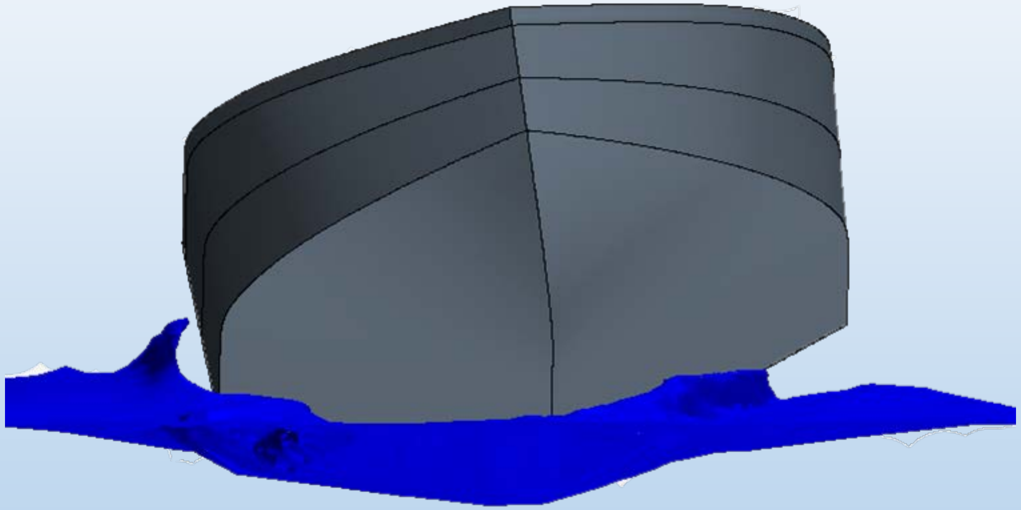
Dynamic transversal instabilities due to coupled pitch-heave-roll motions on a high speed craft

Thesis developed at University of Michigan
and University of Rostock



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Dynamic instabilities on high speed vessels

- Displacement vessel vs high speed craft

Dynamic instabilities

Complex to predict

Crew injury

Boat damage

Aim: “Investigate roll behavior of a high speed vessel”

*** Video source: Stratos 285 Pro XL 70MPH and Chine Walk Correction**

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Dynamic instabilities background

- Prediction of hydrodynamic coefficients

  Carolyn Judge (U.S. Navy)

  Experimental tests of a boat model

  Suggestion → **to incorporate higher harmonics**

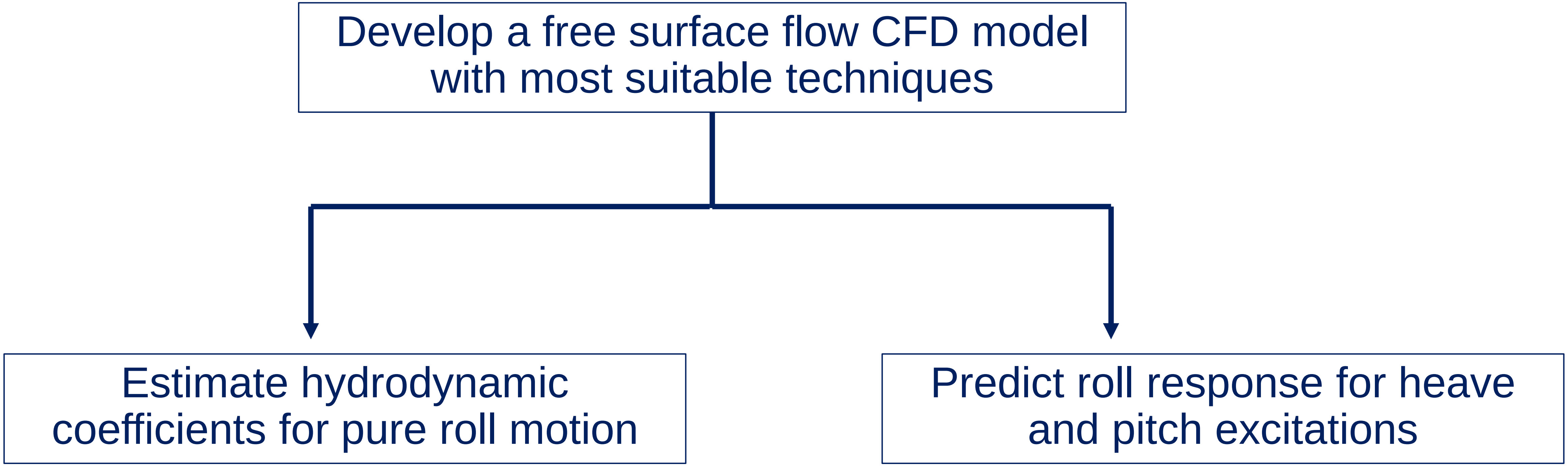
- Development of a reduced order model

  Oscar D. Tascon (University of Michigan)

  2d+t approximation

  Recommendation → **to validate assumptions**

Objectives of the project



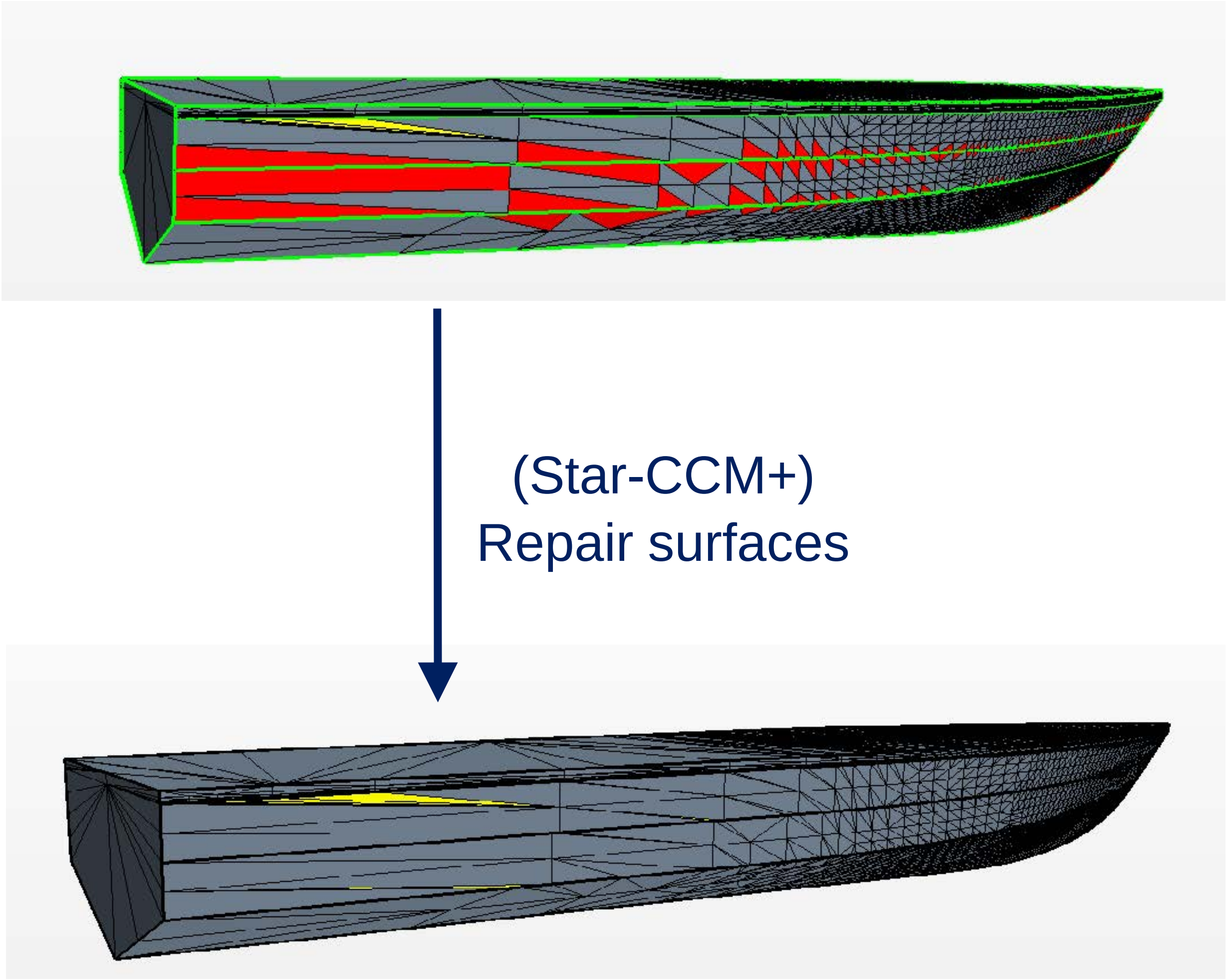
CFD Model – Preparing geometry

- Benchmark for future CFD analysis

- Boat model geometry

Carolyn Judge model

- ✓ Length overall: 1.50 m
- ✓ Chine beam: 0.45 m
- ✓ Draft: 42.60 mm
- ✓ Deadrise: 20°
- ✓ Trim: 2.9°
- ✓ Speed: 17.52 kn (Fn = 4.3)



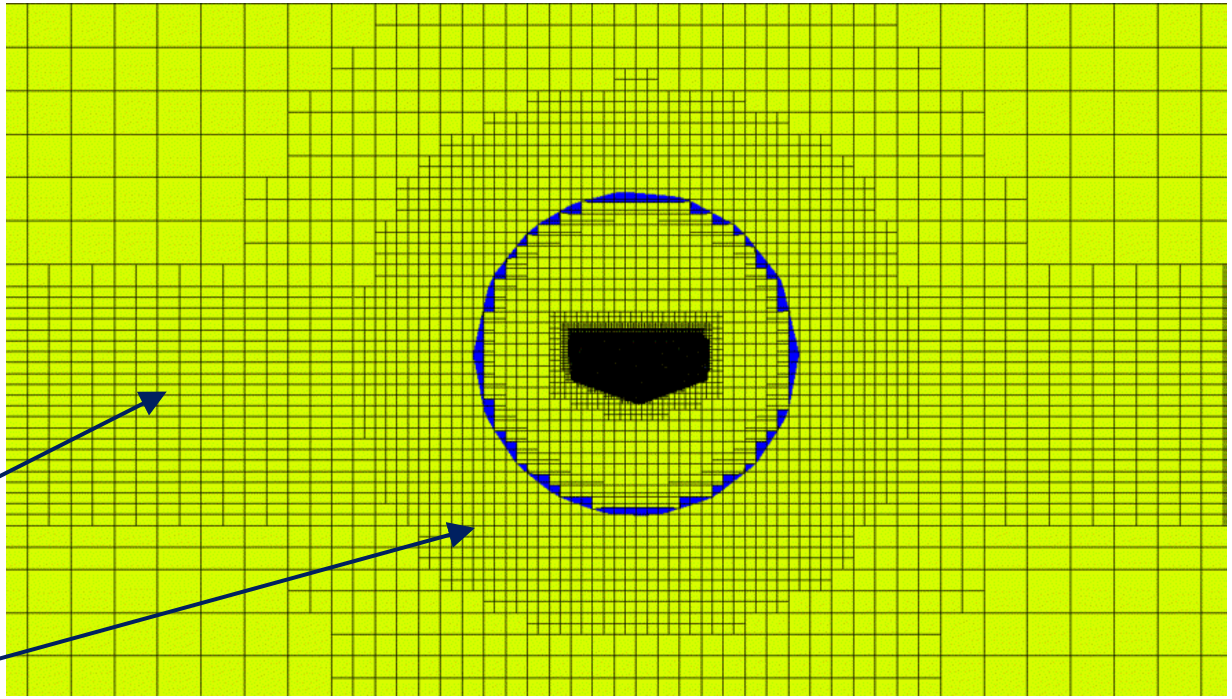
CFD Model – Meshing technique

Meshing for complex dynamic analyses

- Sliding mesh
- Mesh morphing
- Overset mesh

Mesh refinement

- Free surface
- Overset
- Flow around hull

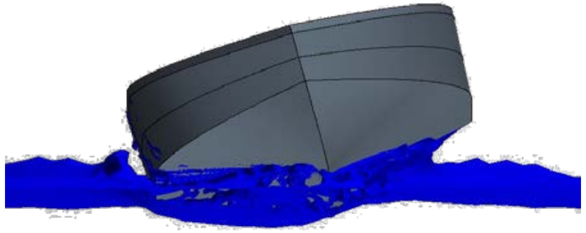


CFD Model – Solvers and post-processing

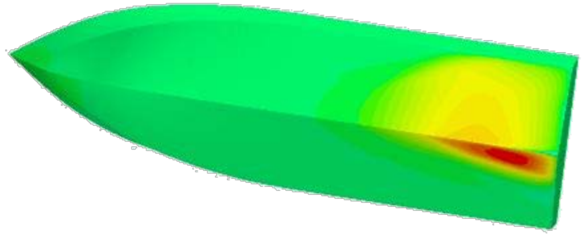
Solvers

- Volume of fluid (VOF)
- Implicit – Unsteady
- Inviscid

Post-processing



Free surface



Pressure on the hull

CFD Model – Verification

Convergence study

- Time step
- Mesh size

→ Select optimum:

accuracy vs CPU resources

* High Performance Computing (Flux): 12 cores – 4GB

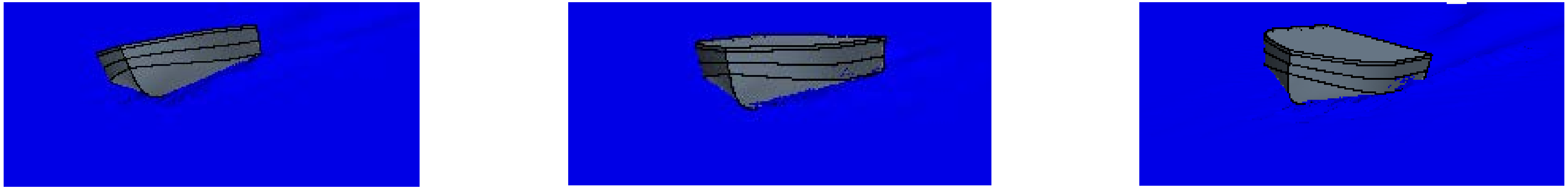
	Rigid body motion model	**DFBI model**
Time step	0.001 seconds	0.0025 seconds
Total number of cells	2.2 million	2.3 million
CPU time per simulation	25 hours	27 hours

Prediction of roll hydrodynamic coefficients

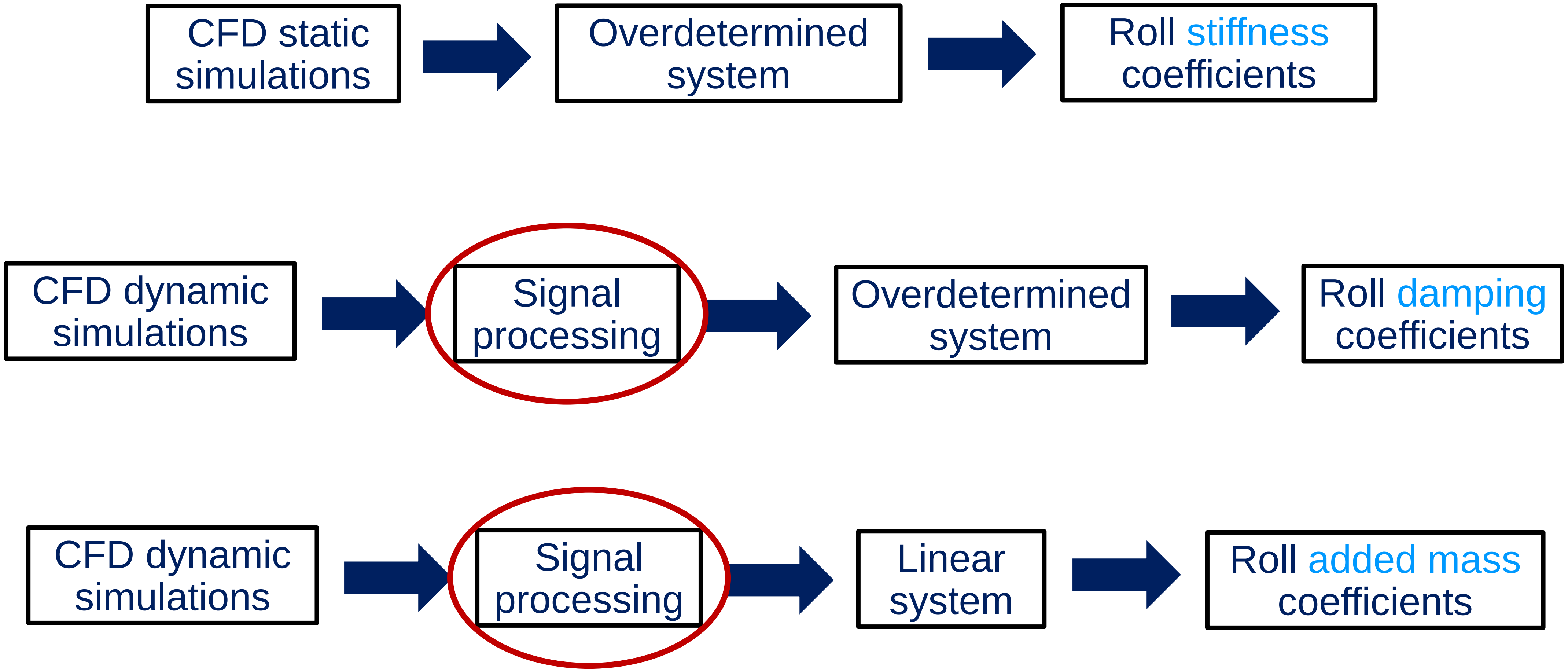
- Experiments
- 2d+t Simplification
- 3d CFD analysis

Rigid body motion (RBM) solver

- Prescribed roll motion
- Measure roll moment



Hydrodynamic coefficients - Procedure



Hydrodynamic coefficients – Discussion

- 3d-CFD close to experimental results
- Inaccurate prediction of inertial terms
- Complex to estimate higher order coefficients

Roll response prediction

- Dynamic Fluid Body Interaction (DFBI) solver

  Fluid pressure and shear forces

  Governing equations

  Motion of rigid body

- 3 Degrees of freedom:

  Heave, pitch and roll

* Porpoising and waves excitation

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Roll response – CFD results

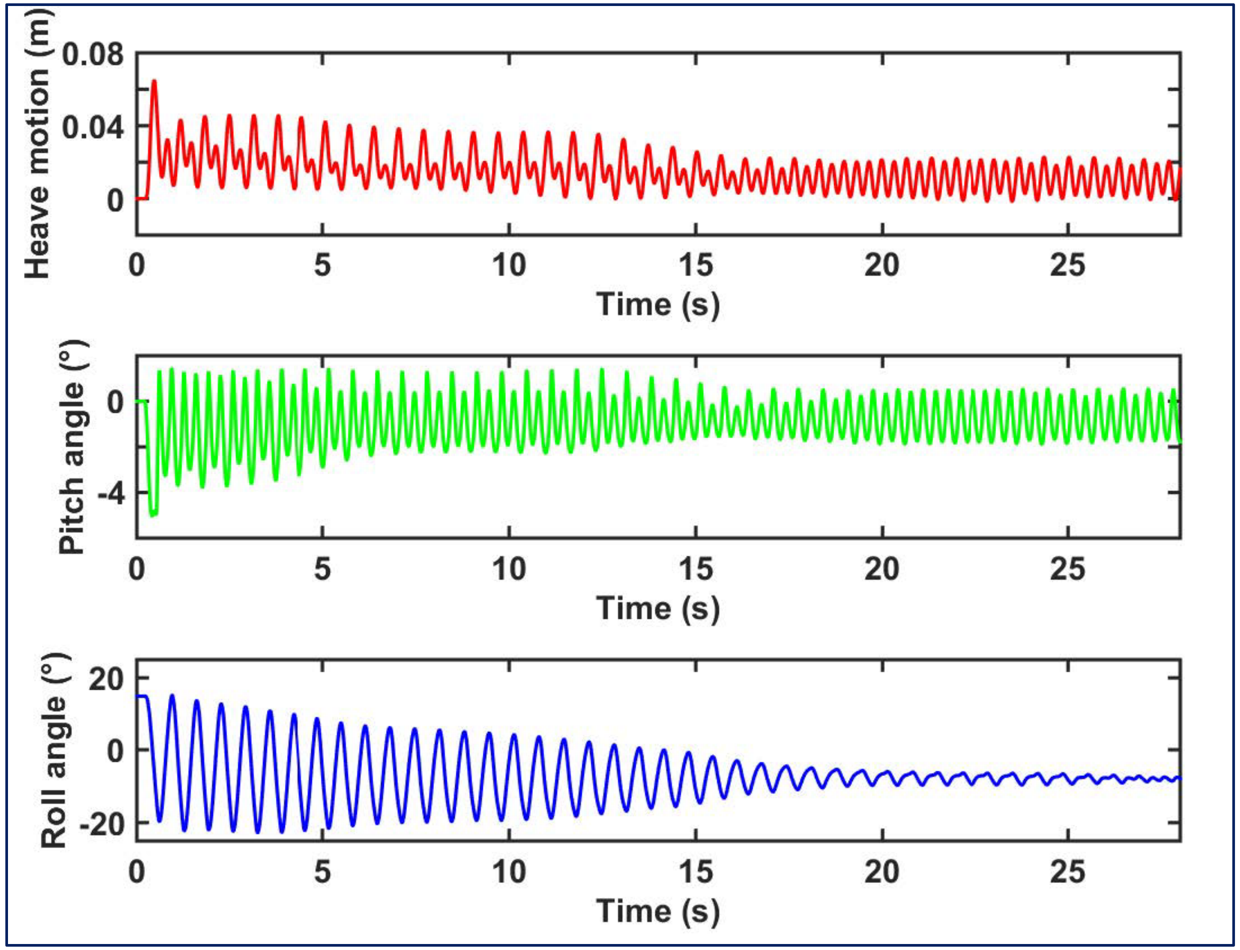
- Dynamic instabilities

  Excitation/natural frequency ratio 2:1

  Increase roll moment of inertia 40%

- Two-ways coupled between roll and heave/pitch

- Dynamic instability (chine walking)
  - Porpoising
  - Head waves



Roll response – Reduced order model

- Developed by Oscar Tascon (University of Michigan)

- Assumptions

  One-way coupled between roll and heave/pitch

  Similar treatment for porpoising or wave excitation

- Approach to obtain roll response

  Pitch and heave motion (Star-CCM+) → ODE 45 Algorithm (Matlab)

  Selection of hydrodynamic coefficients → ODE 45 Algorithm (Matlab)

Roll response – Comparison

- Reduced order model is not robust

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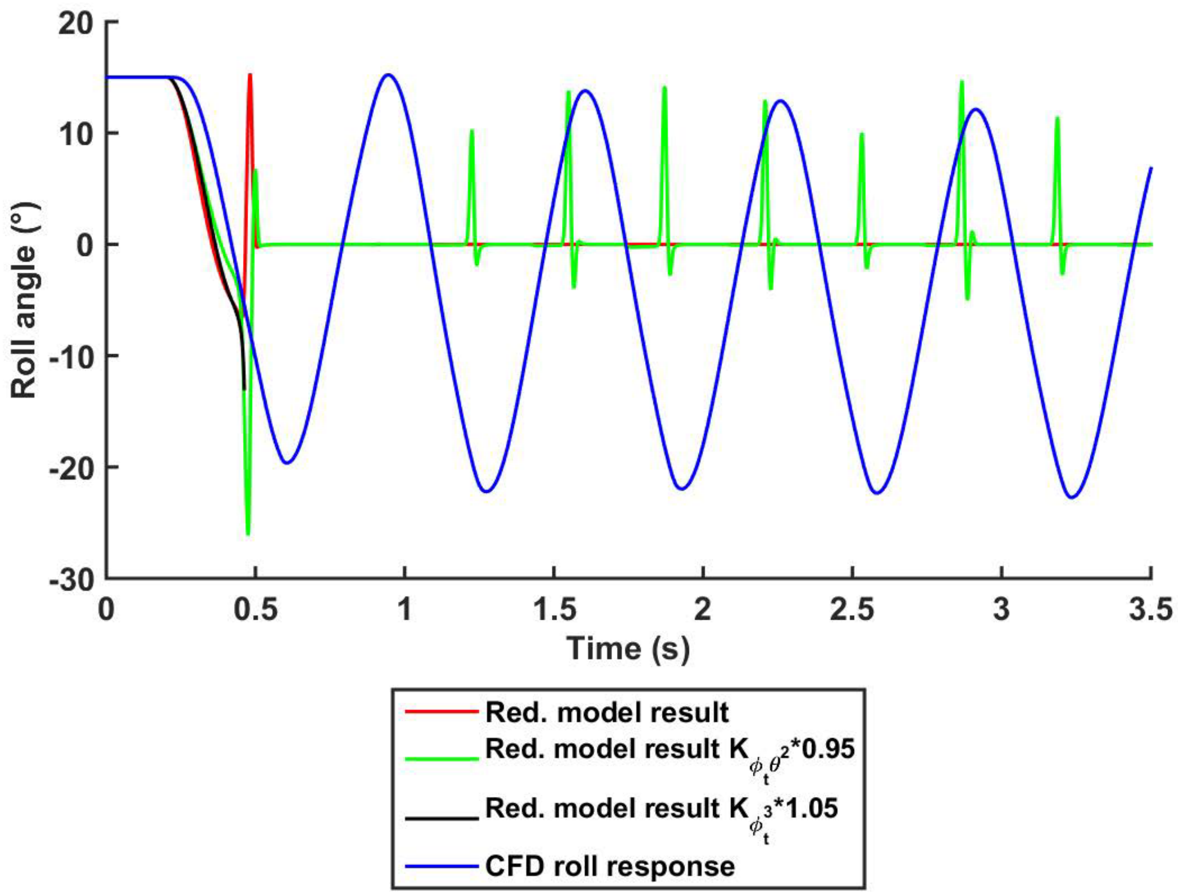
Hydrodynamic coefficients influence roll response

- Similar treatment for porpoising and waves
- One-way coupling between roll and heave/pitch



Conclusions

- CFD analysis provides close results to experiments

- Reduced order model is not robust enough yet

"Ship hydrodynamics of high speed vessels is a very complex issue; however, efforts should be made to predict dynamic instabilities"

(Prof. Armin Troesch)