Utilization of numerical simulation tools for aiding decisions about DP operations

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SUMMARY

• Introduction
• Numerical Simulator
• DP Crane Barge
• DP Drilling Vessel
• DP Shuttle Tanker
Numerical Simulator

Tanque de Provas Numérico
(Numerical Offshore Tank)

Cluster: 1800 processors; 50 TeraFLOPS

Finite Element Line models
DP System
Multi-vessel dynamics

Virtual reality environment
Numerical Simulator

4th Order Runge Kutta Integration

Forces
- Current
- Wave
- Wind
- Hydrostatic
- Hydrodynamic
- DP / Thruster
- Mooring
- Risers
- Connection Lines
- Fenders

Vessel / Body 1
X, Y, Z, XX, YY, ZZ

Vessel / Body 2

Vessel / Body N
X, Y, Z, XX, YY, ZZ

Visualization System
X, Y, Z, XX, YY, ZZ
Numerical Simulator

TPN Time Domain Simulation System

Current
Hydrodynamic Derivatives
Cross Flow
Optional: XY Current Field
Heuristic Model for Interference between Vessels (CFD based)

Waves
Regular or Irregular Waves (several Spectrum formulations)
1st Order Haskind Forces
2nd Order Drift Forces (Including Vertical Motions – Under Research)
Multi-Body Wave Field Interference
Wave coefficients obtained from Wamit – fully integrated in the simulation loop

Optional Coefficients from Hydrostar / Aqwa

Hydrostatic
Integration with non-linear hydrostatic calculation software (under development)
TPN Time Domain Simulation System

Winds
- Constant or Gusts (several spectrum formulations)
- Optional: XY wind field
  - Heuristic model for interference between vessels (CFD based)

Lines (Risers, Mooring, Hawser)
- Characteristic curve
- Catenary Formulation
- Finite Element Model (Cluster Required)
- Fixed point anchor or multi-vessel connection lines

Fenders
- Non-linear restoring forces
- Drag and Friction
Numerical and Experimental Analysis of Floating Systems

TPN Time Domain Simulation System

DP + Thrusters
  PID Control + Kalman Filter
  Thruster Interference Based on Experimental Data
  Azimuth / Tunnel / Main Propeller

Extra Features
  Shallow Water / Confined Water Corrections
  Collision Detection
Calibrate and validate the BGL-1 numerical models with the goal of make feasible and suffice the operation approval based in the numerical analysis with the TPN software.
DP Crane Barge
DP Crane Barge
DP Crane Barge

Thruster

Bar with strain-gages

Propeller

Small Scale Experiments

Wind

Sea-Keeping

Current

Cy

10°Cx

10°Cm
DP Crane Barge

Small Scale Experiments

DP Tests
DP Crane Barge

Real-Scale Monitoring
Numerical Simulation close to a FPSO

- Very important hydrodynamic coupling (see Vieira at al, OMAE 2011)
  - DP performance
  - Tension on lifting lines
  - Acceleration on the Top of crane
  - Relative Motion
    - Barge-Unit
    - Module-boom
  - Motions on DP control point
Numerical Simulation close to a FPSO

- Barge performing a module installation on a FPSO
  - DP performance
  - Tension on lifting lines
  - Acceleration on the Top of crane
  - Relative Motion
    - Barge-Unit
    - Module-boom
  - Motions on DP control point

\[ H_s = 2m \]
Numerical Simulation : Fixed Platform

- **Main Parameters**
  - DP power consumption
  - Tension on lifting lines
  - Acceleration on the Top of crane
  - Relative Motion
    - Barge-Unit
    - Module-boom
  - Motions on DP control point
Numerical Simulation

Numerical Simulation: Fixed Platform

- DP power consumption
- Tension on lifting lines
- Acceleration on the Top of crane
- Relative Motion
  - Barge-Unit
  - Module-boom
- Motions on DP control point
Real drift-off event

DP “Current” 45°; 3.4 knots

Wind 120°; 30 knots

Initial Position 255°

Final Desired Position 120°

Drift Position 320°
Simulations
DP Shuttle Tanker

1:70 model

#1 - Main
Fmax=3.51N
Fmin=-1.70N
X= -1750mm

#2 – Tunnel Stern
Fmax=+0.53N
Fmin=-0.53N
X= -1440mm

#3 – Azim Stern
Fmax=+1.01N
X= -1072mm

#4 – Azim Bow
Fmax=+1.01N
X=1637mm

#5 – Tunnel Bow
Fmax=0.71N
Fmin=-0.71N
X=1810mm

Small Scale Experiments
DP Shuttle Tanker

Failure simulations

Before failure of azimuth bow thruster

After failure of azimuth bow thruster

Delivered Force per Thruster (kN)

Time (s)
Before failure of azimuth bow thruster

After failure of azimuth bow thruster

Failure simulations
**Static Analysis**

Equilibrium equation

- Mean current force
- Mean drift (wave)
- Mean Wind Forces

**Dynamic Analysis**

Time domain simulation

Static effects +
- Current oscillation
- Slow drift (wave)
- First order motions (wave)
- Wind Gusts
- Propeller dynamic response
- Transient motions

Downtime analysis
Table 1. Downtime results for DP1-Enhanced ST

<table>
<thead>
<tr>
<th>Type of offloading station active</th>
<th>Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (Bow or stern operation)</td>
<td>5.3%</td>
</tr>
<tr>
<td>Stern Operation Only</td>
<td>62.0%</td>
</tr>
<tr>
<td>Bow Operation Only</td>
<td>21.5%</td>
</tr>
</tbody>
</table>
Thanks!

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Acknowledgments: