NORDIC 2010 NAFEMS CONFERENCE

Simulation of wave loads on offshore structures with Volume of Fluid (VOF) method

Vidar Tregde

Kongsberg Devotek

Kongsberg Devotek

Kongsberg Devotek **is the largest independent development house in Norway providing high technology solutions to companies developing, owning and selling products and systems subjected to tough environments.** **Expertise in Innovation Counseling, System- and Actuator design, FEA- and CFD analysis, Prototyping and testing**

Kongsberg Devotek **has gained unique technical expertise from a 20 year track of experience in**

development of advanced technologies for the Maritime, Defense, Oil & Gas, Automotive and Embedded market

Kongsberg Devotek **has 90 persons, mainly MSc, BSc and PhD**

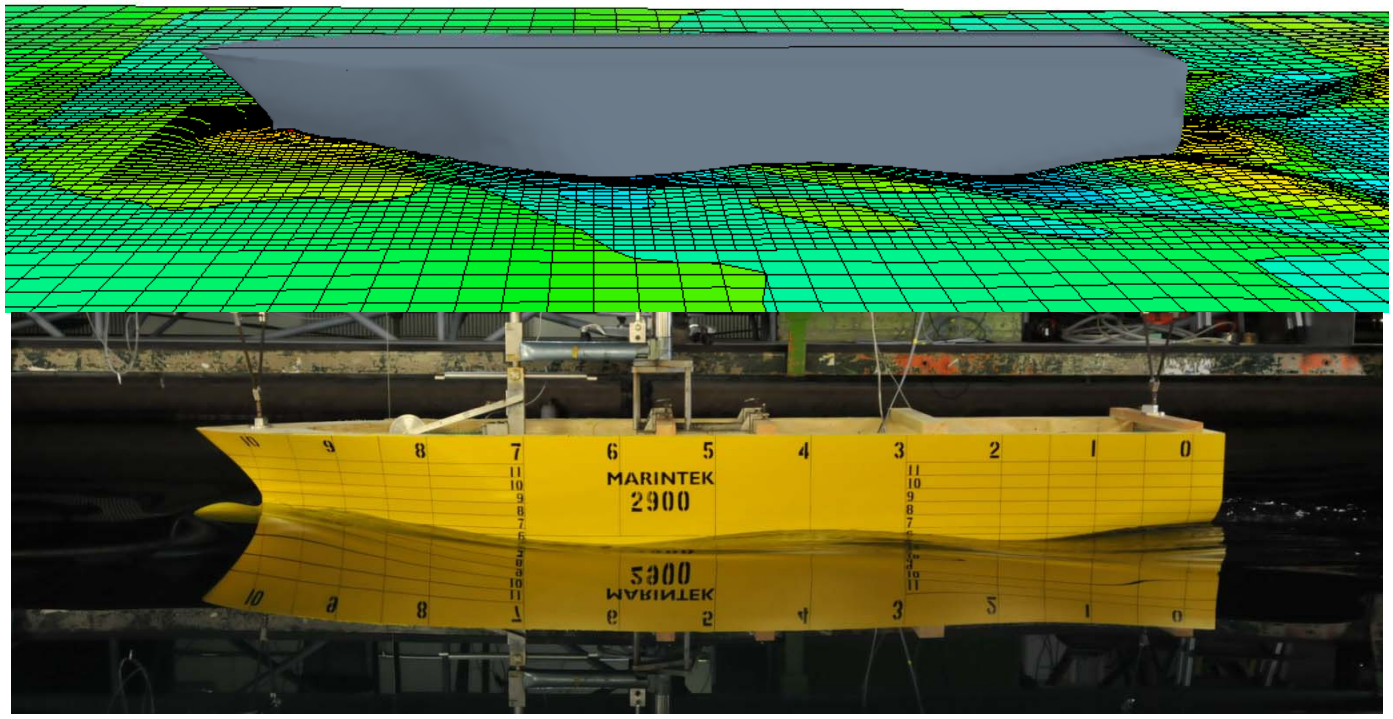
15 mill € budgeted turnover 2010

VOF Wave Simulation:
Introduction

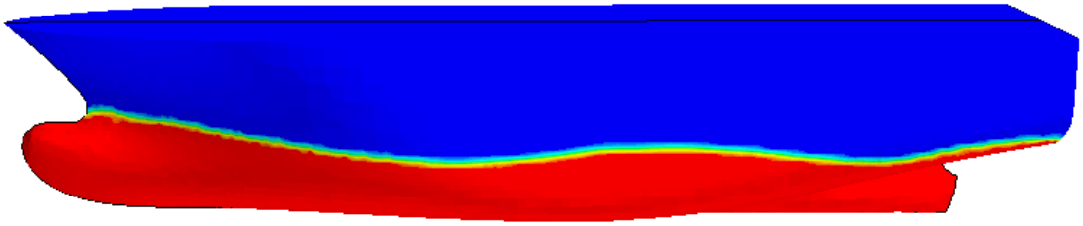
- Ship hydrodynamics
  - Ship resistance
  - Ship propulsion
  - Hull-propeller-rudder interaction
  - Coupled simulation of flow and ship motion
- Cavitation
- Sloshing in tanks
  - Prescribed tank motion
  - Coupled simulation of ship motion and sloshing in tanks
- Fluid-structure interaction
- Slamming loads
  - Green water
  - Wave impact

Resistance and Drag Prediction, I:

Free Surface Calculations, Ship Resistance



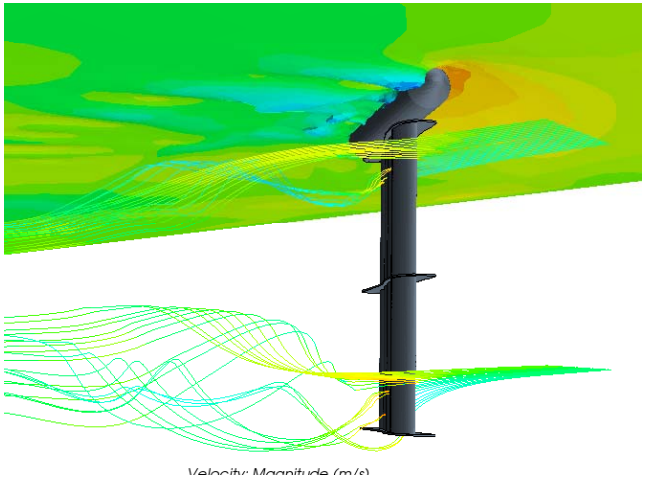
Comparison between CFD and model test of generated waves from a vessel

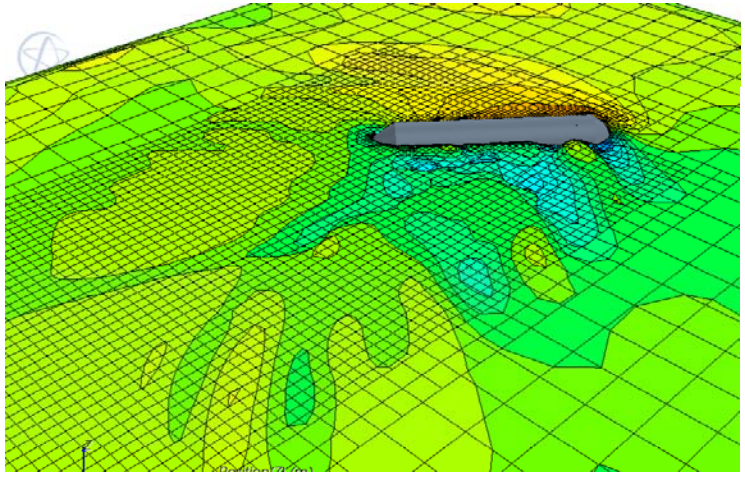


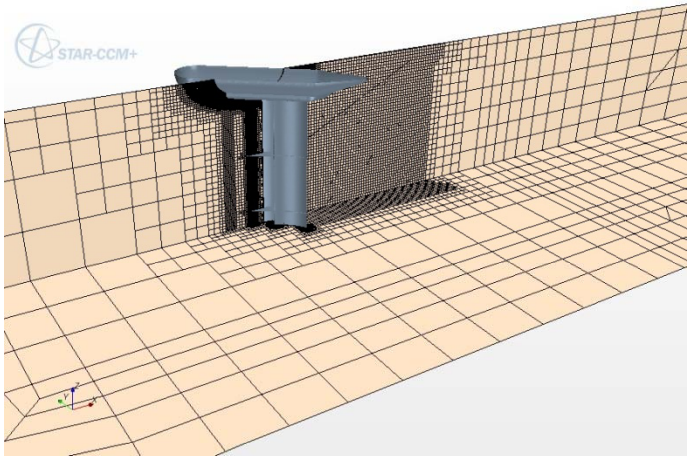
Wet surface of vessel

Resistance and Drag Prediction, II:

Drag and Lift from Seismic Deflector



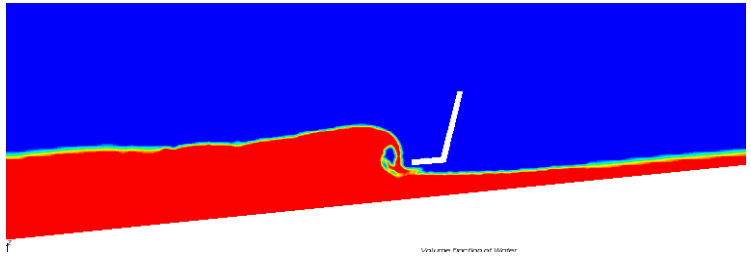


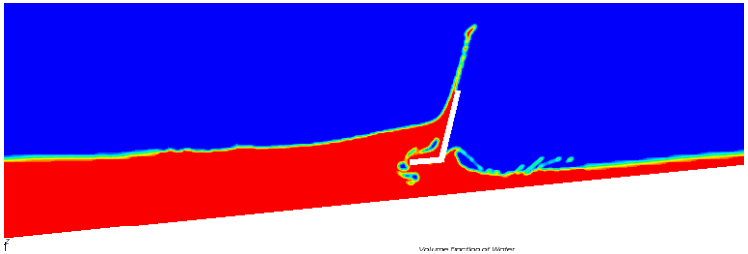


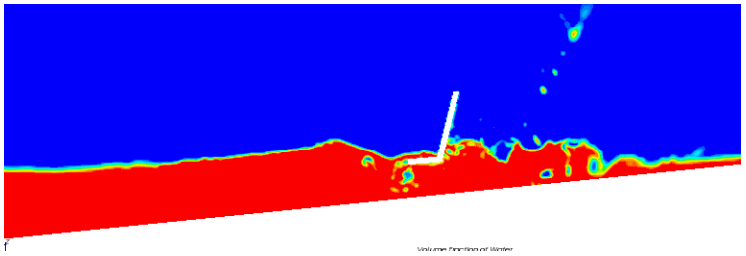
Slamming Loads:
Green Water and Wave Impact

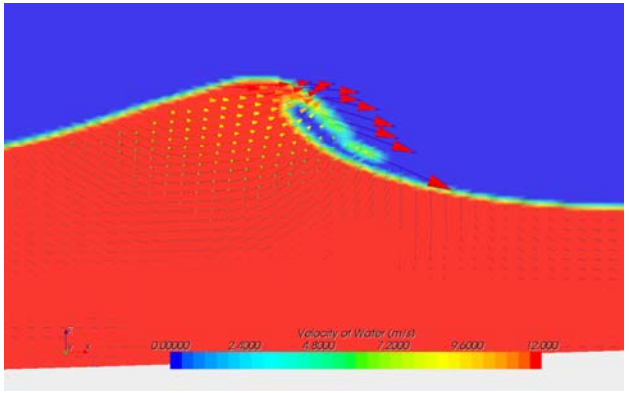
Scope of work:

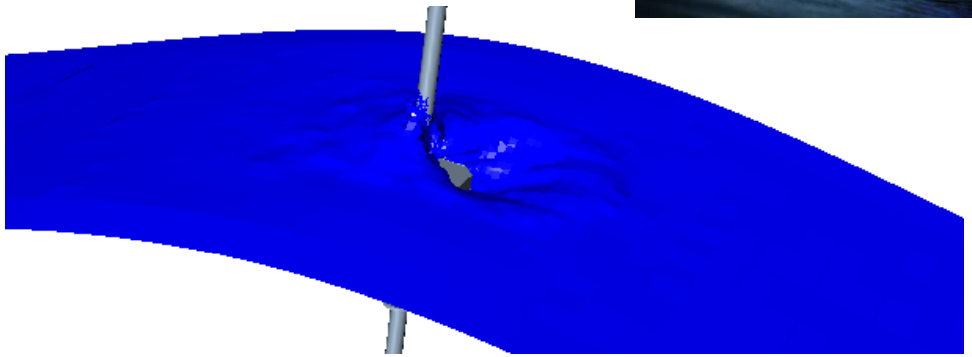
Geometrical model -> Mesh model -> Set incoming wave -> Perform wave loads calculation with time simulation -> Pressure on struture can be monitored











Physics for VOF Wave Simulation

- VOF (Volume of Fluid) method
- Water and air (incompressible)
- HRIC for VOF (high resolution interface capturing)

  Scheme is designed to mimic the convective transport of immiscible fluid components, resulting in a scheme that is well suited for tracking sharp interfaces.
- Bounded, i.e. VOF between 0 and 1
- Turbulence Model: k-ε two equation model
- Trimmed and/or polyhedral mesh
- Stokes 5^{th} order wave
- Coupled simulation of flow and motion of floating bodies

Waves hitting a Rigid Structure
Objecive and Topics

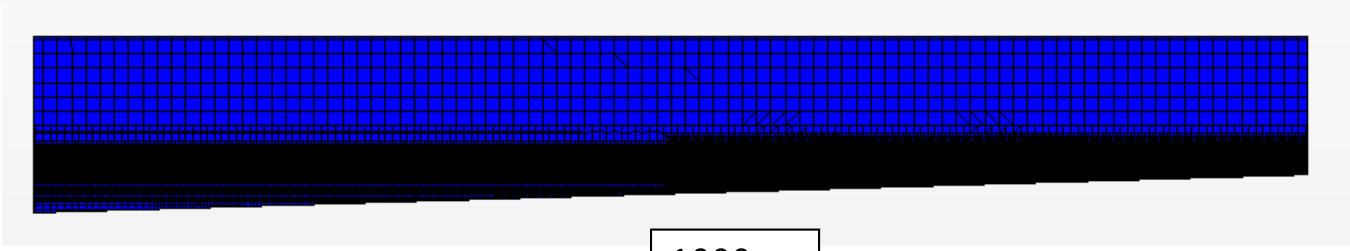
Objective:

Perform CFD simulations of breaking waves, and waves close to breaking hitting rigid offshore structures. Volume of Fluid (VOF) method are used for simulations. The motivation for simulations are finding the worst possible forces at realistic waves with a given probability of occurence.

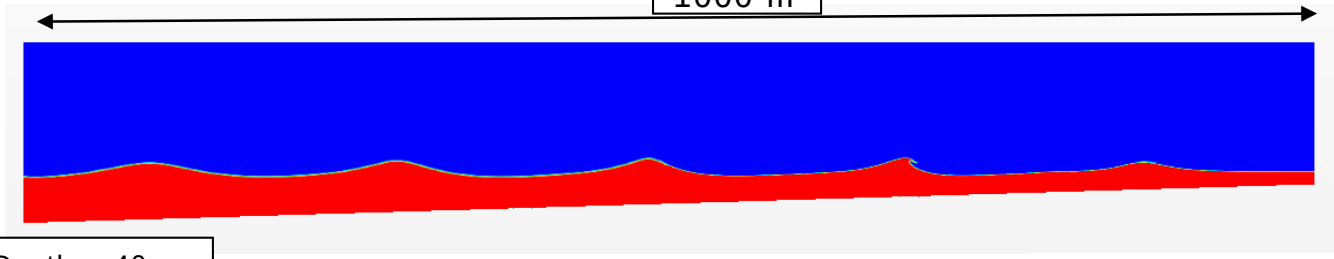
Topics:

- **Hydrodynamical analysis of waves on a beach hitting a rigid structure is performed.**
- **The waves are regular. In this study the region is modelled as slightly 3D, that means the extension in direction parallel to the beach is only very small compared to x- and z-direction. The flow is assumed 2D.**
- **The software used is Star CCM+. The software handles 3D cases with free floating bodies and with waves and speed/current, and the numerical method is a Volume of Fluid (VOF) method. This has proven very good for free surface flow cases.**
- **Simulation of waves propagating into a plane beach, results are compared to experiments.**
- **Analysis of slamming loads from simulations are sensitive to time step in unsteady analysis.**

Breaking Waves



1000 m

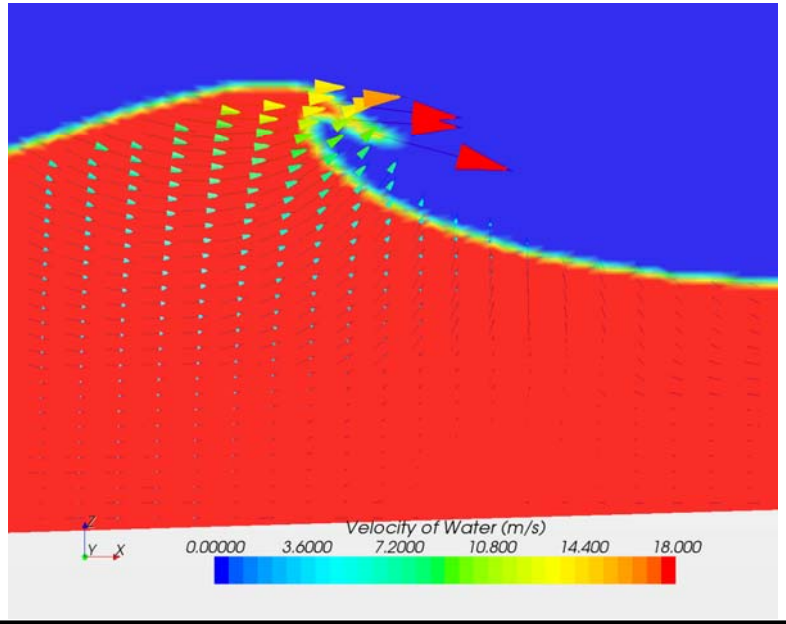


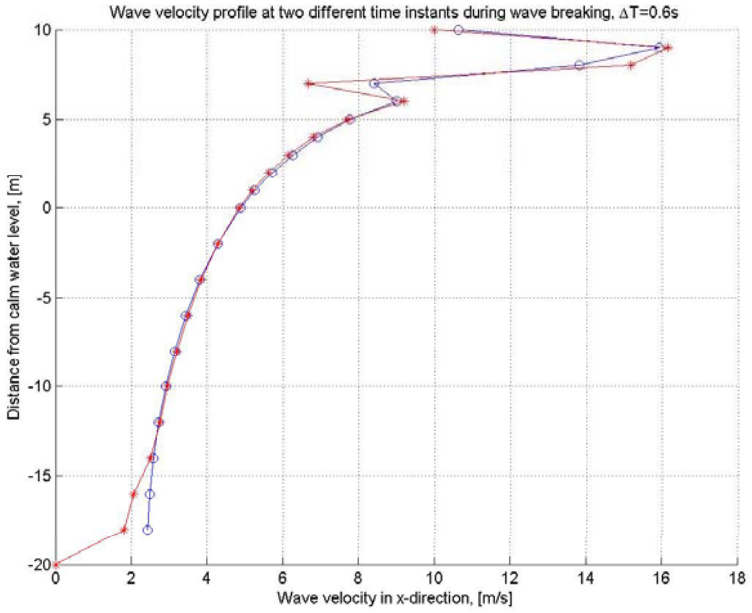
Depth = 40 m

Beach Slope 1:33
Incoming wave:
H = 12.2 m
T = 11.6 s

Mesh: 93.000 cells, 2D simulation

Depth = 10 m





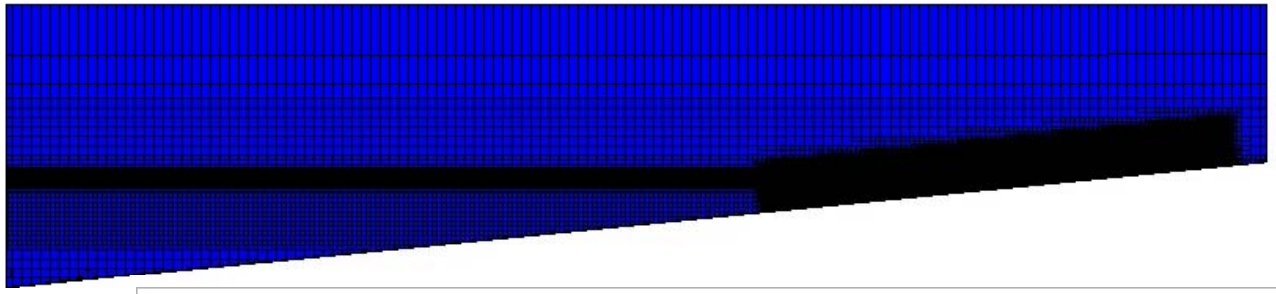
Breaking Waves: Comparison with Experiments

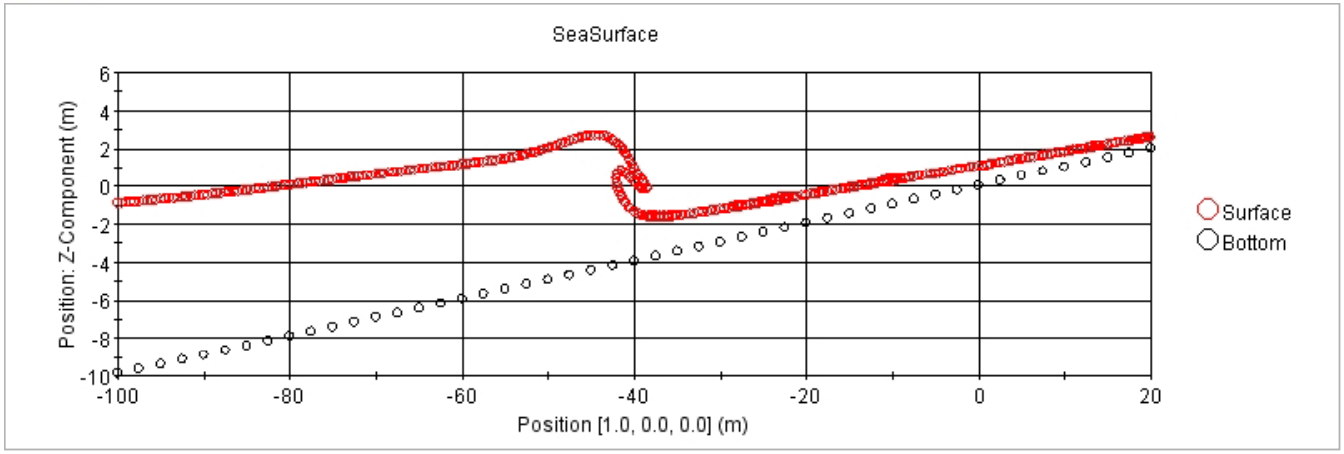
Plunging jet impact pressure distribution		T (s)	H_b (m)	D_b (m)	ξ	H_b/D_b
	Experiment	2.4	0.26	0.33	0.59	0.79
	This study	9.0	3.6	4.5	0.58	0.82

Beach Slope 1:10
Incoming wave:
H = 3.76 m
T = 9 s

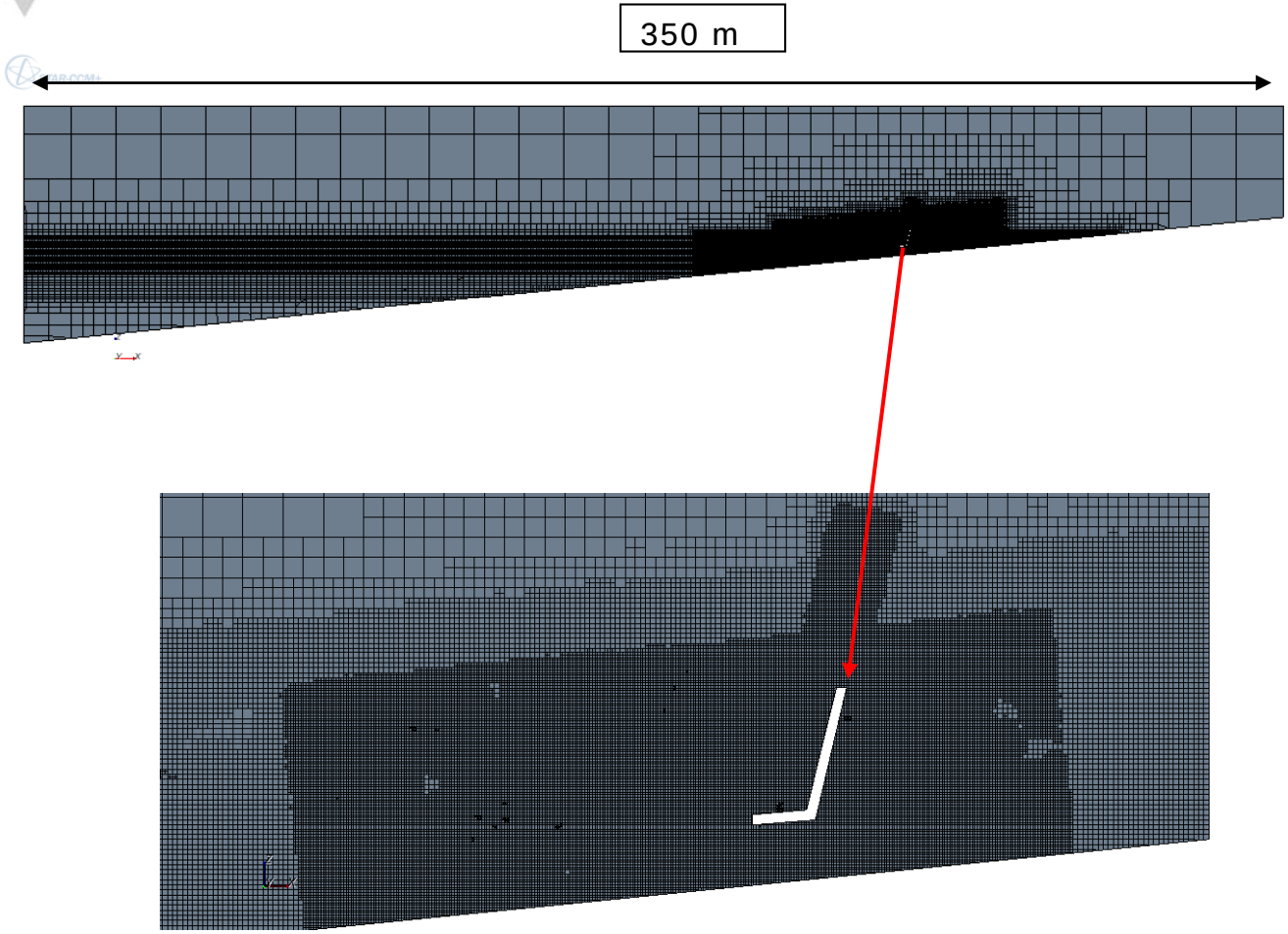
Mesh: 40.000 cells, 2D simulation

H_b : wave height at breaking, D_b : still water depth at breaking, ξ = slope/sqrt(H_b/λ_∞): surf similarity parameter





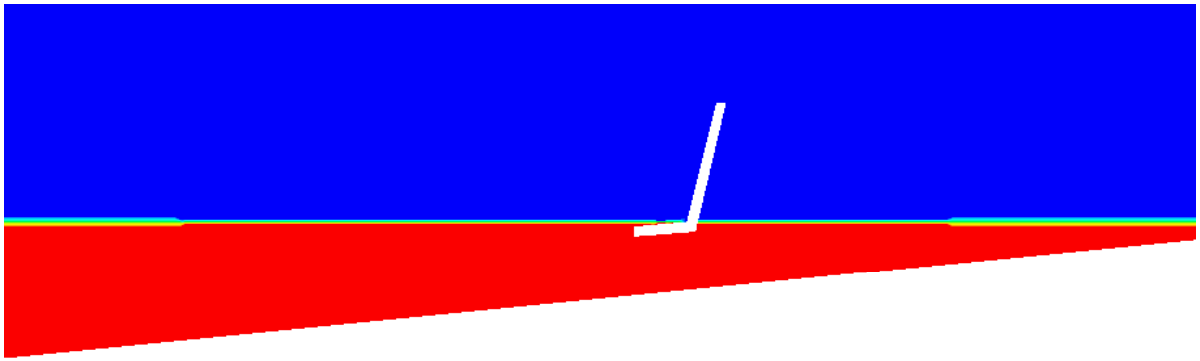
Waves hitting a Rigid Structure:
Mesh



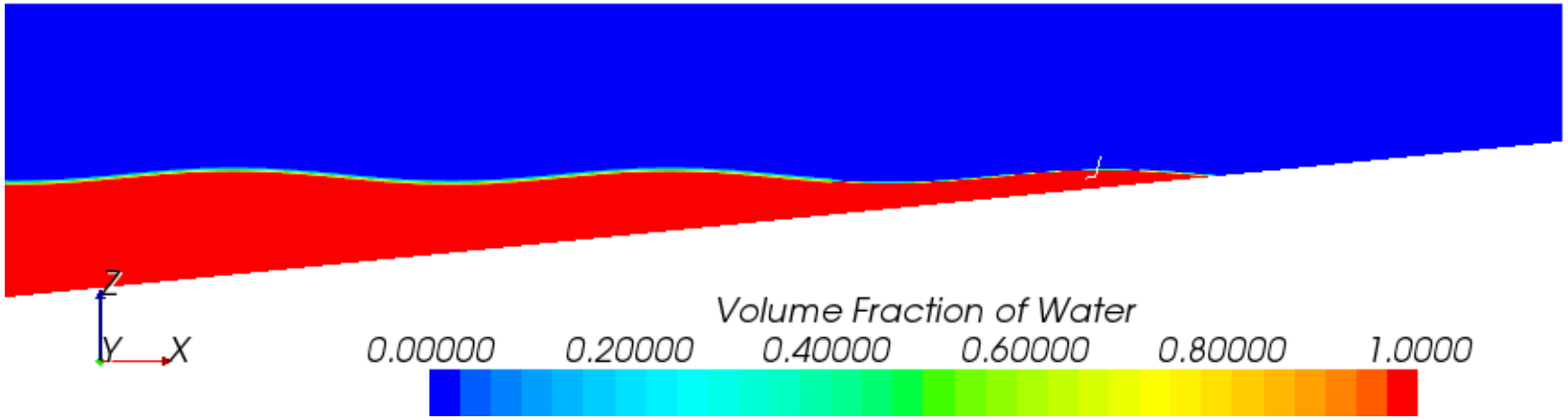
Beach Slope 1:10
Incoming wave:
H = 3.76 m
T = 9 s

Mesh: 60.000 cells,
2D simulation
Timestep: 2ms

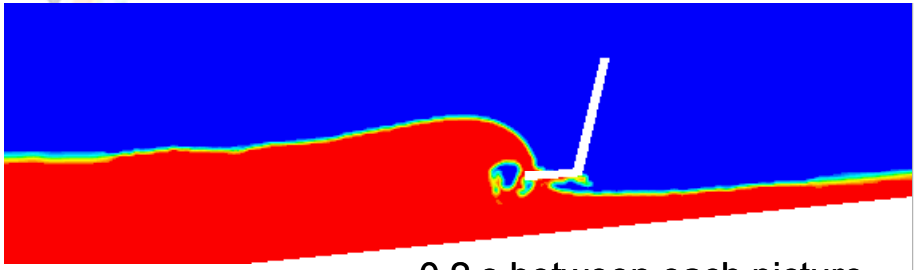
Waves hitting a Rigid Structure:
Initialization



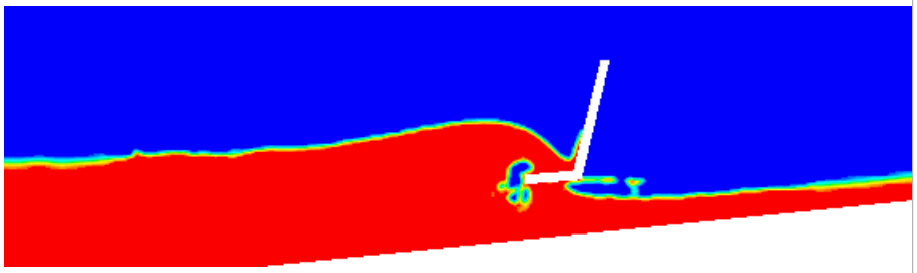
Regular waves

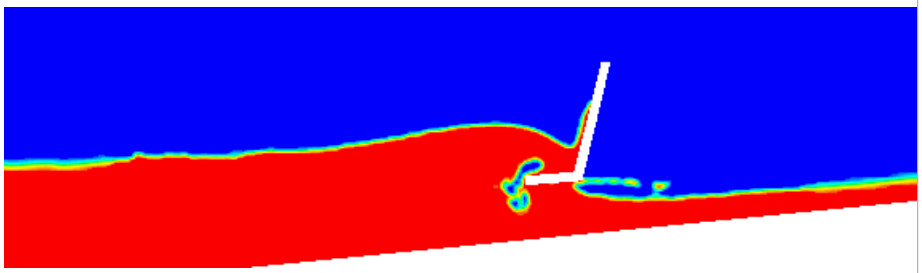


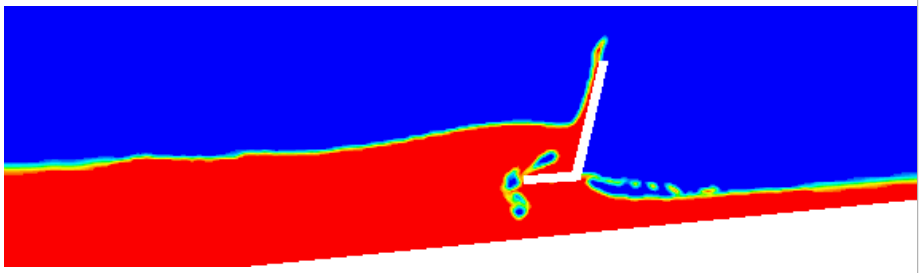
Waves hitting a Rigid Structure: First Wave



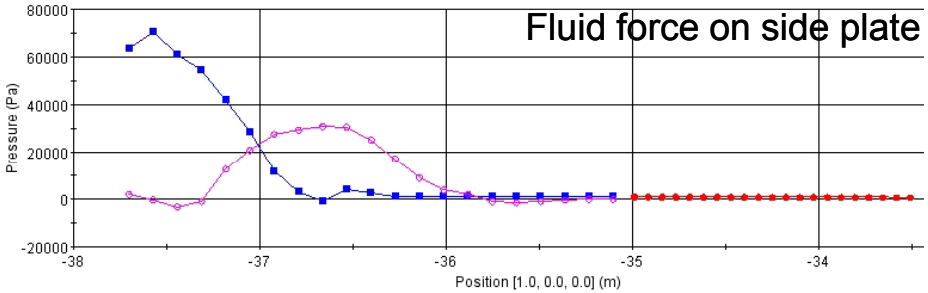
0.2 s between each picture



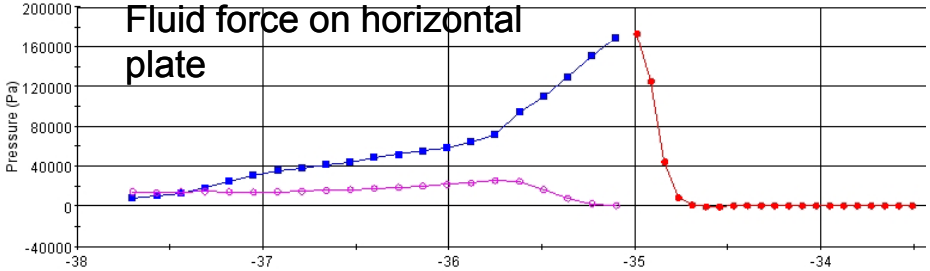


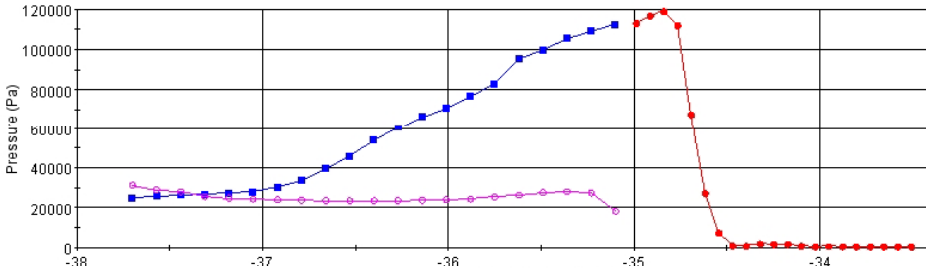


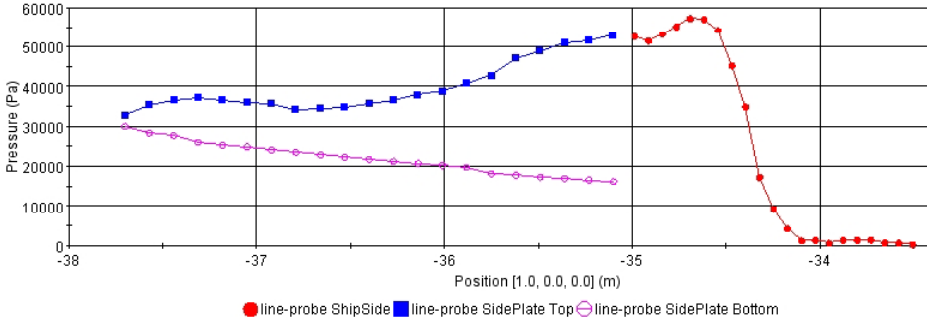
Fluid force on side plate



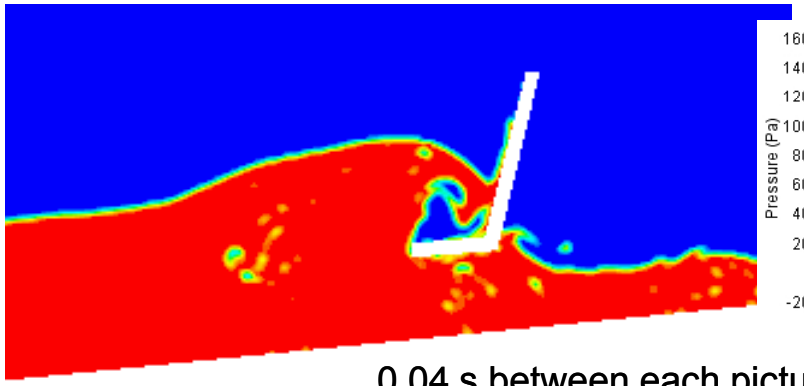
Fluid force on horizontal plate

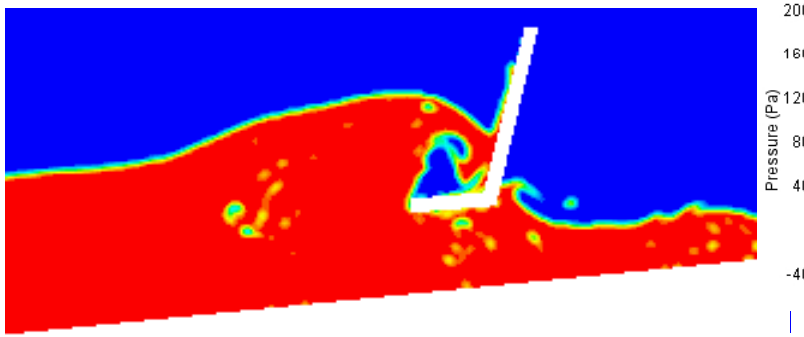


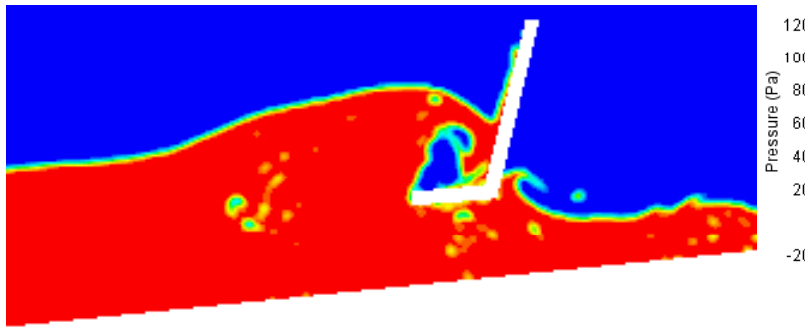




Waves hitting a Rigid Structure: Second Wave



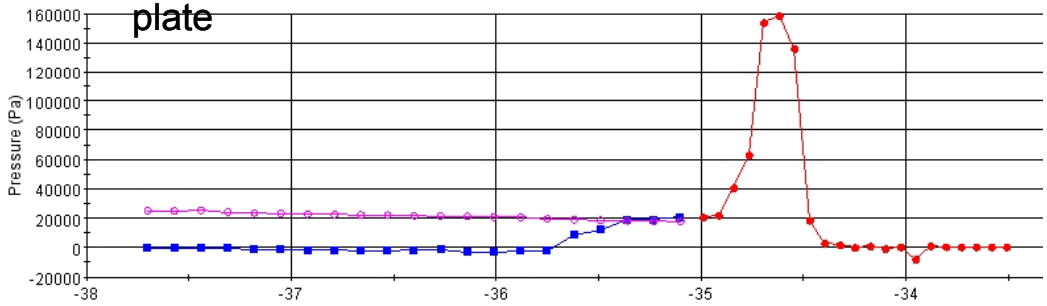


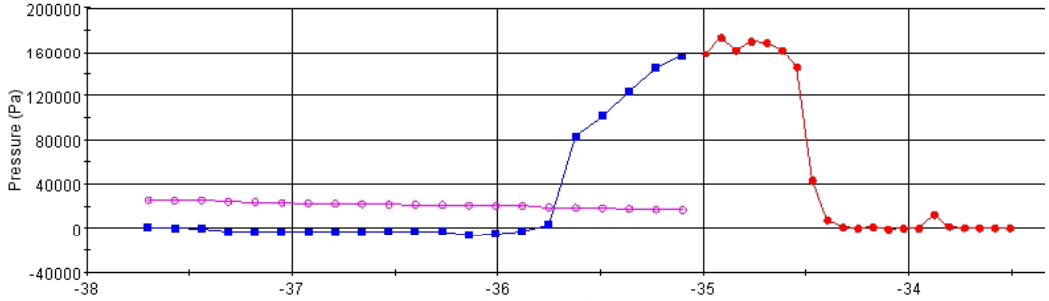


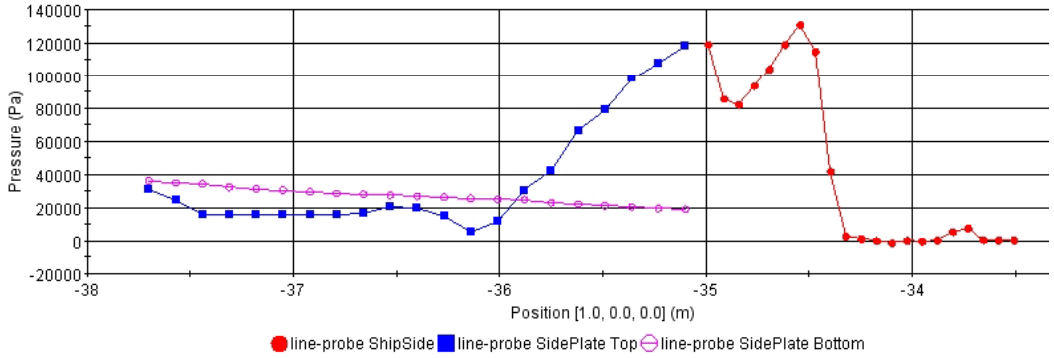
0.04 s between each picture

Fluid force on horizontal plate

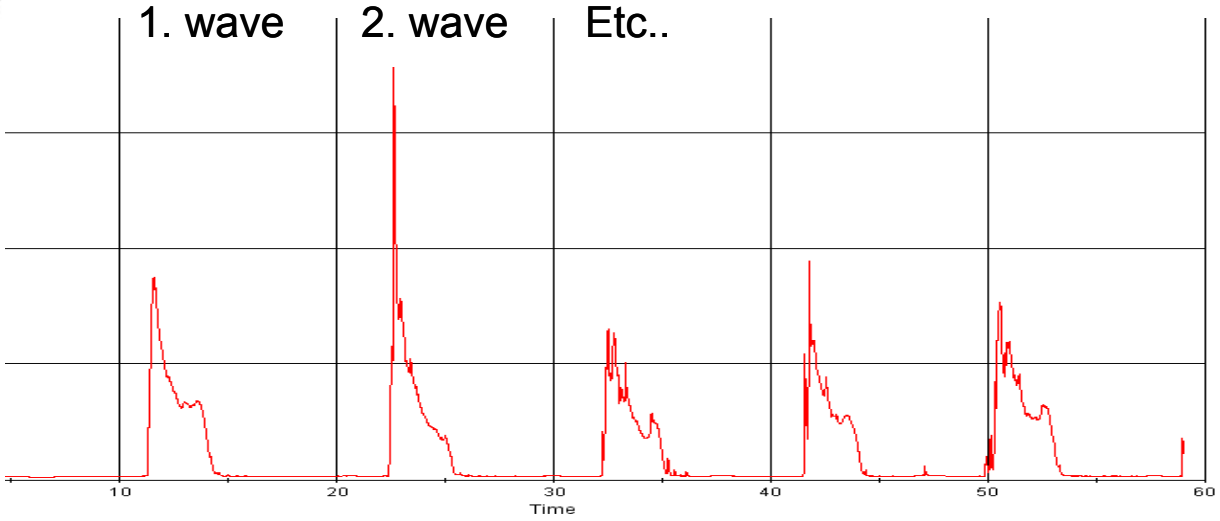
Fluid force on side plate





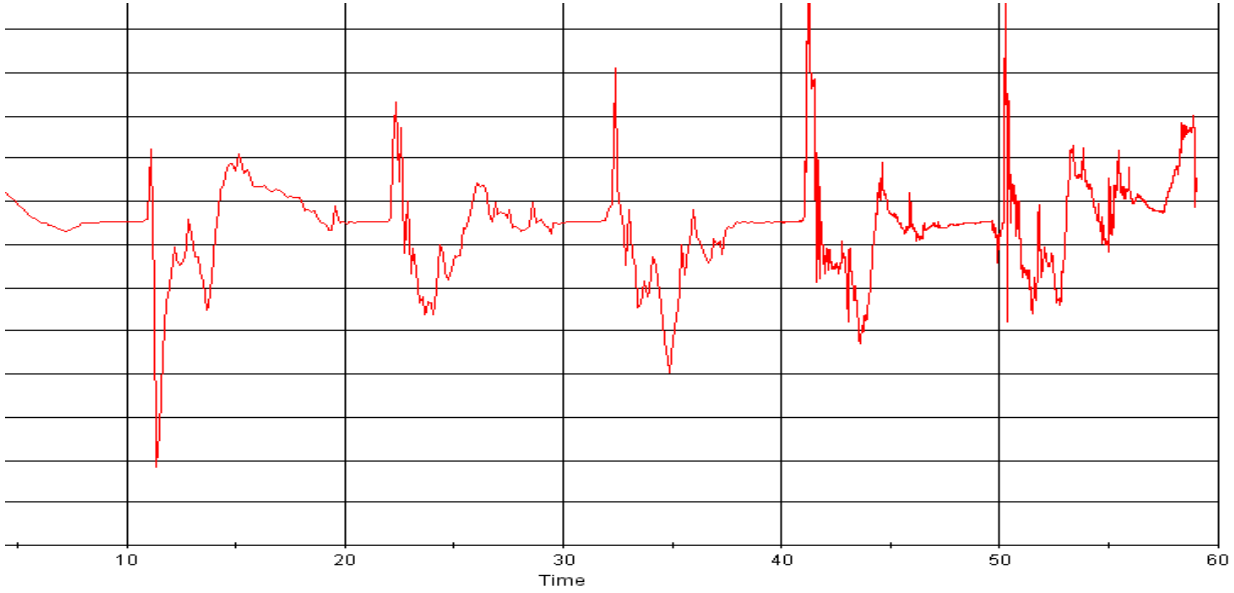


Waves hitting a Rigid Structure: Sealoads on Structure



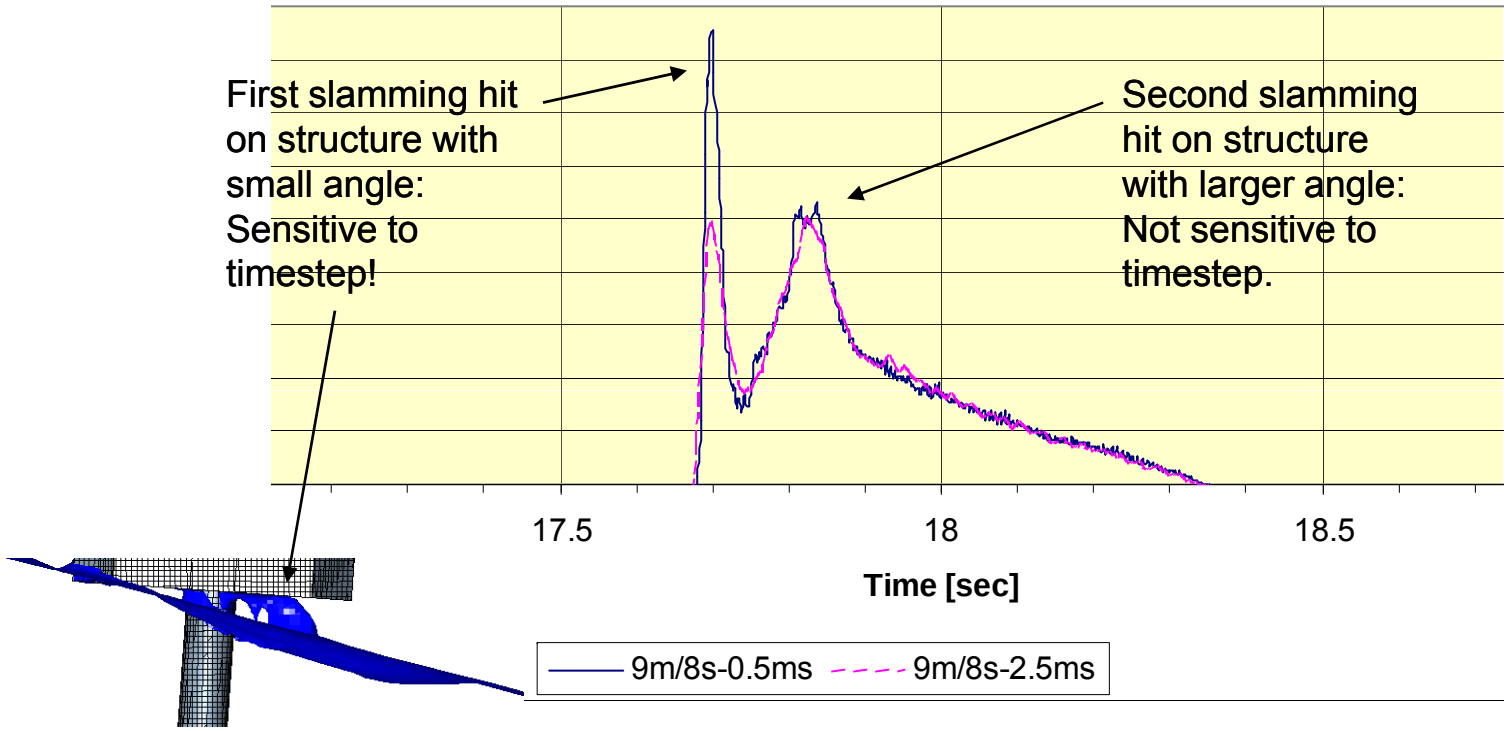
Fluid force on side plate

Timestep of 2ms OK



Fluid force on horizontal plate

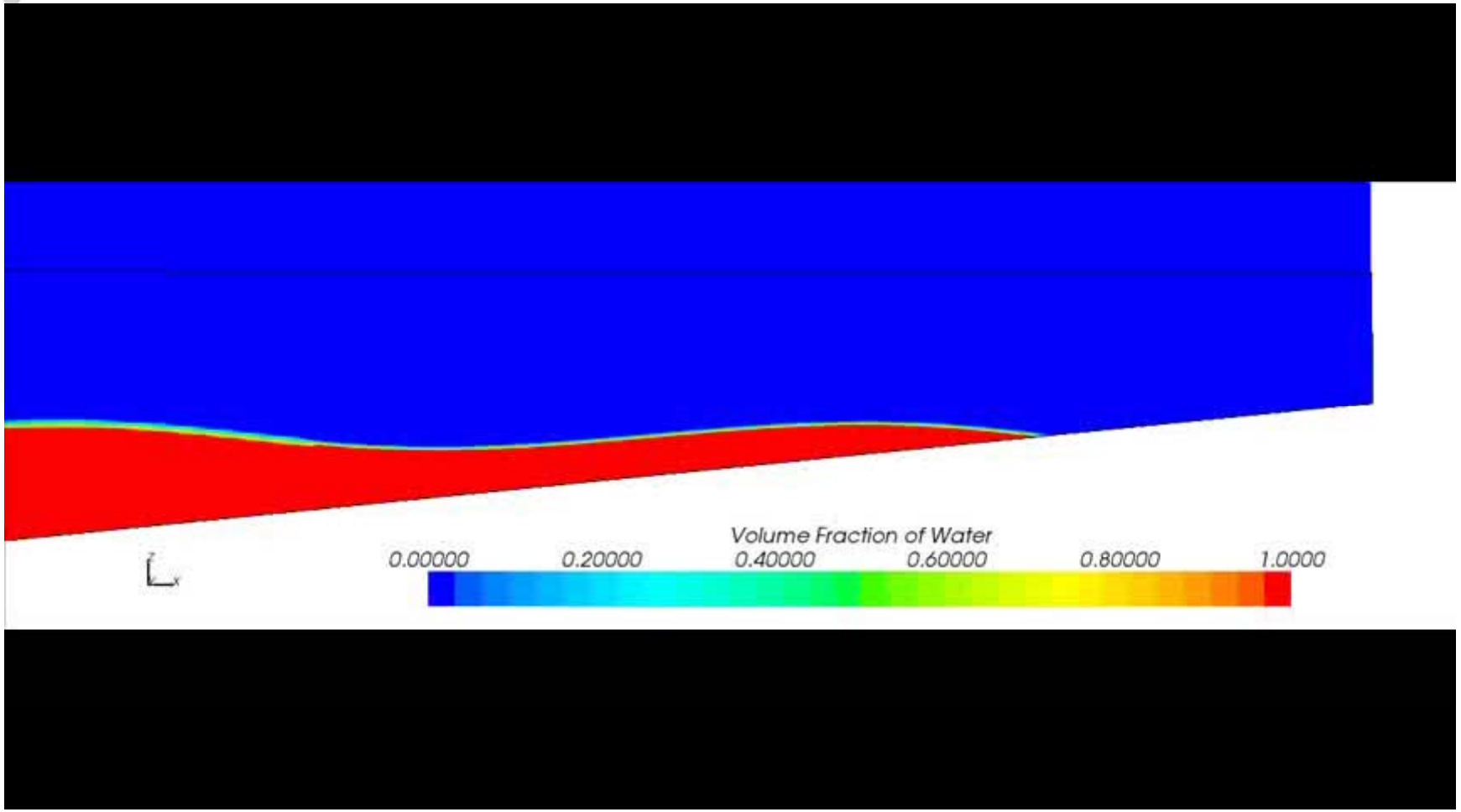
Waves hitting a Rigid Structure: Timestep Influence on Peak Force



Example of slamming case very sensitive to timestep due to small slamming angle between water and structure

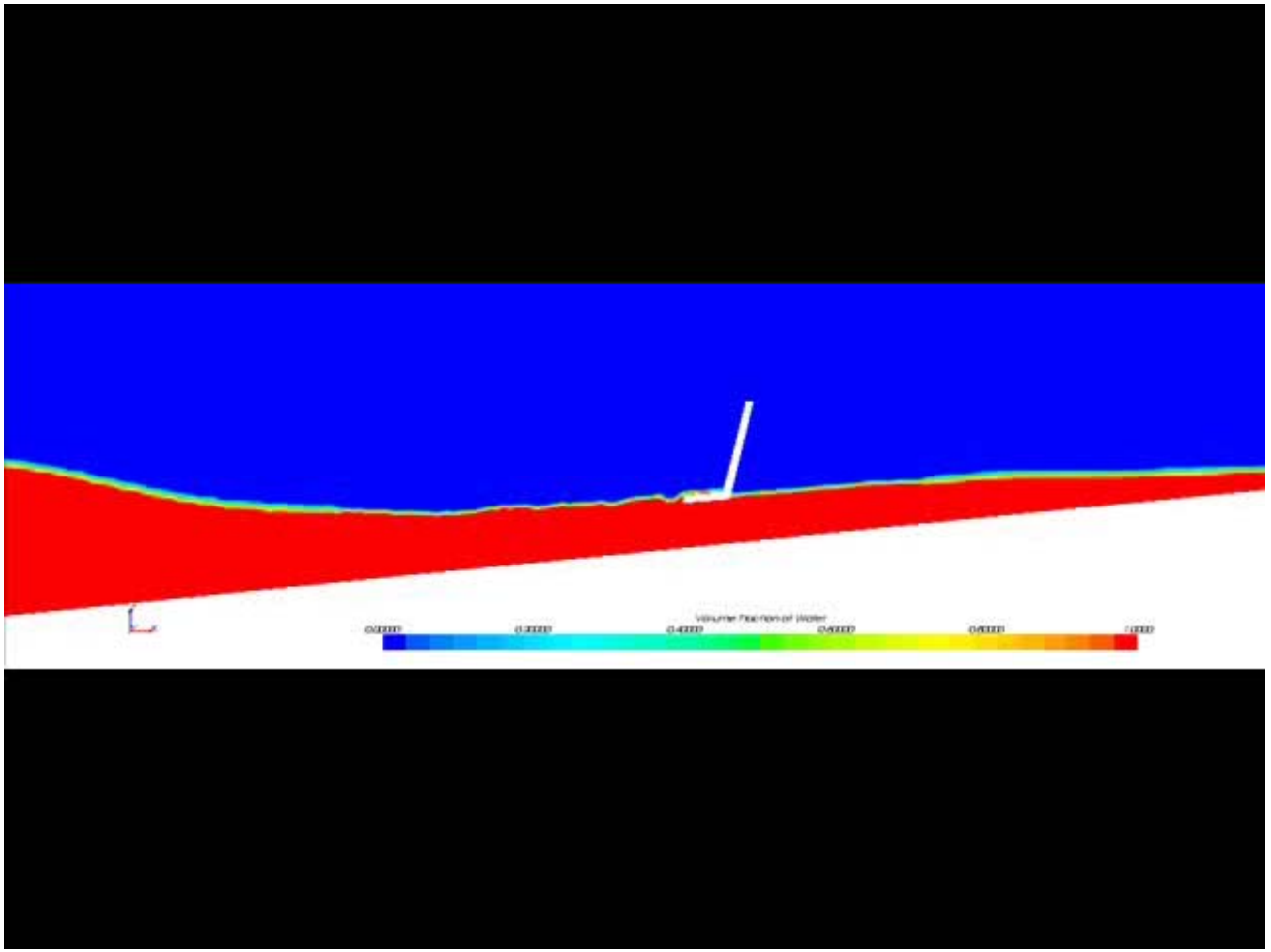
VOF Wave Simulation:

Animations..



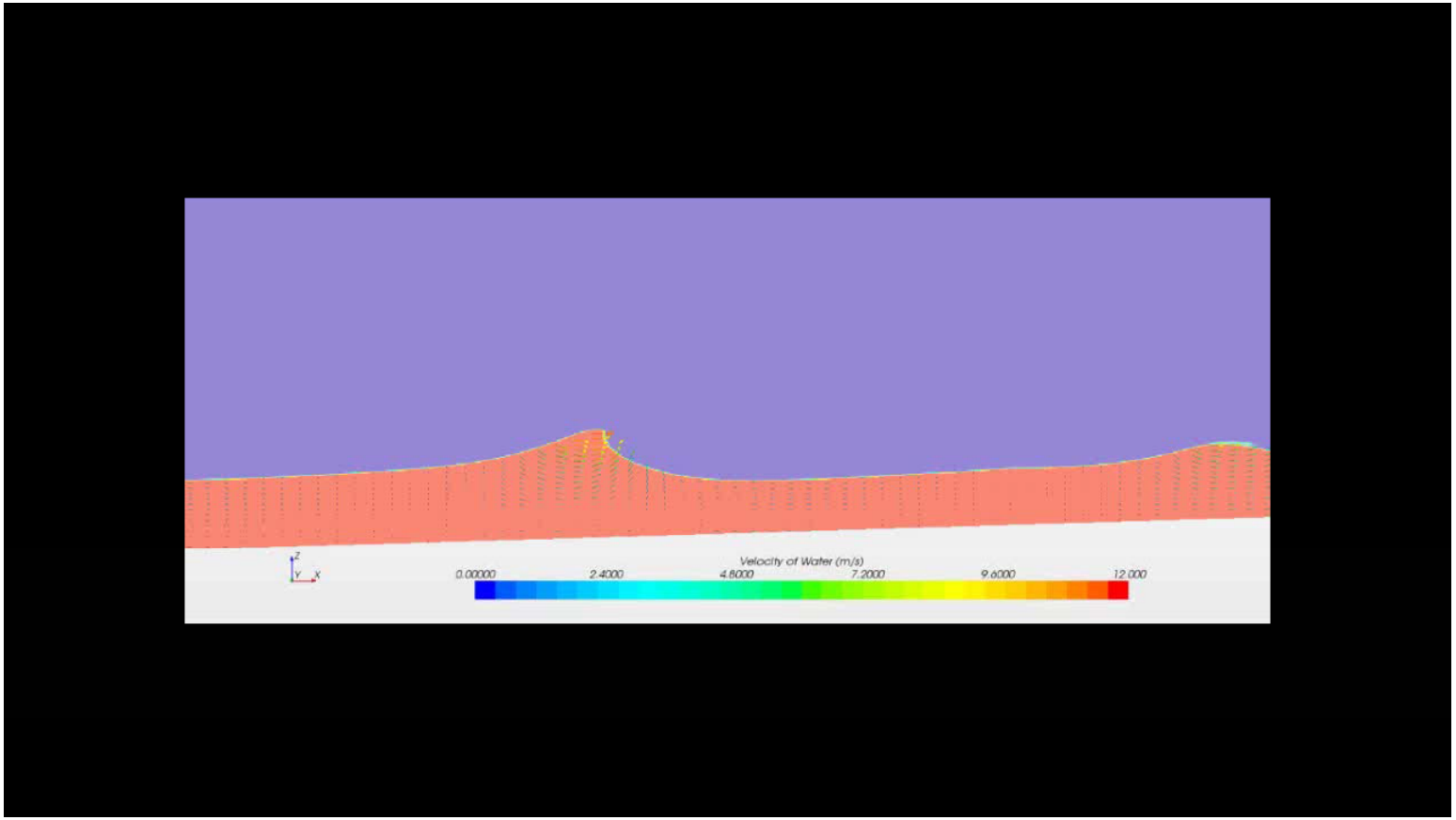
VOF Wave Simulation:

Animations..



VOF Wave Simulation:

Animations..



VOF Wave Simulation:
Conclusions and Outlook

- Simulation of large scale ocean wave slamming cases are possible with VOF.
- Breaking waves on a beach show good agreement with experiments
- Simulation of waves over long time is possible without deterioration of accuracy.
- Coupled simulation of flow, motion, and structural deformation is also possible.