Naval Hydro Pack: Problem Classes and Example Simulations

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Outline

Objective

- Describe main classes of problems and basic setup for problems solved with the Naval Hydro pack

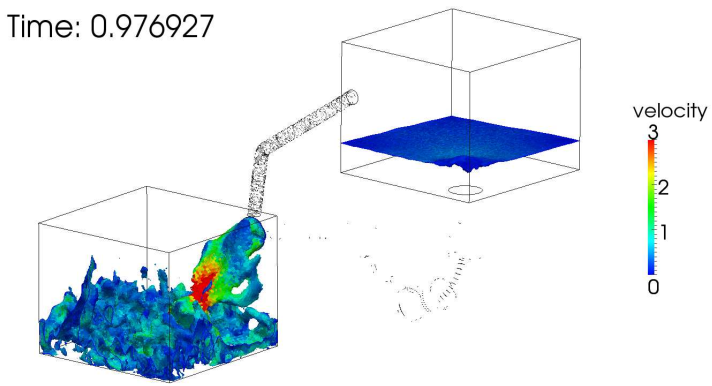
Topics

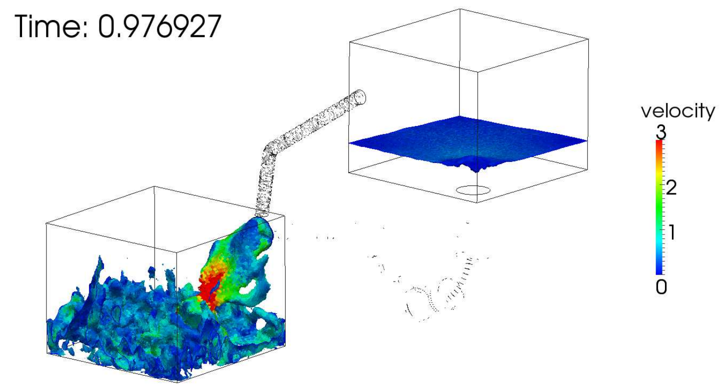
1. Introduction
2. Basic transient simulations
3. Sloshing, slamming and water wave impact on structures
4. Green water simulations
5. Steady resistance simulations
6. Drift angle simulations
7. Forced oscillation simulations
8. Constrained motion cases
9. Incoming wave conditions
10. Sea-keeping simulations
11. Summary

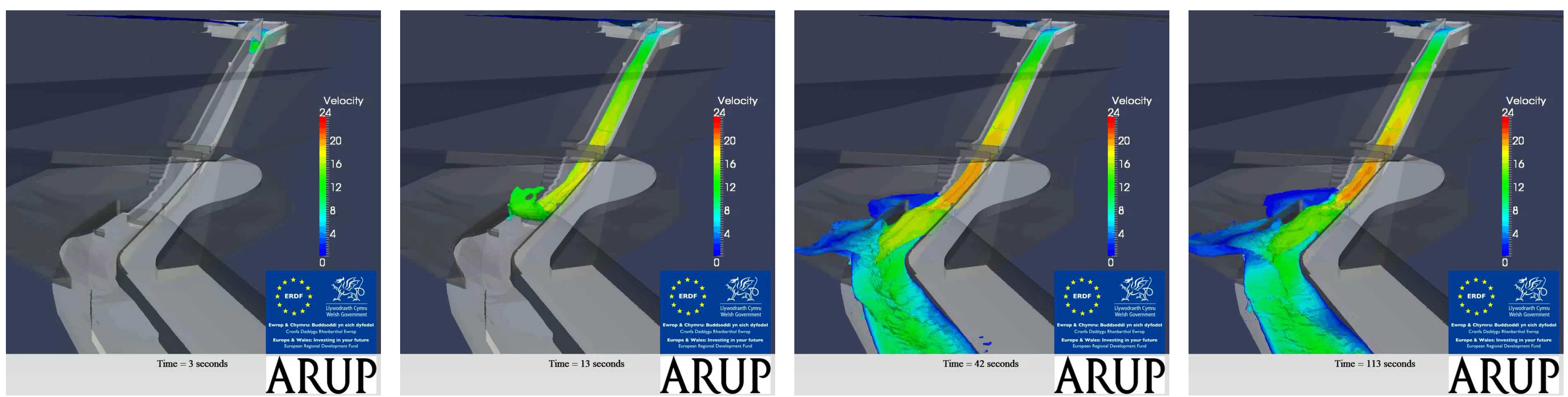
Basic Transient Simulations

Basic Transient Simulations

- Naval hydro pack is capable of performing basic free surface flow simulations rapidly, especially in cases where long simulation time is required
- Improved handling of free surface and momentum equation reduces simulation time by a factor of 10-100 compered to `interFoam`



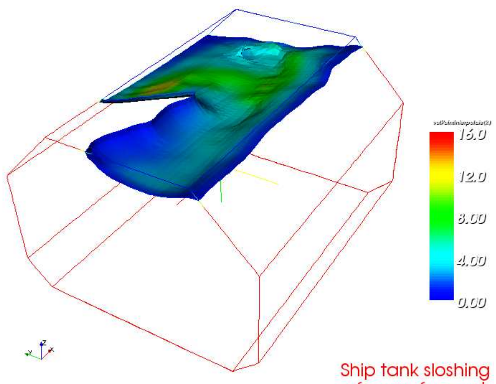




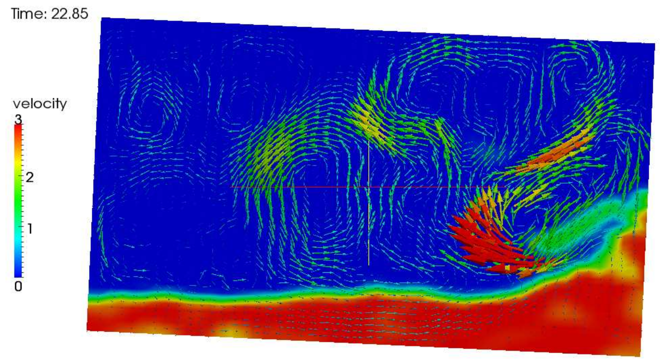
Sloshing and Slamming

Sloshing and Slamming Simulations

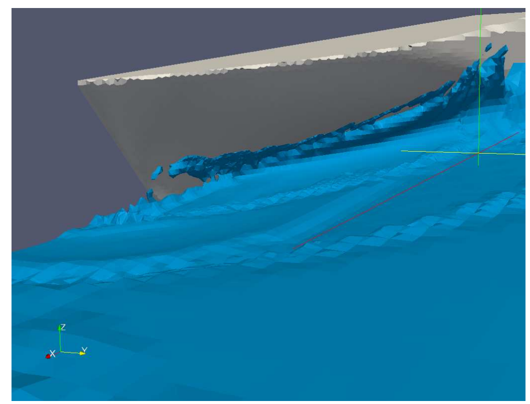
- Sloshing and slamming are cases of prescribed rigid body motion, with possibility of 6-DOF motion coupling (force response at impact)
- Influence of turbulence in flow on impact pressure is uncertain
- Options on sloshing/slamming motion
  - Static mesh with time-varying direction of gravity + acceleration
  - Dynamic mesh: prescribed rigid body motion, either harmonic or graph-based
- Spline interpolation of graph-based motion data: no artificial peaks in acceleration



Ship tank sloshing
free surface + k

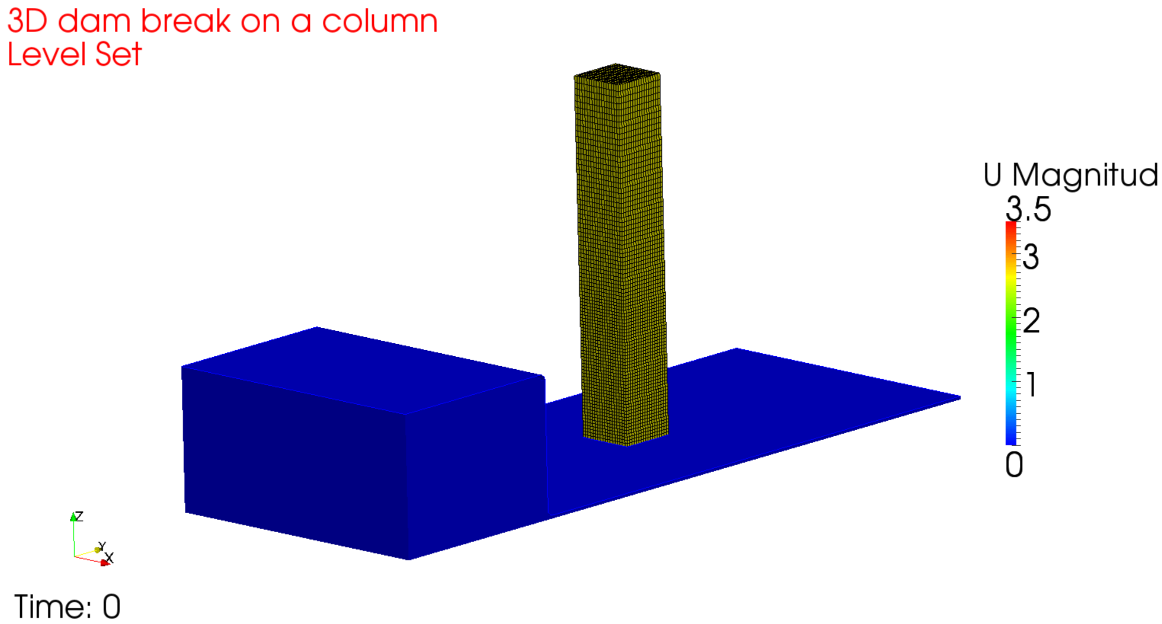


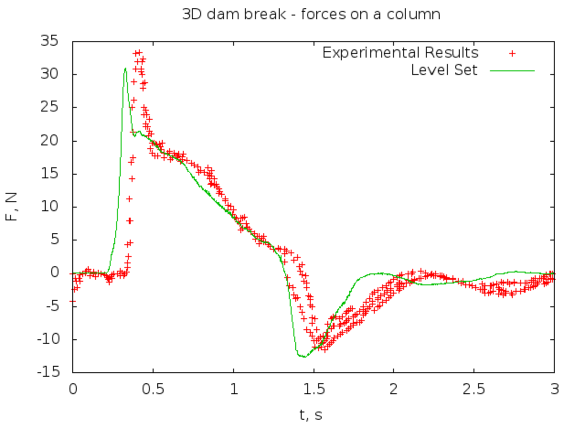
Sloshing in 2-D

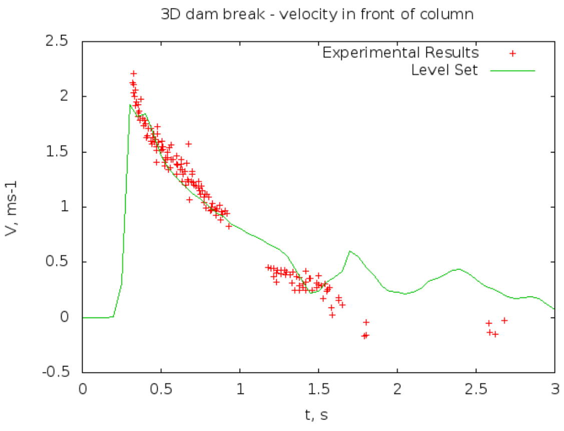


Sloshing and Slamming

Water Column Impact Simulations

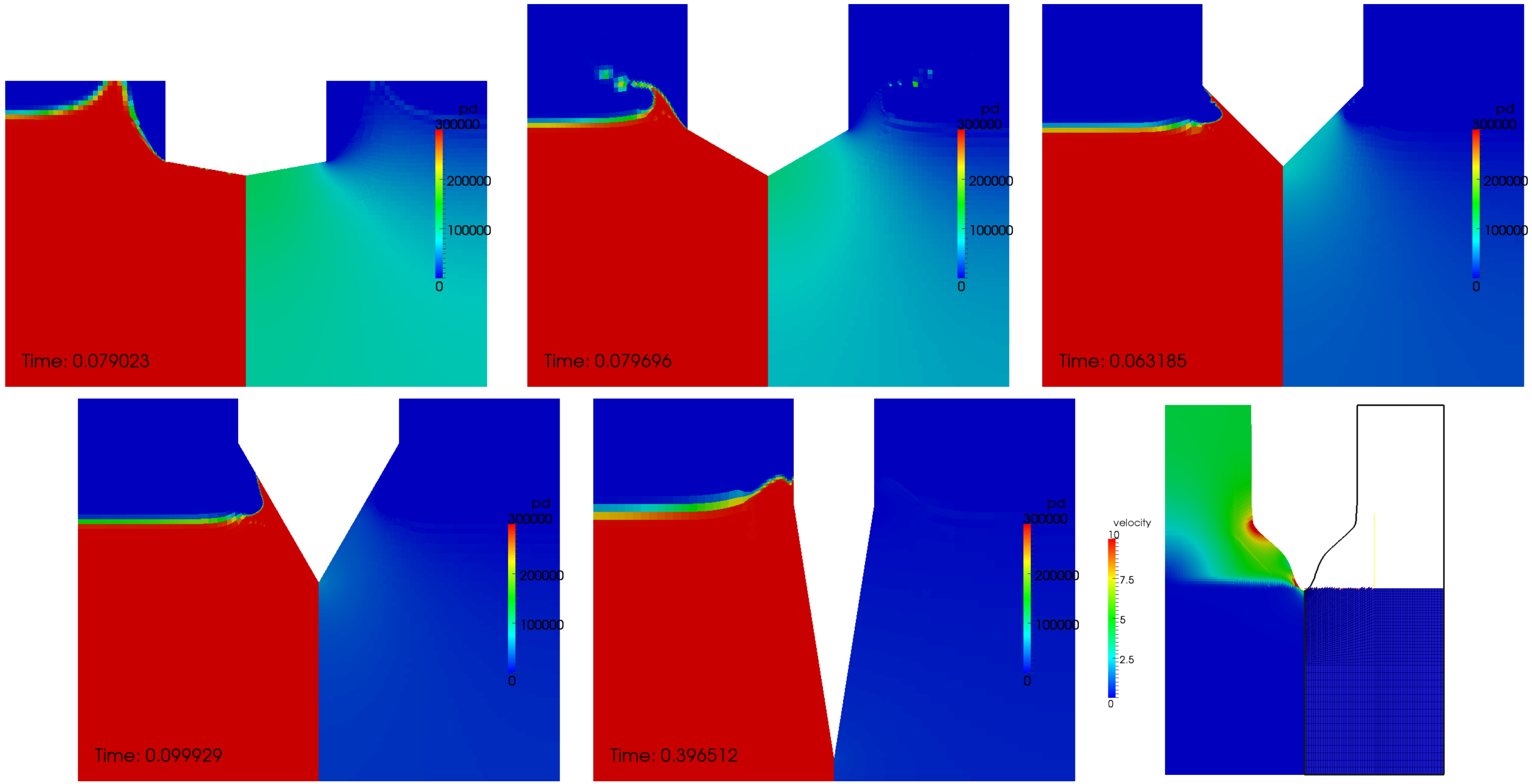






Sloshing and Slamming

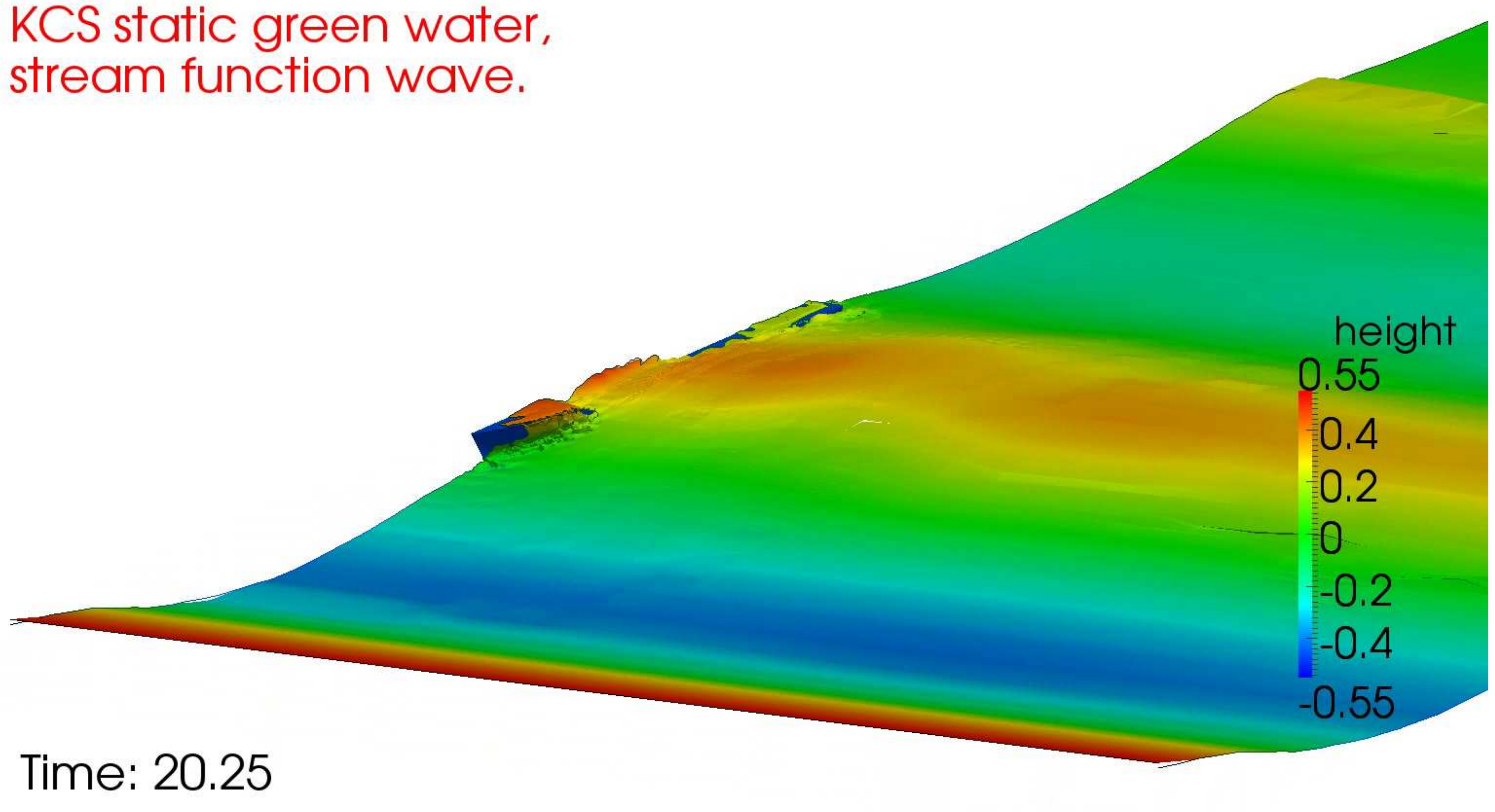
2-D Slamming Test: Wedge Geometries with Varying Angle: Splash



Green Water Simulation

Simulation of Water on Deck: Green Water

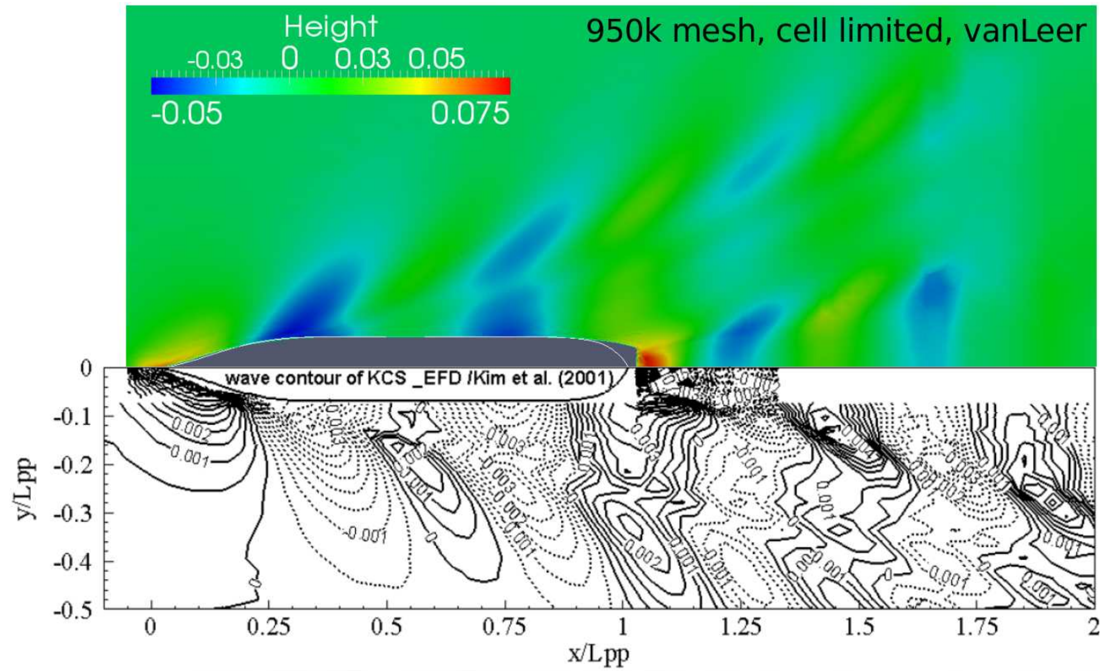
- Combination of incoming waves and impact on superstructure: already demonstrated
- Transient solver with incoming waves: static mesh or 6-DOF

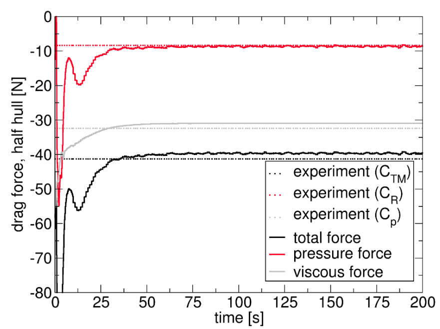


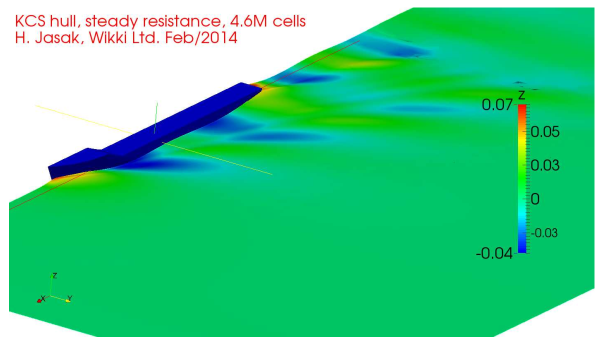
Steady Resistance Simulations

Steady Resistance in Calm Water: KCS Hull

- Using a special “steady-state” formulation of the free surface flow



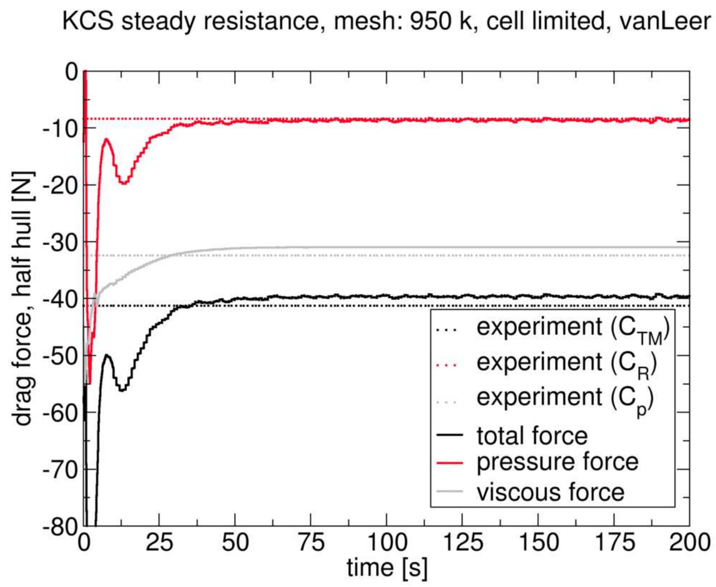


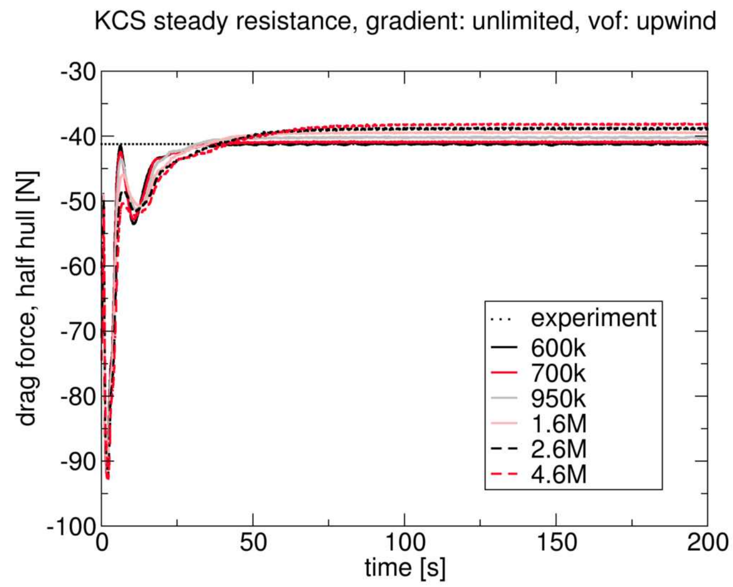


Validation: KCS Hull

Steady Resistance in Calm Water: **MOERI Container Ship (KCS)**

- Convergence of drag component in pseudo-time
- Study of mesh refinement on a series of meshes: 600k to 4.6M cells





- Note that experiments show unsteady flow at the stern and oscillation in drag data

Validation: KCS Hull

Steady Resistance in Calm Water: **MOERI Container Ship (KCS)**

- Computer: Single processor Intel I7 4820K, 3.7 GHz, 4 cores , 16 GB RAM

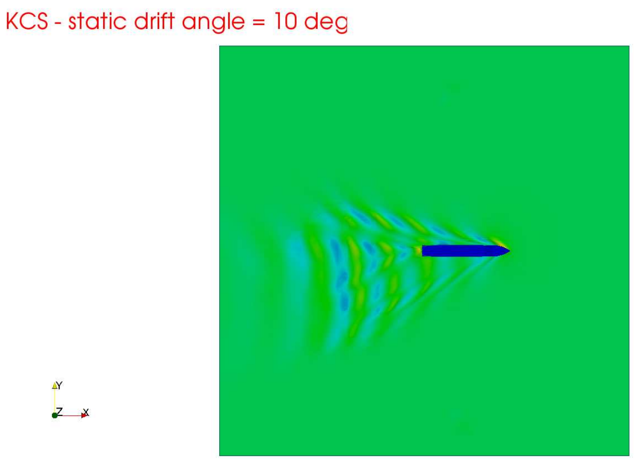
Mesh size	Drag [N]	Simulation Time for 200 s	Converged Force Simulation Time [s]
600k	41.93	1153 = 19 min	50
700k	41.09	1285 = 21 min	50
950k	40.35	1752 = 29 min	50
1.6M	39.93	2996 = 50 min	50
2.6M	38.91	14249 = 4.0 hrs	125/75
4.6M	38.58	27888 = 7.7 hrs	125/75

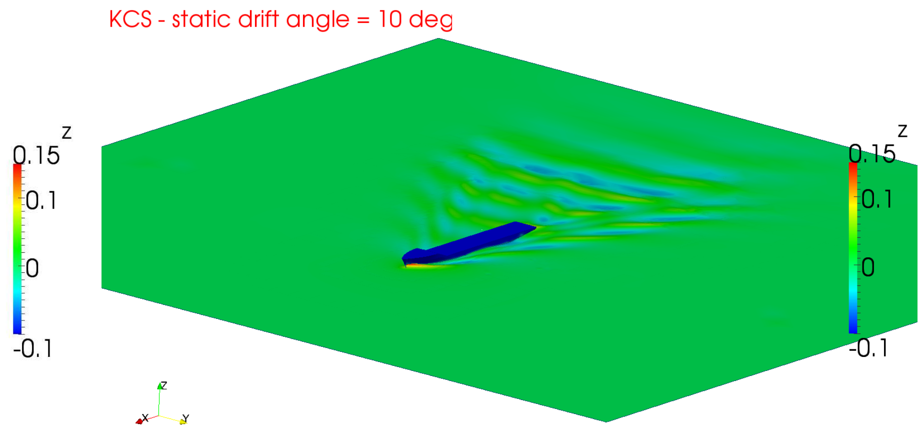
- Force drifts off on finer meshes due to wet stern effect; (also in other codes)
- **A converged and accurate resistance force in 30 min on 1 CPU!**
- (Note: This is an ugly mesh sequence, y+ values are not refined consistently)
- Other validation cases (5451 hull, proprietary hull shapes) show identical convergence behaviour; further mesh refinement studies on appended hulls
- Equivalent simulations performed on all-tet meshes with good results

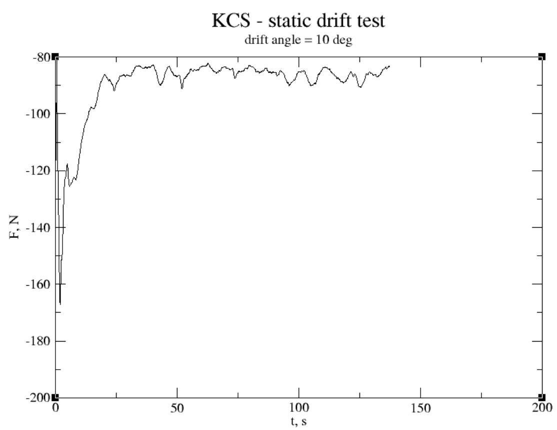
Drift Angle Resistance Simulations

Drift Angle Resistance in Calm Water: KCS Hull

- Angled incoming velocity is accounted for in far-field boundary conditions
- Encountered flow unsteadiness in drag force



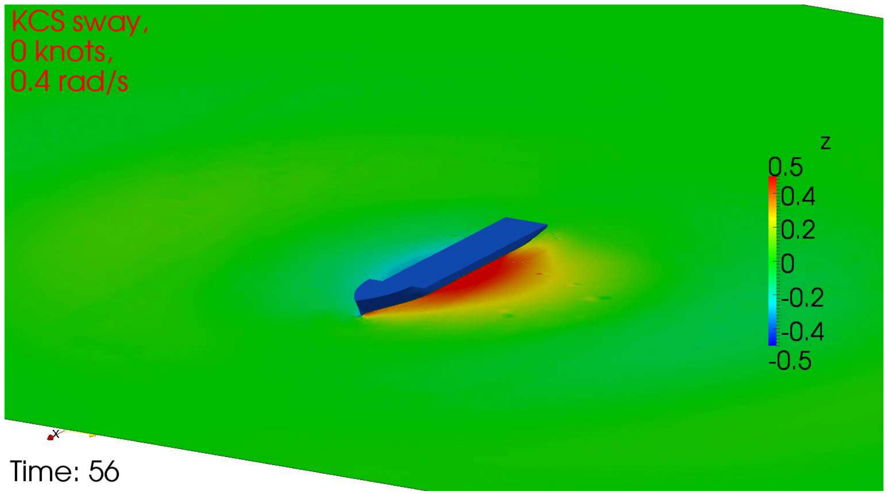


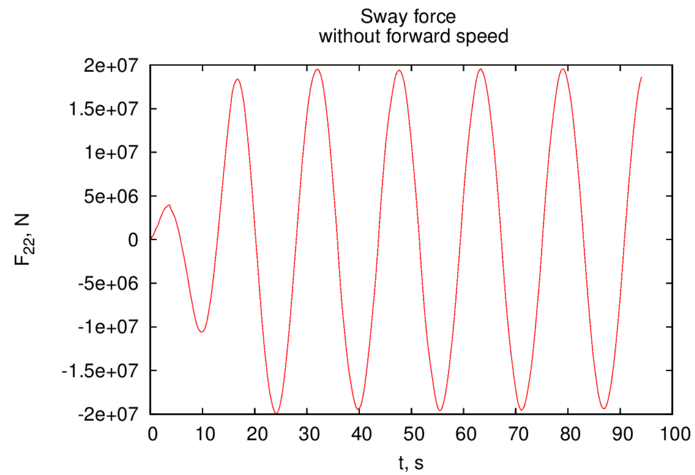


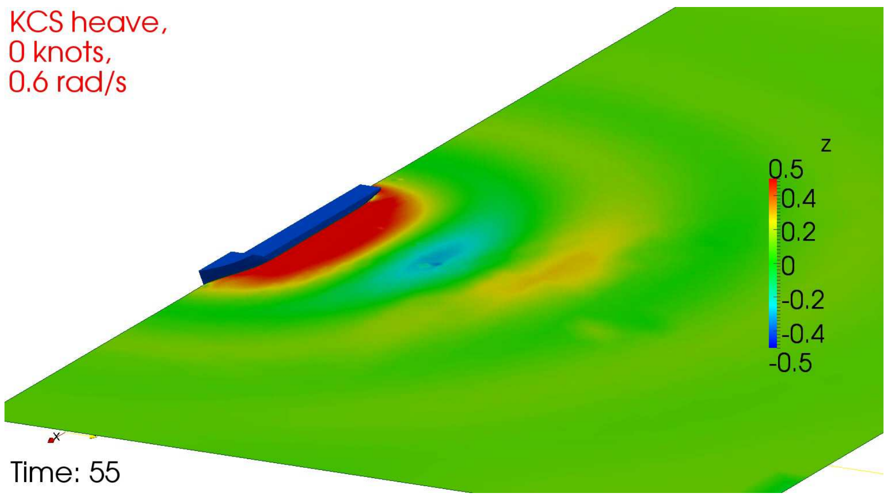
Forced Oscillation Simulations

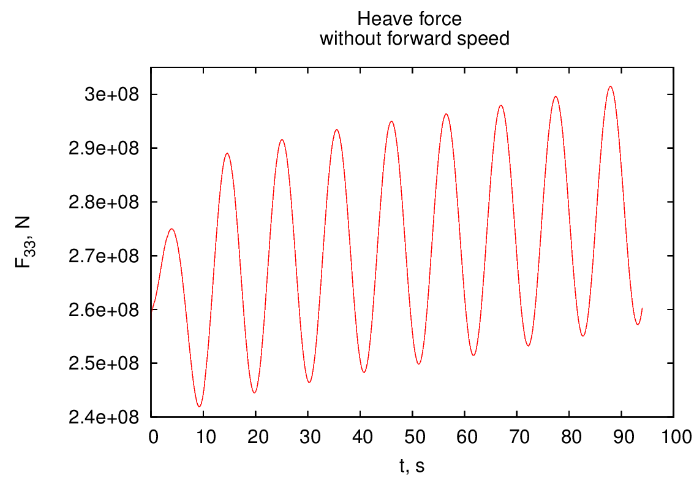
Forced Oscillation Simulations

- Displacement of the hull is prescribed: heave and sway; zero forward speed





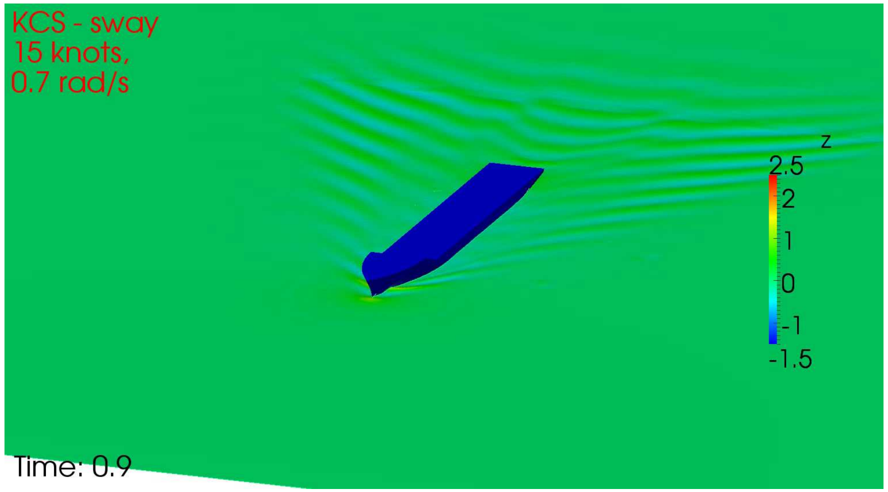


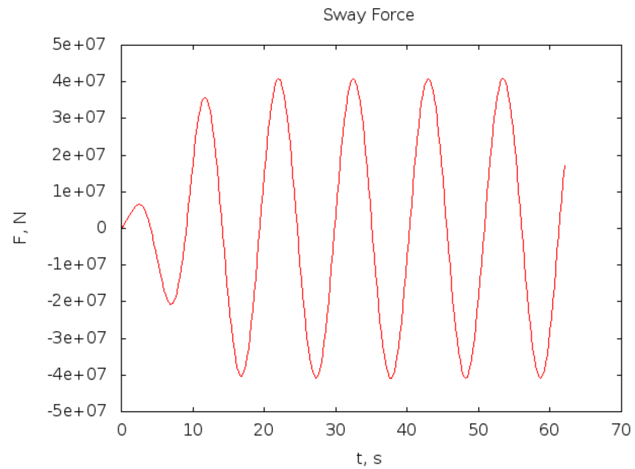


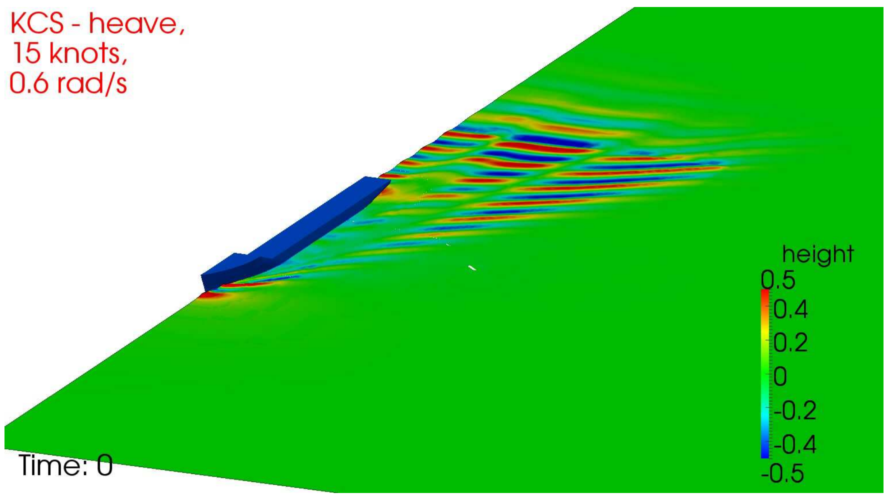
Forced Oscillation Simulations

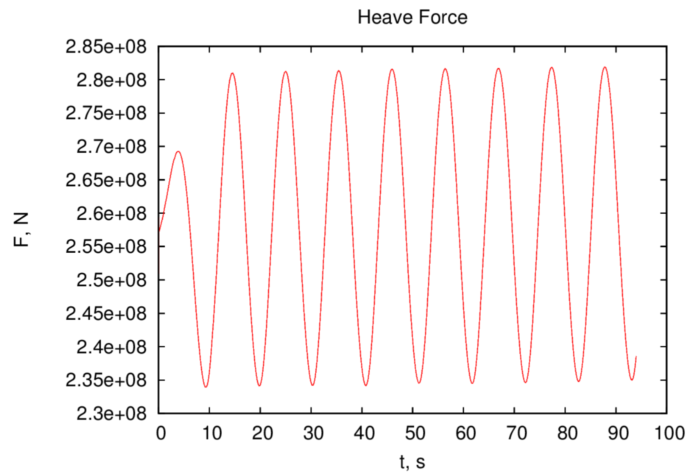
Forced Oscillation Simulations with Forward Speed

- Displacement of the hull is prescribed, accounting for forward speed





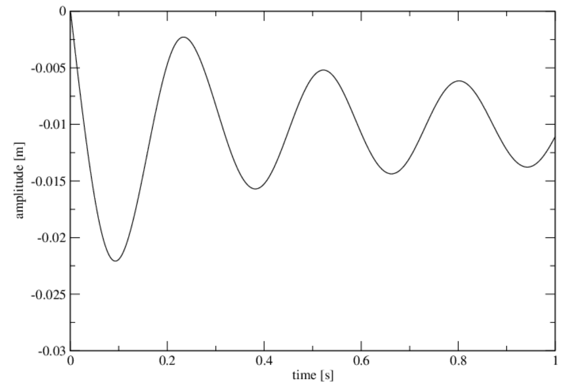


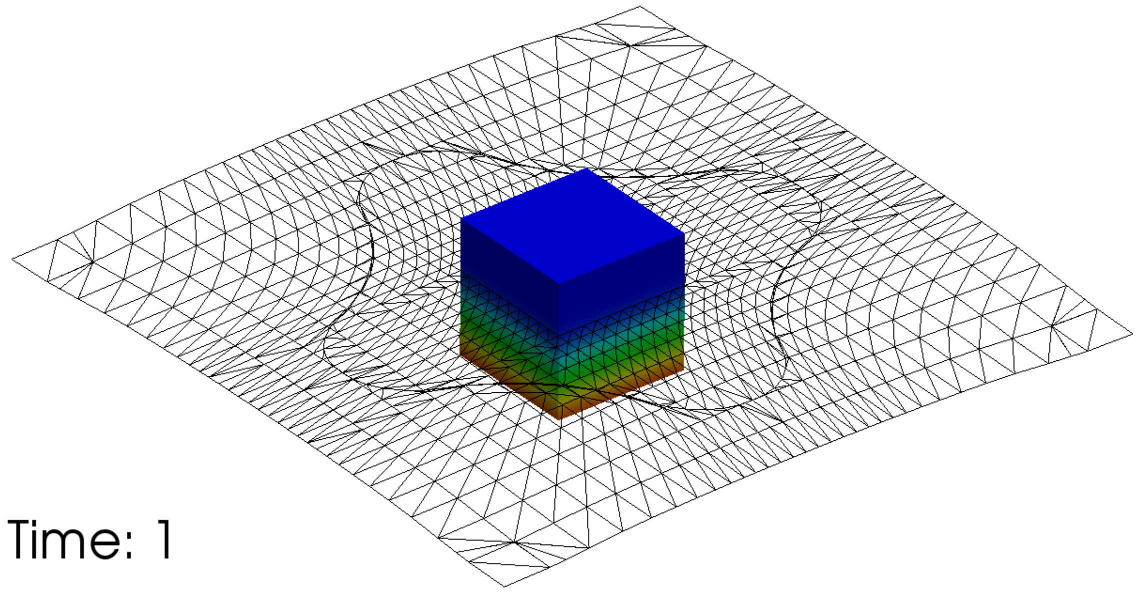


Constrained Motion Simulations

Example: Vertical Container Drop

- Constrained 6-DOF motion of a box: only surge allowed
- Domain is moved as a solid body in response to 6-DOF solution
- Water level preserved in motion

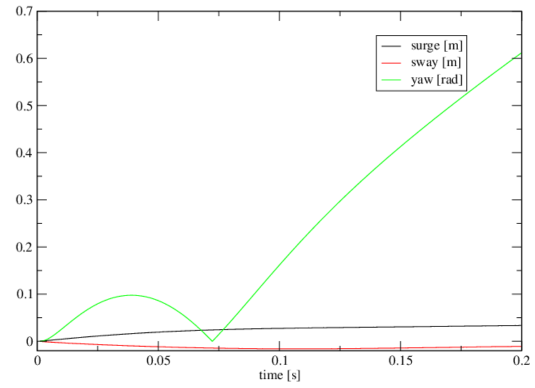


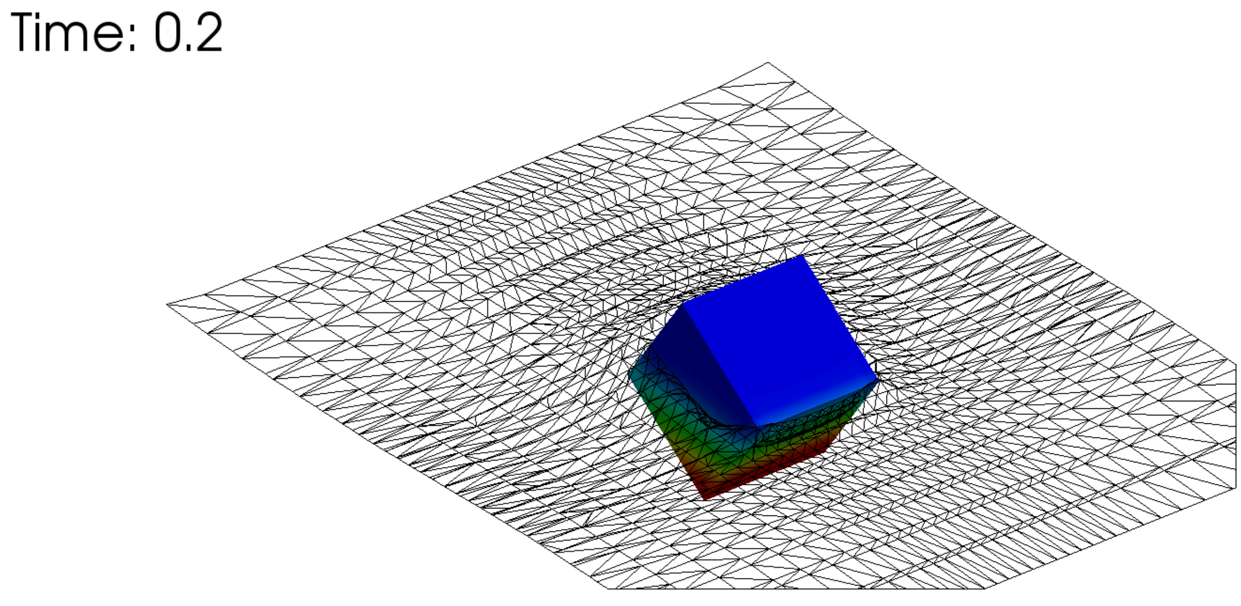


Constrained Motion Simulations

Example: Oblique Container Drop

- Constrained 6-DOF motion: surge, sway and yaw motion permitted
- Domain is moved as a solid body in response to 6-DOF solution
- Full capsize handled by the far-field `waterTable` boundary condition

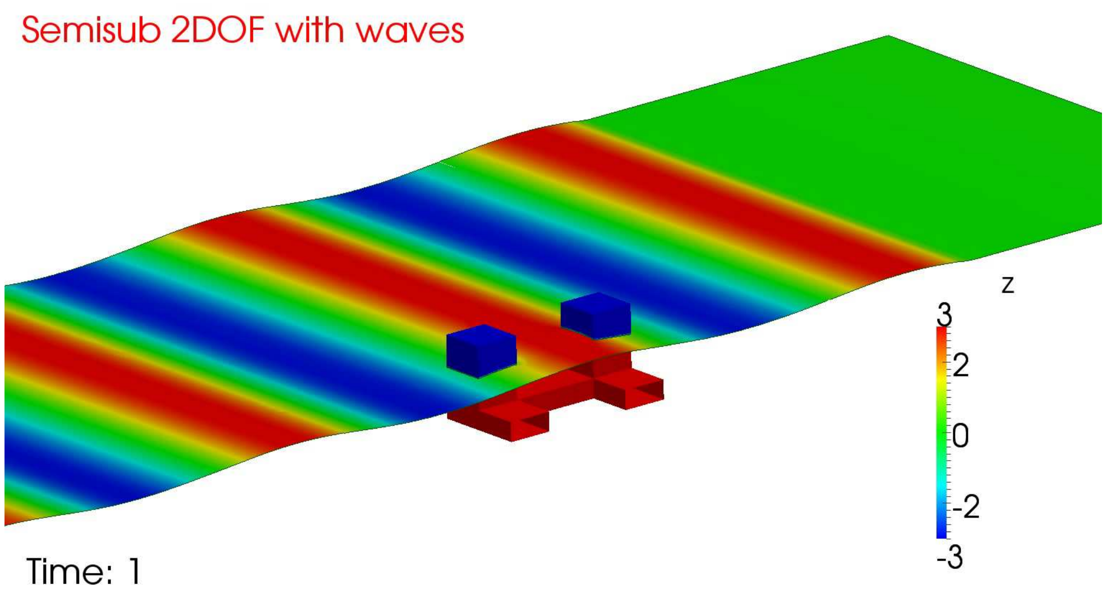


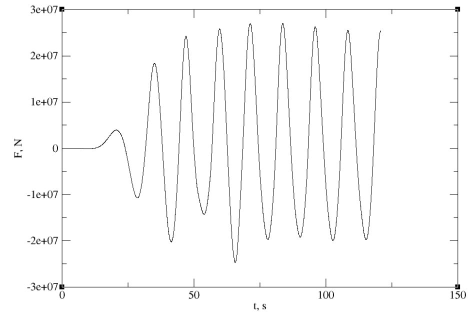


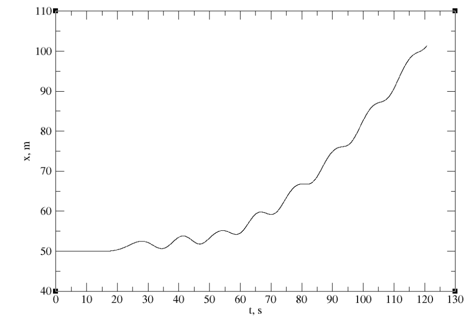
Constrained Motion Simulations

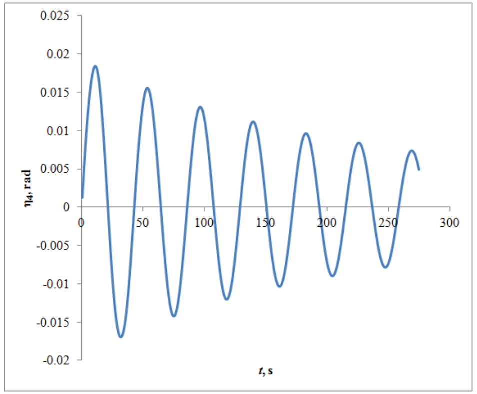
Numerical Studies of a Semi-Submersible Platform

- Simplified semi-submersible platform 100x100x28 m, symmetric half model
- Studies of wave forces, wave response in surge and heave and roll damping
- Incoming wave train enforced via inlet relaxation zone numerical beach outlet
- Variation of incoming wave length and wave height





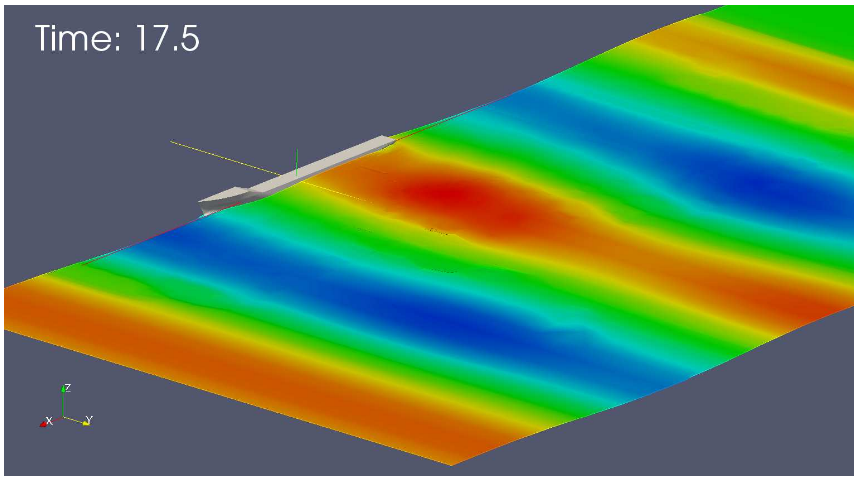


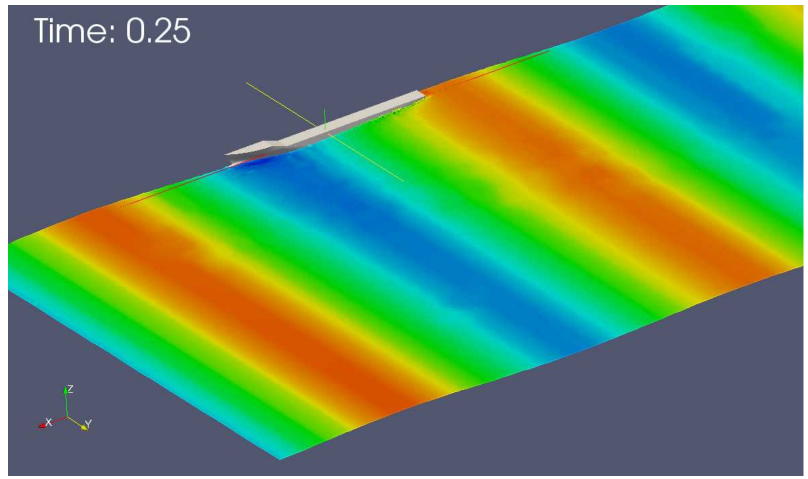


Incoming Wave Conditions

Simulation of a Fixed Hull on Waves With and Without Forward Speed

- Incoming wave relaxation zones are used to generate far-field
- Hull (mesh) is fixed: no sinkage and trim
- Using high Co number resistant formulation of the transient solver: `navalFoam`
- Issues with mesh resolution in far field resolved in relaxation zones: providing sub-cell and sub-face free surface resolution
- Addition of forward speed causes no further complications: mean current is superimposed onto the incoming wave profile in the far field and numerical beach

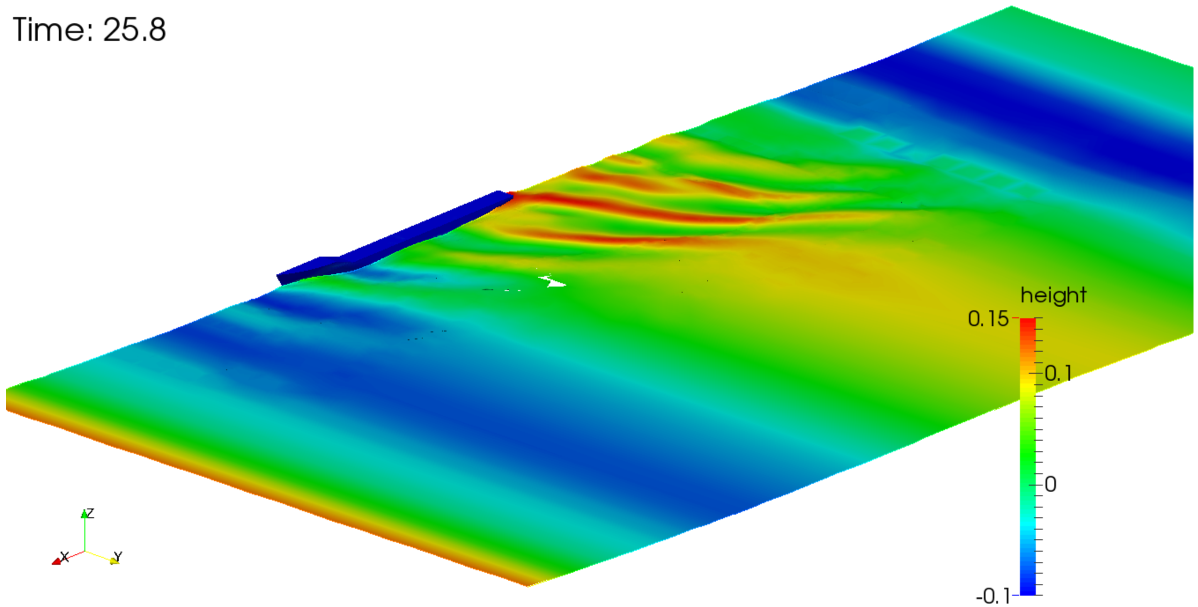




Sea-Keeping Simulations

Sea-Keeping Simulation of a Hull on Waves: KCS Hull

- Incoming wave relaxation zones are used to generate far-field
- 6-DOF solver for calculation of forces on the body
- Mesh motion performed in two modes
  - Mesh deformation, using protected near-hull mesh
  - Domain motion: the complete domain moving with prescribed motion of hull
- Using high Co number resistant formulation of the transient solver: `navalFoam`



Summary

Naval Hydro Pack: Improvements

- Significant improvement in speed and robustness across the spectrum of simulations
- Developed steady and transient high Co number resistant solver. Typical max Co number 2 000-10 000, with free surface Co number of 100-1 000.
- Inclusion of volumetric relaxation zones for wave generation in far field
  - Blending analytical wave equations in relaxation zones with the Navier-Stokes solution in the region of interest
  - Sub-cell and sub-face resolution of the free surface in relaxation zones for VOF and velocity
  - Dynamic iterative calculation of free surface intersection (if needed)
- Dynamic mesh classes for deformation or solid body motion
- Successful simulations for ship-on-waves and 6-DOF sea-keeping