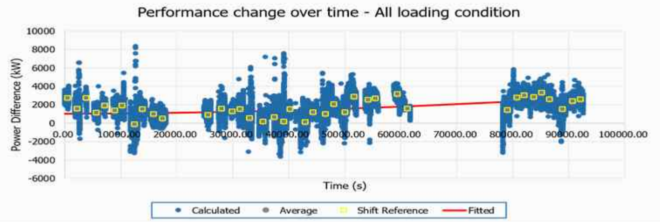
- ✓ Performance of a ship during operation can be obtained by correcting environmental force from measured data
- ✓ Predicted performance from model test or sea trial can be verified with operating performance





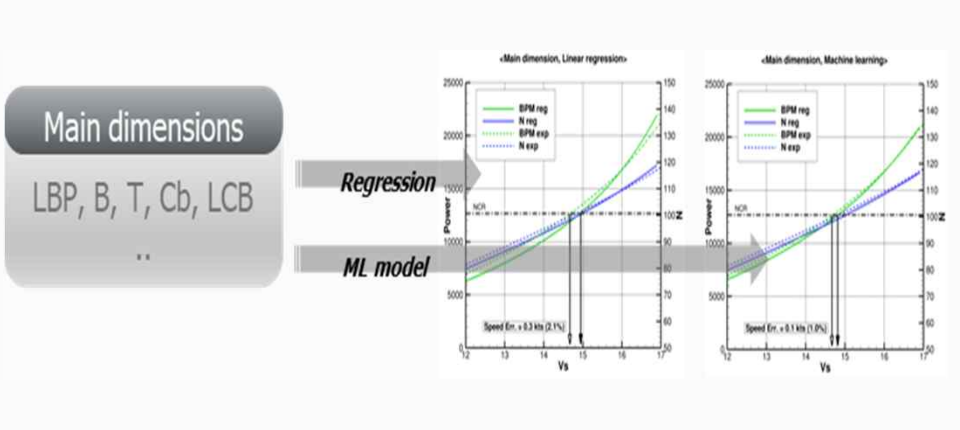
Optimal Maintenance scheduling

- ✓ Performance of a ship during operation degrades over the time due to aging such as hull fouling.
- ✓ Optimal maintenance such as hull cleaning and propeller polishing can be scheduled based on performance degradation trends and expected gain from maintenance.

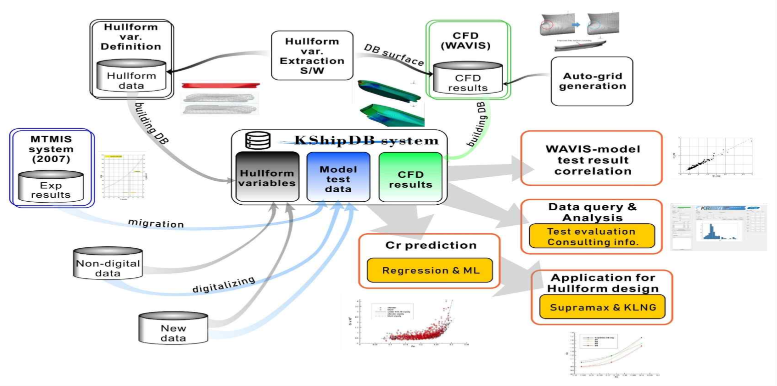


Database and Machine Learning : Hull form design and improvement

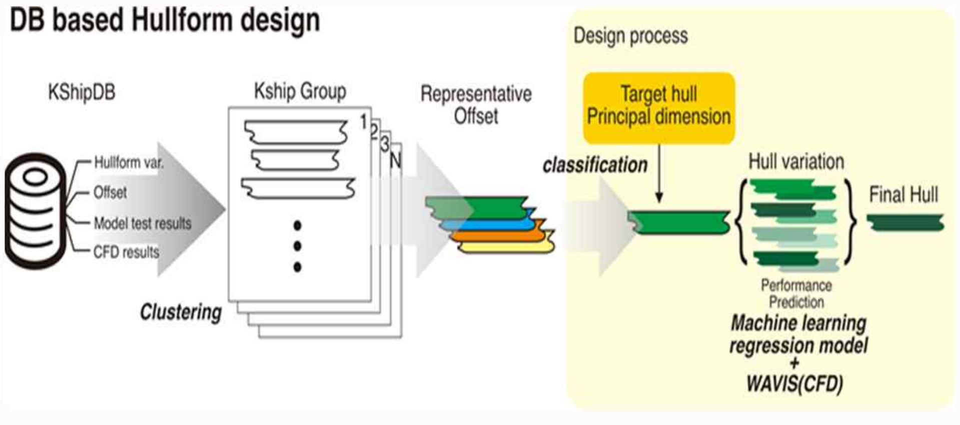
Speed-power prediction based on DB



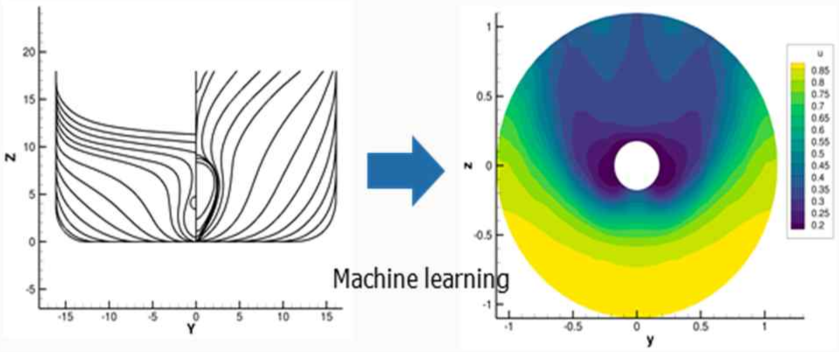
KRISO database system (KshipDB)


Hullform var. Definition
Hullform data
Hullform var. Extraction S/W
DB surface
CFD (WAVIS)
CFD results
Auto-grid generation
building DB
building DB
MTMIS system (2007)
Exp results
KShipDB system
Hullform variables
Model test data
CFD results
WAVIS-model test result correlation
Data query & Analysis
Test evaluation Consulting info.
migration
Non-digital data
digitalizing
New data
Cr prediction
Regression & ML
Application for Hullform design
Supramax & KLNG

DB-based hull form design


DB based Hullform design
KShipDB
Hullform var.
Offset
Model test results
CFD results
Kship Group
1
2
3
N
Clustering
Representative Offset
classification
Design process
Target hull Principal dimension
Hull variation
Final Hull
Performance Prediction
Machine learning regression model
+
WAVIS(CFD)

Offset-based ML for local flow prediction



WEB-based Design Platform: Hull, Propeller and ESD

→ Frame of Platform

LeadsSHIP

Database for Hydrodynamic Design

- Design Particulars
- Geometry
- CFD Results
- Model Tests Results

Standardization of Geometry Variation

- Hull form
- Propeller
- ESD
- Rudder

Standardization of CFD Analysis

- Resistance
- Self-Propulsion
- P.O.W
- Added Resistance

Optimization Scheme

- Bulbous Bow
- Stern Profile
- Propeller Geometry
- ESD Geometry

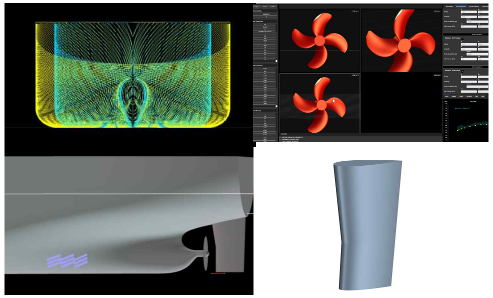
WEB based UX for Easy Access

- Server & Client
- Parallel Machine
- Commercial & In-house Codes

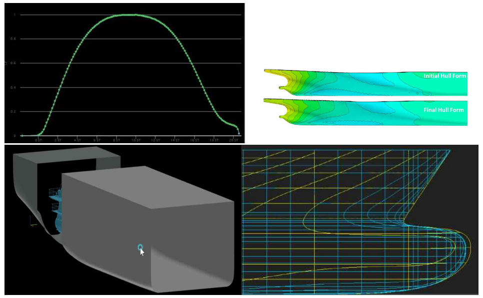
RANS with Parallel Machine

→ Implemented Functions

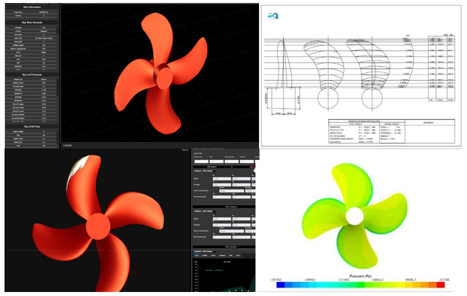
Geometry Variation



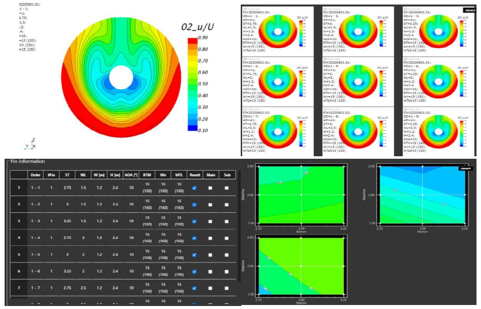
Hull form Optimization



Propeller Optimization

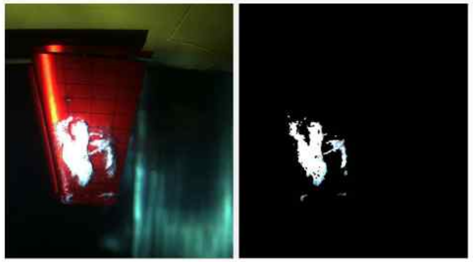


ESD Optimization



Database and Machine Learning : Cavitation & Noise

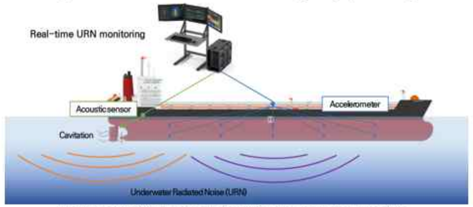
Monitoring and control of cavitation and noise



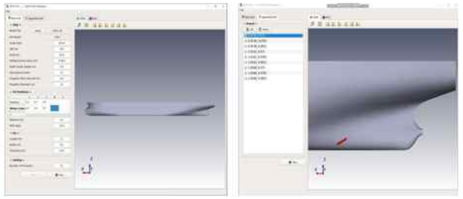
Quantification of cavitation amount using image processing

K-V.G.(KRISO Vortex Generator)

Conceptual diagram of K-V.G.


Real-time URN monitoring
Acoustic sensor
Accelerometer
Cavitation
Underwater Radiated Noise (URN)

URN monitoring using on-board noise and vibration data



K.V.G. design software

Digitalization of cavitation and noise using ICT

Real-time Monitoring

Operating Conditions

Noise and Vibration

Smart Noise Control

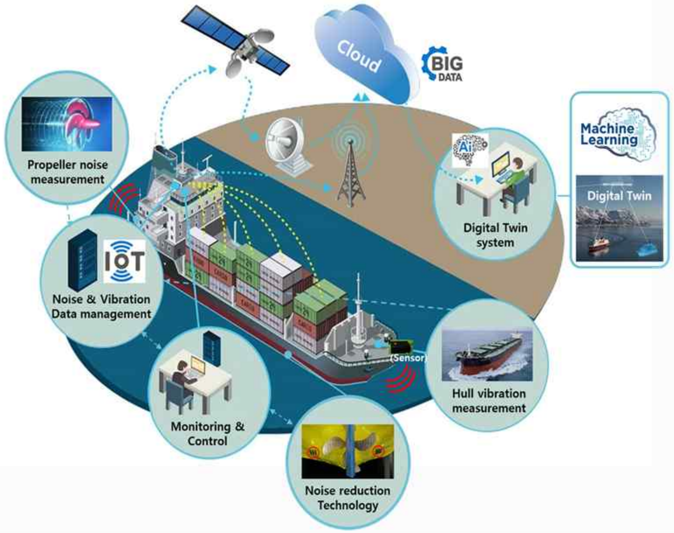
Monitoring Feedback

Active Noise Control

Noise Prediction with ML

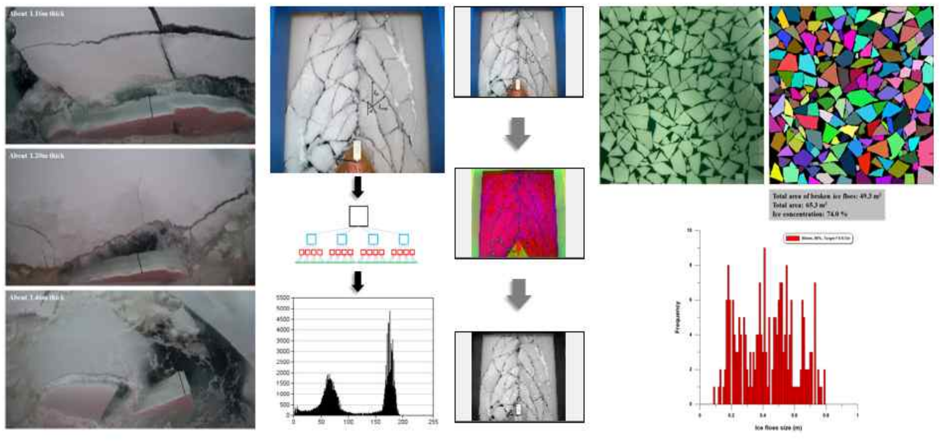
Noise Footprint Mapping

Digital Twin


Cloud
BIG DATA
Propeller noise measurement
Noise & Vibration Data management
IOT
Monitoring & Control
Noise reduction Technology
Hull vibration measurement
(Sensor)
Digital Twin system
Ai
Machine Learning
Digital Twin

AI and Big Data : ICE

Image processing Technique based on AI algorithms

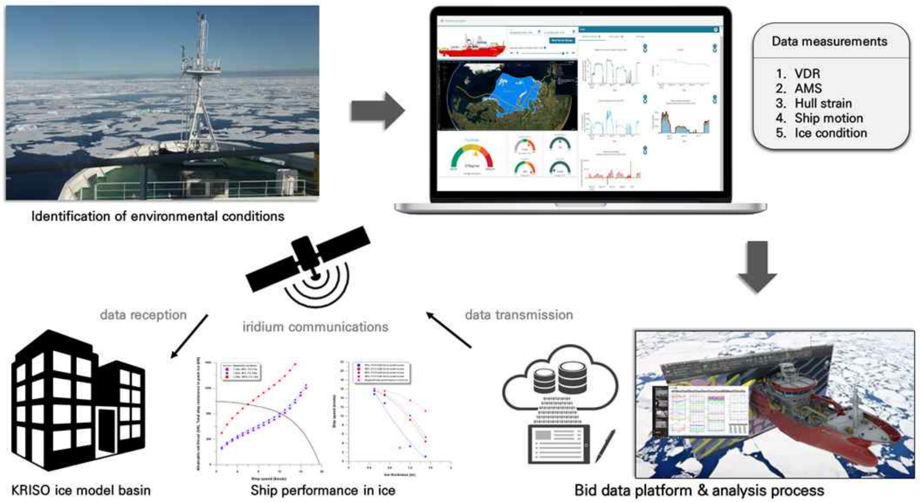


Ice thickness analysis

Icebreaking pattern analysis

Ice size and coverage analysis

Ship Performance Monitoring System under Ice Conditions



Identification of environmental conditions

Data measurements

1. VDR
2. AMS
3. Hull strain
4. Ship motion
5. Ice condition

data reception

iridium communications

data transmission

KRISO ice model basin

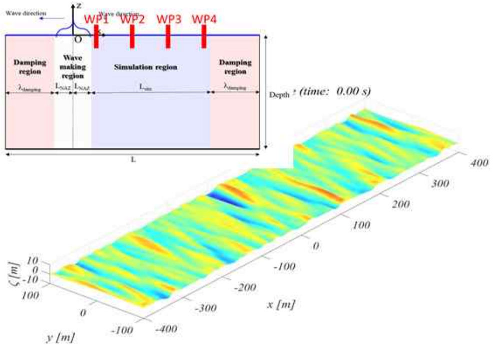
Ship performance in ice

Bid data platform & analysis process

Virtual Ocean Engineering Basin based on High Fidelity CFD Simulation

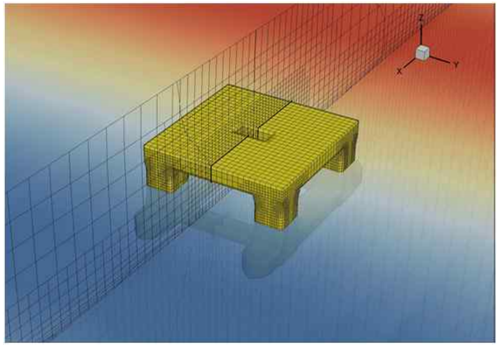
Virtual Ocean Basin

- **Ocean Environmental Conditions**
  - Irregular waves based on High Order Spectral Methods + CFD Coupling
  - Realistic Wind/Current generation beyond Ocean Basin Scale


Wave direction
WP1
WP2
WP3
WP4
Damping region
Wave making region
Simulation region
Damping region
Depth
(time: 0.00 s)
L
ζ [m]
x [m]
y [m]
400
300
200
100
0
-100
-200
-300
-400

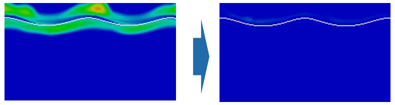
Global Performance Evaluation

- **Motion stability & Maneuverability**
  - 3hr. Simulation of Model Scale Offshore Floaters
  - Final Goal: Full-scale Simulation for Operation and Maintenance

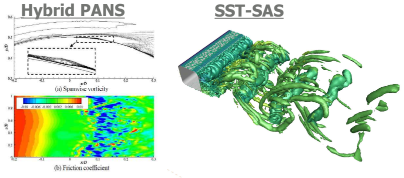


Customization

- **Motion stability & Maneuverability**
  - Minimization of the Numerical Dissipation for Wave Propagations



  - Low Calculation Cost for Simulating Turbulent Flows at High Reynolds Number (O~106), within ±3.5% Error

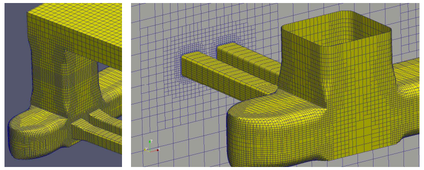


Only 3-5 millions cells to capture turbulent flows at high Re

Etc.

- Validation for High Fidelity Simulation
  - Abundant Experimental Data from the KRISO's Ocean Engineering Basin

- Customized Grid Generation Program (Collaborated with NEXTfoam)
  - Cartesian Cut-Cell based Grid System Optimized for Offshore Platform

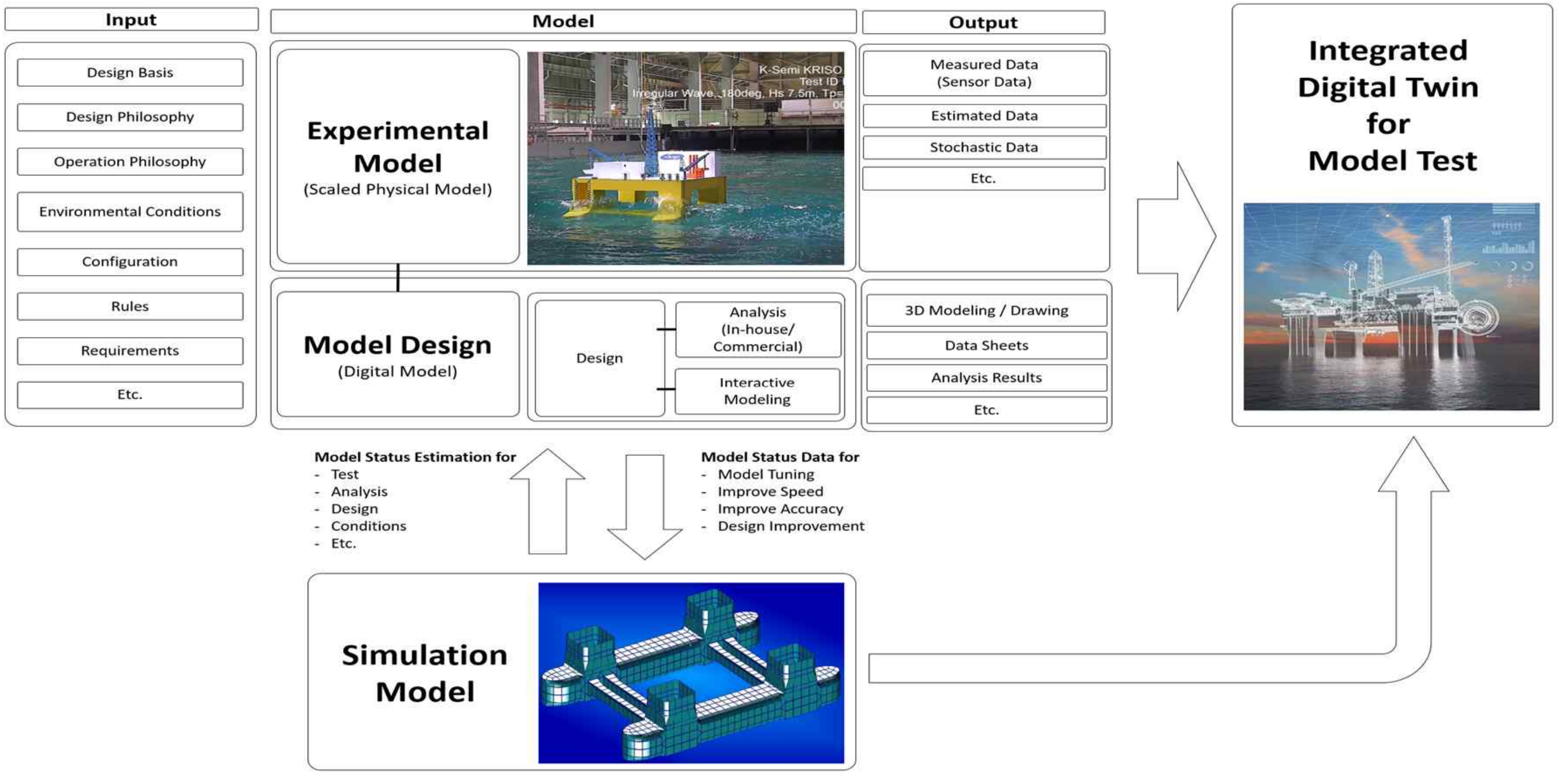


Digital Twin for Model Tests

*Concept Stage

Digital Twin For Model Tests

- Digital Twin based on the data from physical model test and simulation tool
- Digital Twin for model test can be accessed at any where, any time by authorized personals
- Provides an opportunity to observe the model test and review the results without visiting the basin e.g. at the time of COVID-19



Input

- Design Basis
- Design Philosophy
- Operation Philosophy
- Environmental Conditions
- Configuration
- Rules
- Requirements
- Etc.

Model

Experimental Model
(Scaled Physical Model)

Model Design
(Digital Model)

- Design
  - Analysis (In-house/ Commercial)
  - Interactive Modeling

Output

- Measured Data (Sensor Data)
- Estimated Data
- Stochastic Data
- Etc.

- 3D Modeling / Drawing
- Data Sheets
- Analysis Results
- Etc.

Integrated Digital Twin for Model Test

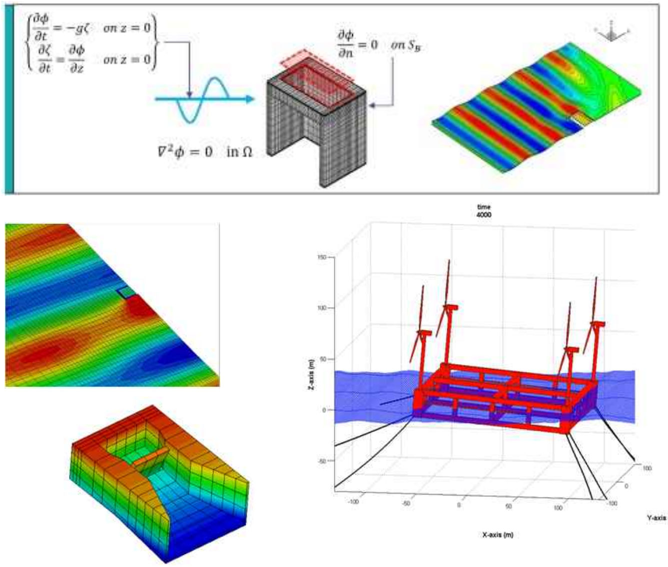
Model Status Estimation for
- Test
- Analysis
- Design
- Conditions
- Etc.

Model Status Data for
- Model Tuning
- Improve Speed
- Improve Accuracy
- Design Improvement

Simulation Model

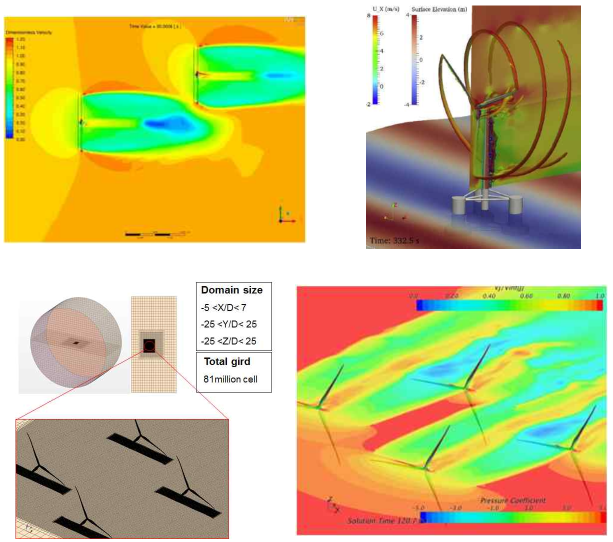
Simulation-based Design of Marine Renewable Energy

Potential Flow based Analysis



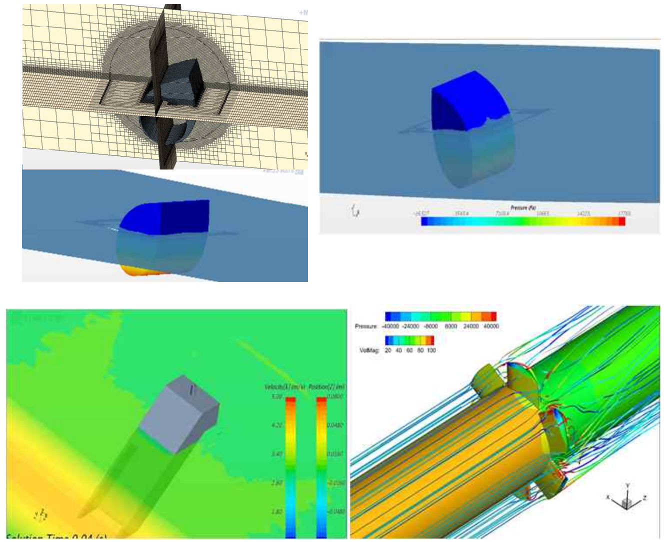
$\frac{\partial\phi}{\partial t} = -g\zeta$ on $z=0$
$\frac{\partial\zeta}{\partial t} = \frac{\partial\phi}{\partial z}$ on $z=0$
$\frac{\partial\phi}{\partial n} = 0$ on S_B
$\nabla^2\phi = 0$ in Ω
time
4000
Z-axis (m)
X-axis (m)
Y-axis (m)

CFD Analysis for FOWT



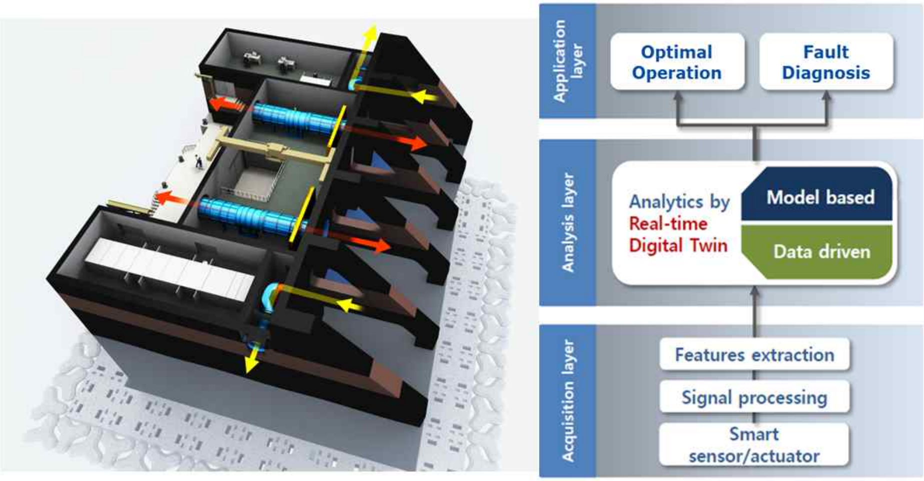
Domain size
-5 <X/D< 7
-25 <Y/D< 25
-25 <Z/D< 25
Total gird
81million cell
Time: 332.5 s
Pressure Coefficient

CFD Application on WEC



Digital Twin for OWC Wave Energy Converter

Marine Renewable Energy & Digital Twin

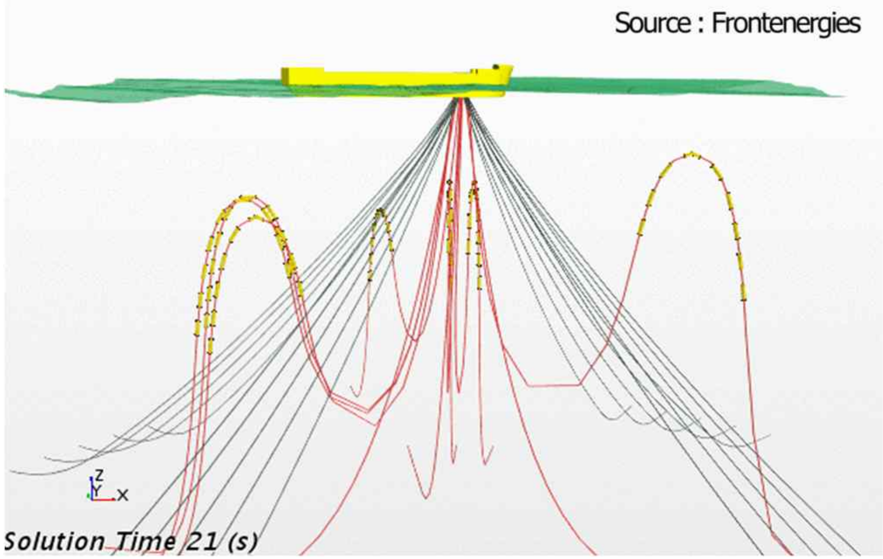

Application layer
Optimal Operation
Fault Diagnosis
Analysis layer
Analytics by Real-time Digital Twin
Model based
Data driven
Acquisition layer
Features extraction
Signal processing
Smart sensor/actuator

Digital Twin of KRISO OWC Wave Energy Converter

www.BANDICAM.com
KRISO
선박해양플랜트연구소

CFD / FEA can be an alternative approach for design validation?

CFD Application in Offshore Engineering



Source : Frontenergies

Z
Y
X
Solution Time 21 (s)

Structural Digital Twin for Asset Management

Source : AKSELOS

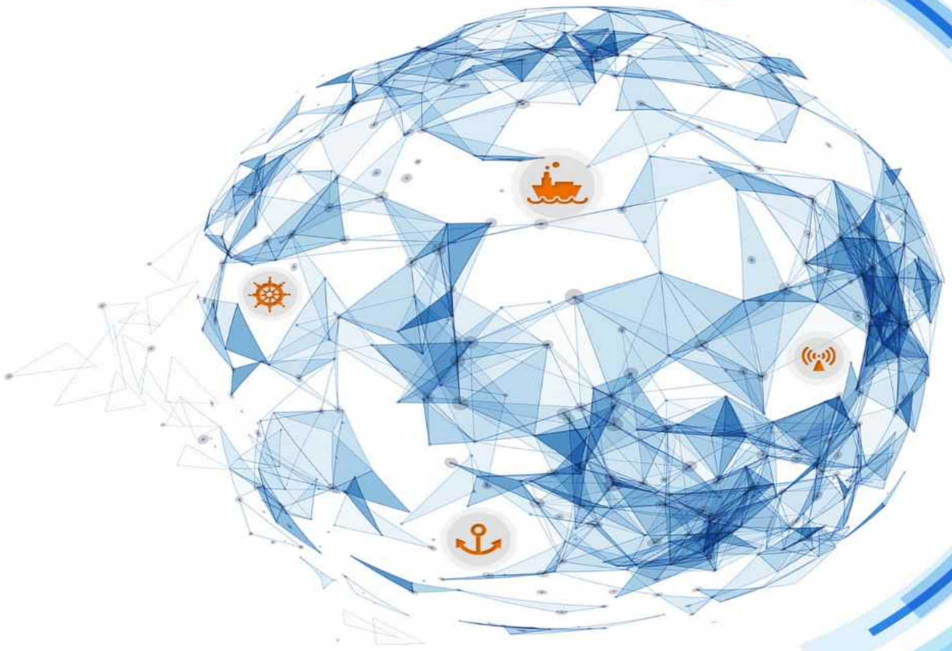
Concluding Remarks

- “Digitalization in Marine hydrodynamics” is on-going expanding area and will be more essential.
- Can “Digitalization in Marine hydrodynamics” provide better design, performance and efficient solution to maritime industry ?
- Can “Digitalization in Marine hydrodynamics” contribute to the recent driving force for safe, autonomous, and zero emission technology in shipbuilding and offshore engineering?
- For ITTC aspects:

  Beyond the model test procedures, how can the guideline of “Digitalization in Marine hydrodynamics” be provided by?

  (standardization, reliability, accessibility, security, collaboration with IT professionals, etc.)

Korea
Research
Institute of
Ships &
Ocean Engineering

Thank You !