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MTS Dynamic Positioning Conference 2018, 9-10 October, Houston, Texas, USA
Services & Products

Arctic Engineering
- Dynamic Positioning
- Basin Tests
- Full Scale Tests
- R&D

Dynamic Positioning
- Design & Simulations
- FMEA & Commissioning
- Complex Operations
- R&D

Offshore Engineering
- Hydrodynamics studies (BEM, CFD,...)
- Simulations
- Design
- Metocean analysis
- Route Planning

Drilling Engineering
- Drilling Control R&D
- Drilling Simulations

Marine Energies
- Offshore Wind
- Control Systems design
- Transport, Installation & Maintenance
- R&D

Ocean intelligent Control Systems
- Route Optimization
- Advanced Monitoring & Aid-Decision
- Autonomous Vessels
- Foil Control Systems

About us...

R&D Company founded in 2015
Offices in Nantes & Paris (France)
15 PhDs & Engineers

Worldwide Projects

Services – R&D
- Control Engineering
- System Engineering
- Applied Mathematics
- IT & Algorithms
- Big Data
- Simulations
...

High-technology and Innovation

Proud Member of
neopolia
Pole Mer
Bretagne Atlantique
ATLANPOLE
Feedback on NRL project.

Project Feedback (1/2)

Example of Piles Installations (2/2)

Drift between initial plans & operational feedback

- Increased Risks
- Lessons learned?
- Several numerical tools used at different stages of the lifecycle
- Black-box & expensive softwares
Context

Planification

Simulations
Procedures
Modeling
Analyze

Lessons learned

Operations

Objectives

✓ Improve global processes
✓ Optimize CAPEX / OPEX
✓ Framework for the full lifecycle
✓ Improve Scientific knowledge (open-source)
✓ Develop & assess new technologies
Flexible and Rigid body Dynamic modeling for Marine operations

- 2 years project launched in 2016
- Versatile Simulation tool for design of marine operations
- Open-source code to be released in 2018
Flexible and Rigid body Dynamic modeling for Marine operations

A long journey littered with pluridisciplinary tasks

- Physics
- Mechanics
- Hydrodynamics
- Mathematics
- Control Engineering
- Optimization
- Software Engineering
- Visualisation
Multibody dynamics
Assumptions under Potential Flow Theory

- Inviscid Fluid $\nu = 0$
- Incompressible & irrotational flow
  \[ \vec{V} \cdot \vec{V} = 0 \]
  \[ \vec{V} \times \vec{V} = 0 \]
  - Velocity derives from a potential $\vec{V} = \nabla \phi$
- Pressures follows Bernouilli formula $p + \rho g z + \frac{1}{2} (\nabla \phi)^2 + \rho \frac{\partial \phi}{\partial t} = \text{constant}$
- From 3D to 2D!
Environment modelling

- Sea States
  - Linear Sea States
  - Nonlinear
    - High Order Spectrum (HOS)

- Wind
  - Spectral Decomposition (Harris)
  - Full field Stochastic - Turbsim (NREL)

- Current
  - Tides model
  - Copernicus / Mercator Ocean
Propeller Forces Modelling

Model equation

\[ T = \frac{1}{2} \rho_w c_T(\beta)(v_a^2 + v_p^2)\pi R^2 \]
\[ Q = \frac{1}{2} \rho_w c_Q(\beta)(v_a^2 + v_p^2)\pi R^2 d \]

Non-dimensional thrust and torque coeff.: 
\[ c_T(\beta), c_Q(\beta) \text{ function of the propeller blade} \]
\[ \text{advance angle } \beta = \pi - \arctan(\nu_a, \nu_p) \]

Data:
- van Lammeren et al / Oosterveld
- Healey et al’s approximation
- L-model
Propeller Forces Modelling

Environment

Vessel dynamics

Sensors

Vessel observer

Thruster dynamics

Thrust allocation

Vessel control

Waves wind Current

Thrust forces

Motion

Meas.

Filtered & reconstructed signals

Desired thrust vector

Inline / transverse velocity fluctuations

Ventilation

Water exit

Other losses

Motion

Shaft speed

Motor torque

Local thruster control

Source: Propulsion Control - Øyvind N. Smogeli, Asgeir J. Sørensen – TMR4240 Spring 2009
Software Engineering

- 1,000,000+ lines of code

Software Architecture

Visualisation & First POC

Cable modelling

- CMake
- Python
- Git
- Doxygen
• Estimator
  o Linear Kalman filter
  o Nonlinear Kalman Filters
  o High Gain Observers
  o Sliding Modes

• Controllers
  o PID
  o Feedforward
  o H2 / LQR
  o Hinfinity

• Control Modes
  o Joystick Modes
  o Station Keeping Mode
  o Track Keeping
  o Heading Keeping

• Thrust allocation
  o Linear Optimization
  o Nonlinear Optimization
Validation Process
Validation of Hydrodynamics Module

Benchmark: DTMB5512 presentation

Hull model DTMB5512

Test conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Froude Number</td>
<td>0; 0.19; 0.28; 0.34; 0.41</td>
</tr>
<tr>
<td>Steepness (A.k)</td>
<td>0.025; 0.05; 0.075</td>
</tr>
<tr>
<td>Frequencies (Hz)</td>
<td>0.3 Hz -&gt; 1.4 Hz</td>
</tr>
</tbody>
</table>

Geometrical parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>5512</th>
<th>Full Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear scale ratio</td>
<td></td>
<td>46.6</td>
<td>1</td>
</tr>
<tr>
<td>Length ($L_{pp}$)</td>
<td>m</td>
<td>3.048</td>
<td>142.04</td>
</tr>
<tr>
<td>Beam ($B$)</td>
<td>m</td>
<td>0.405</td>
<td>18.87</td>
</tr>
<tr>
<td>Draft ($T$)</td>
<td>m</td>
<td>0.132</td>
<td>6.15</td>
</tr>
<tr>
<td>Wetted surface area ($S$)</td>
<td>m²</td>
<td>1.371</td>
<td>2.977</td>
</tr>
<tr>
<td>Block coefficient ($C_B$)</td>
<td></td>
<td>0.506</td>
<td>0.506</td>
</tr>
<tr>
<td>LCG</td>
<td>m</td>
<td>1.536</td>
<td>71.58</td>
</tr>
<tr>
<td>VCG</td>
<td>m</td>
<td>0.162</td>
<td>7.55</td>
</tr>
<tr>
<td>Pitch radius of gyration $k_g$ = $0.25L_{pp}$</td>
<td>m</td>
<td>0.762</td>
<td>35.51</td>
</tr>
</tbody>
</table>

Validation of Hydrodynamics Module

Benchmark: DTMB5512 captive tests

Surge

Heave

Pitch
Validation of Hydrodynamics Module

Benchmark: DTMB5512 free floating tests

Head Wave
A.k = 0.025

Fr = 0
Fr = 0.28
Fr = 0.41

Heave / A
Pitch / A

Encounter Frequency (Hz)
Applications & Perspectives
Perspectives


DP & Tug Operation

HIL Testing

Videos Example
Context

Marine operations are omnipresent during full MRE's life cycle. All technologies are concerned; from floating wind or offshore wind up to tidal & wave energies. The missions are various, complex, expensive and can present high human, material and economical risks. The mastering and the assessment of complex marine operations are important levers to optimize and reduce CAPEX, OPEX or LCOE.

Solution

FryDoM is based on solid scientific disruptive approaches:

- Multibody dynamics modelling and tight coupling with hydrodynamics interactions and large deformation cable models.
- Native integration of control modules including dynamic positioning systems.

FryDoM mailing list <frydom@d-ice.fr>

Numerical framework for the development of innovative products or tailored tools (training, virtual reality, embedded system...)

A multibody solver based software

FryDoM allows complex multibody systems modelling, integrating rigid and flexible bodies, kinematic joints, actuators and thrusters in a marine environment.

Service offer

Tailored studies or products are enabled such as tug assist in harsh environment, installation of wind turbines, etc.

Real Challenges. True Solutions.

Fast and complete modelling of installation operations including transients

Both Open-sources (GPLv3) and commercial licensing

Strong ongoing roadmap