Viscous CFD Applications

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Presentation Outline

Applications

- Hydrodynamic loading on subsea pipeline
- Ballast tank sloshing in hurricanes
- Submarine and ship hydrodynamics
BMT Fluid Mechanics – What we do

Engineering Consultancy with skills in fluid dynamics, physical modelling and numerical modelling. We help designers and operators optimise design, minimise commercial risk and maximise safety.

**Wind Tunnel Testing**
- Wind loads for civil structures
- Wind & current loads for oil & gas and defence vessels
- Helideck wind environment

**Numerical Modelling**
- Computational Fluid Dynamics (CFD)
- Consequence & HSE
- Vessel Hydrodynamic Loading & Response
- Operational Simulation
Hydrodynamic Loading on a Subsea Pipelines

Problem

Shallow water pipelines can be subjected to large wave and current loads requiring costly ballasting to maintain stability.

Current empirical methods for load estimation may be too conservative.

Drives up cost of pipeline stabilization.
Hydrodynamic Loading on a Subsea Pipelines

Current Method for Load Estimation

- Use only the component of the fluid velocity perpendicular to the pipe
Hydrodynamic Loading on a Subsea Pipelines

Proposed Study

- Use CFD flow analysis to investigate the effect on pipeline hydrodynamic forces of highly oblique waves and steady currents
- Check the accuracy of the independence principle under different wave / current directionalities and flow regimes

Two-Stage Approach

- Stage 1: Validation (sub-critical to critical Re numbers)
- Stage 2: Experimental investigation (critical to super-critical Re numbers)
Hydrodynamic Loading on a Subsea Pipelines

Stage 1 – Validation with Experiment

Hydrodynamic Loading on a Subsea Pipelines

CFD Setup

- ANSYS CFX Version 12.1
- Hexa mesh
- Scale Adaptive Simulation (SAS) Turbulence Model – Menter et al. 2003

Flow Conditions Modelled

- Various pipeline stand-off distances
- 90° and 45° AOA
- T=2.03 sec, Amp=0.44 m/s (KC=10)
Hydrodynamic Loading on a Subsea Pipelines

Typical Simulation Visualisation
Hydrodynamic Loading on a Subsea Pipelines

Added Mass, Drag and Lift Coefficient Comparisons – No gap
Hydrodynamic Loading on a Subsea Pipelines

Added Mass, Drag and Lift Coefficient Comparisons – Small gap
Ballast Tank Sloshing in Hurricanes

Problem

Offshore floating production platforms have large ballast tanks. Platforms can undergo large motions when subjected to hurricane conditions.

Monitoring and control of ballast level vital for platform stability.

Inaccurate level sensor readings can lead to:

- Structural damage: violent sloshing can create localized high impact loads.
- Wrong ballasting: if sloshing period coincides with tank probing sampling period, inaccurate readings could lead to wrong ballasting.
Ballast Tank Sloshing in Hurricanes

Proposed Study

• Use CFD to improve accuracy of liquid level measurements

• Provide basis for appropriate sampling intervals

Approach

• Numerically simulate the liquid motion in ballast tanks based on 6 degrees of freedom motions (from full-scale measurements)

• Use of VOF method to capture free surface

• Compare results in both time and frequency domains
Ballast Tank Sloshing in Hurricanes

Typical Simulation Visualisation and Pressure Time Histories
Submarine Hydrodynamics

Force Coefficients and Flow Structure
- Wakes and acceleration around hull form
- Pressure distribution
- Submarine manoeuvring coefficients
- Propulsion
- Flow stagnation/separation
- Turning performance
Submarine Hydrodynamics

Wake at Propeller

- Detrimental effects on propeller
  - Increased generation of noise
  - Fatigue loading on blades
  - Reduction in efficiency

Baseline fin design

Rounded fin design
Submarine Hydrodynamics

Underwater Vehicle Optimisation

- Large stagnation / high pressure region at the aft
- Re-design of aft part
  - Significant flow improvement
- Re-design of front part
  - Additional drag reduction
Ship Hydrodynamics

“Free to Sink and Trim” Approach

- Predict resistance and dynamic attitude using “free to sink and trim” approach coupled with free surface modelling (VOF method)
- Vessel attitude adjusted to reduce the unbalanced trim

Ship moving to final “equilibrium” position
Ship Hydrodynamics

Appendages Optimization

- Undesirable effects (e.g. cavitation, noise, erosion) if wake peaks and poor flow in propeller plane
- Correct alignment of A-brackets very important
Ship Hydrodynamics
Comparison of Propulsion Options
- Successfully applied the “free to sink and trim” methodology
- Able to identify regions requiring re-design

Conventional propeller
Advanced waterjet propulsion
BMT Fluid Mechanics

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