UNIVERSITEIT GENT

FACULTY OF ENGINEERING AND ARCHITECTURE

Numerical simulation of a single Floating Point Absorber Wave Energy Converter using OpenFOAM®

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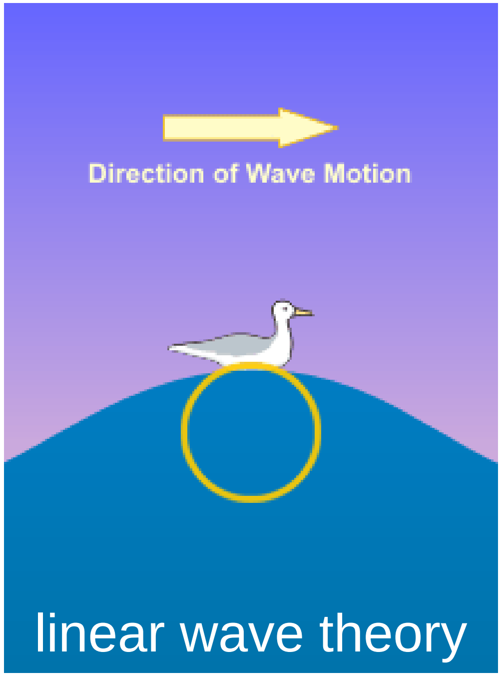
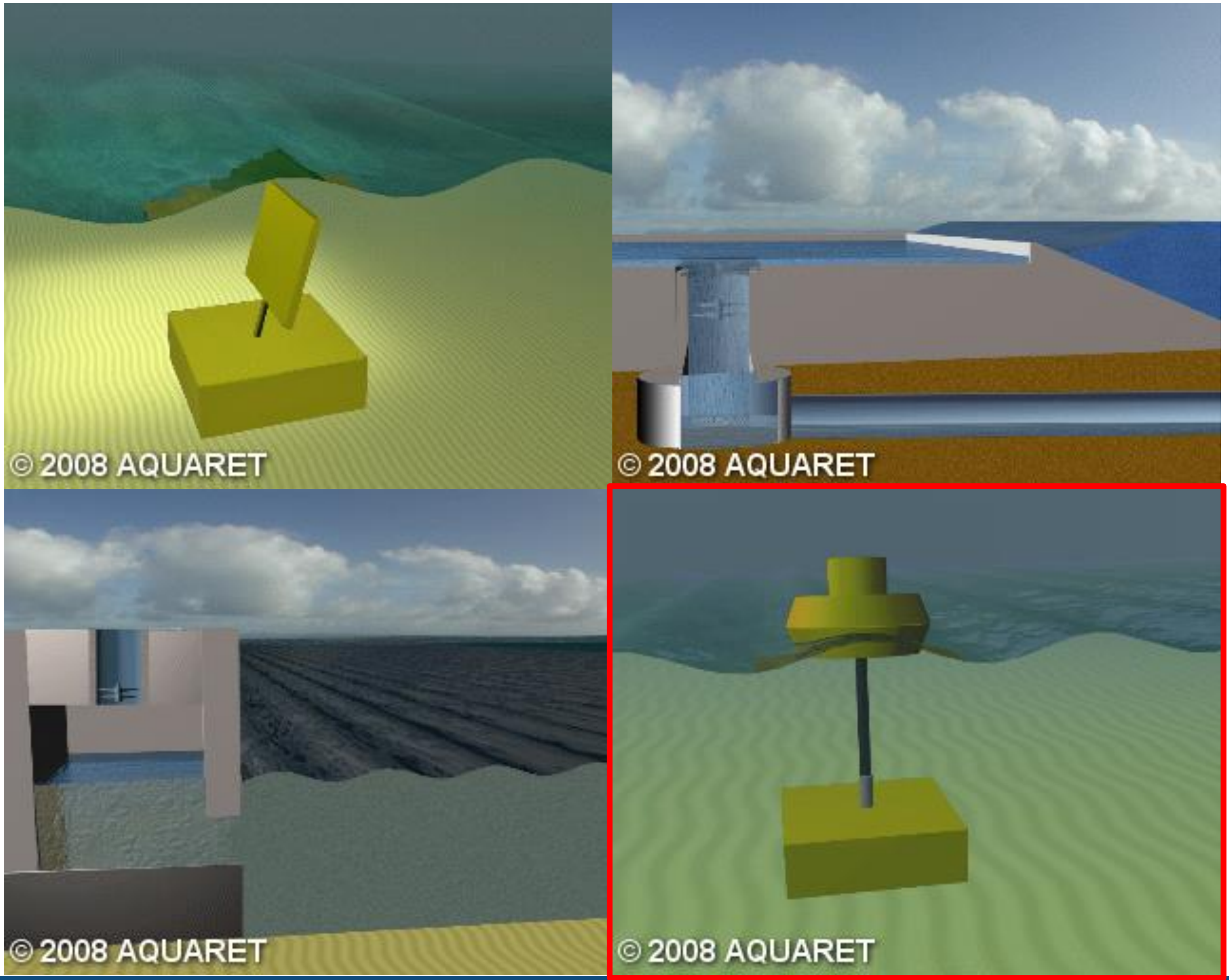
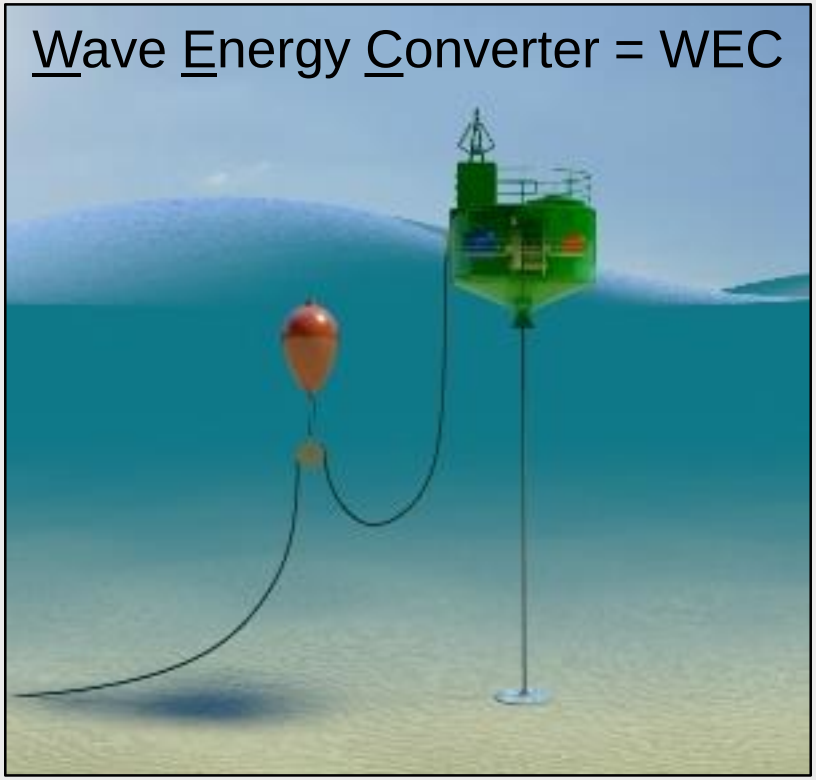
Wave energy converters





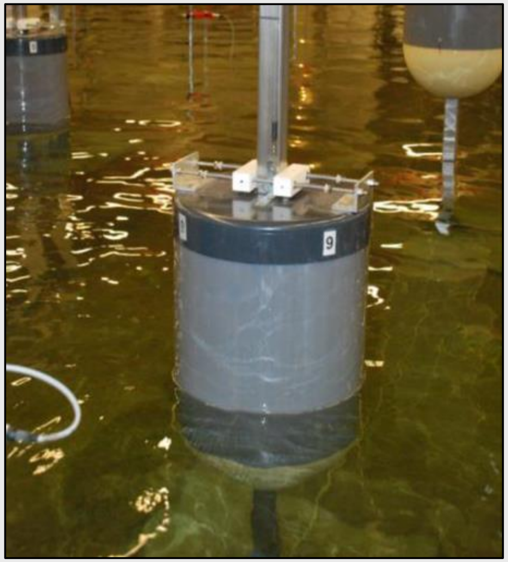
Overview of the presentation

- **Introduction**
  - Problem statement
  - Main goal
- **Models**
  - Experimental (wave flume)
  - Numerical (CFD)
- **Results**
  - Free decay test
  - Regular wave trains
- **Conclusions**



Introduction

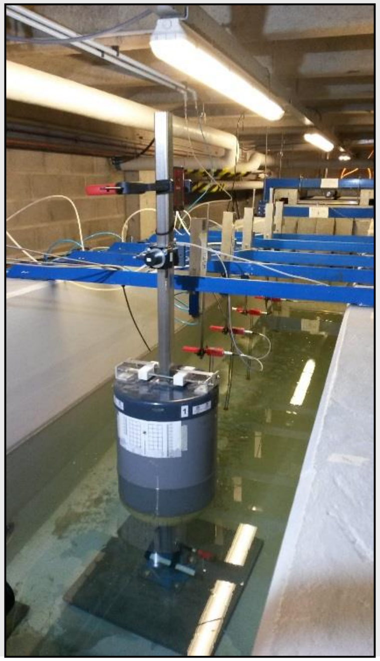
- **Problem statement**
  - Wave Energy Converters (WECs) are arranged in farms → farm effects
  - OpenFOAM®: solve the 3D viscous flow field and the response of a WEC in an incident wave field
  - Why CFD? → viscous forces, turbulent and nonlinear effects

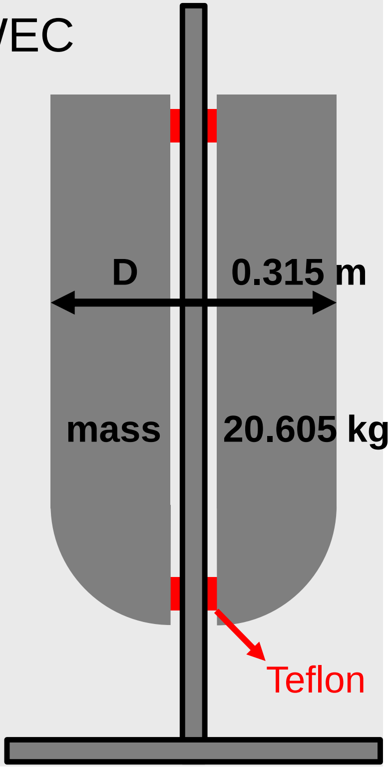


- **Main goal**
  - Accuracy and validation of the numerical model by using experimental data
  - Free decay test and regular wave trains

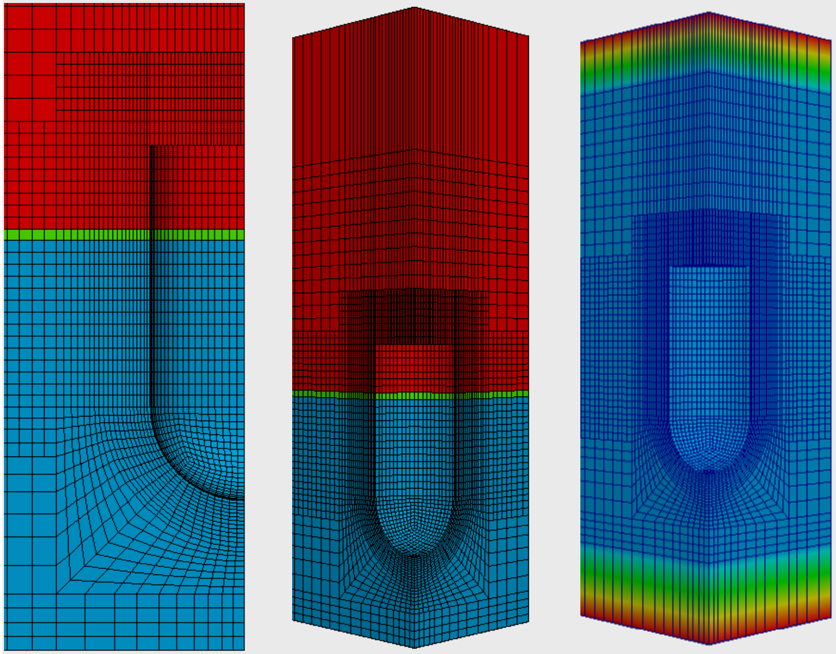
Models

- **Experimental (wave flume)**
  - Only heave motion
  - Shaft inside WEC





- **Numerical (CFD)**
  - No shaft inside WEC
  - What to do?



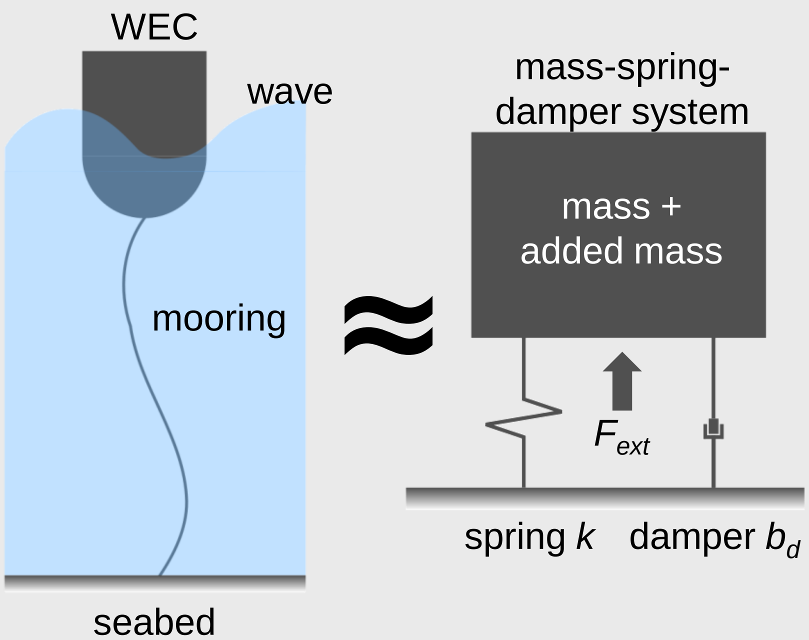
Motion of a floating body

- **CFD**
  - $F = m\ddot{z}$
  - $F_{ext} + \sum_j^{body}(p_j A_j + \tau_j A_j) - mg = m\ddot{z}$

- **Analytical**
  - $F_{ext} = (m + m_a)\ddot{z} + b_d\dot{z} + kz$
  - $F_{ext} \underline{- m_a\ddot{z} - b_d\dot{z}} \; \underline{- kz} = m\ddot{z}$

radiation (generation of waves) — restoring force

  - m, m_a, b_d and k
    → geometry-dependent



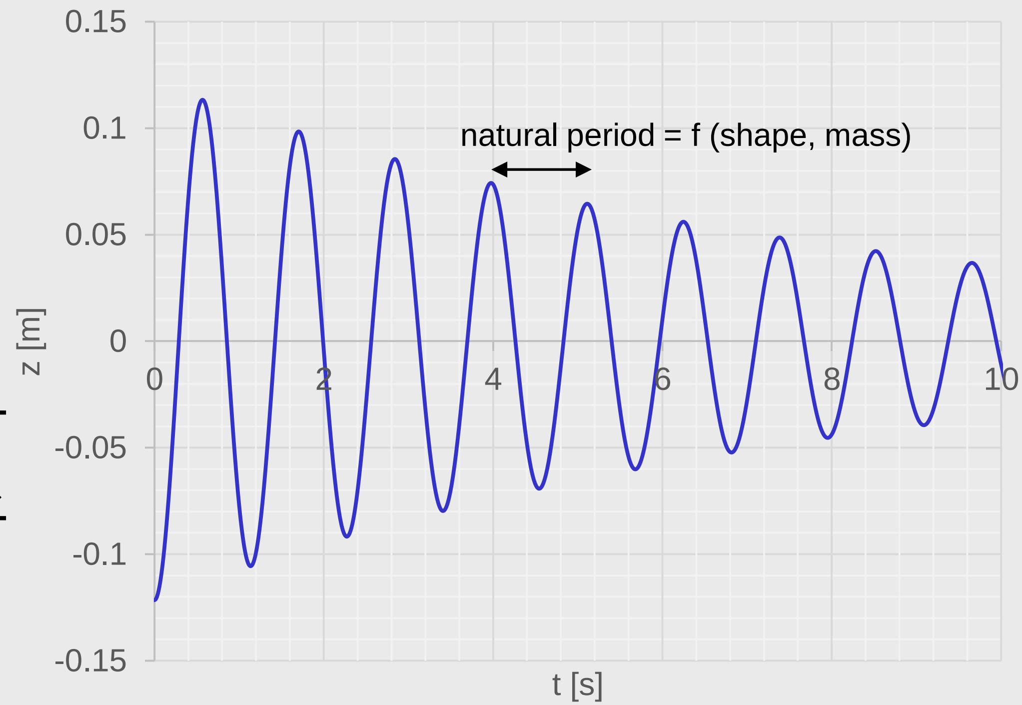
Numerical model (CFD)

experimental hydro. parameters = numerical hydro. parameters

experimental geometry ≠ numerical geometry

- Natural period
  - Water-plane area (A_w)

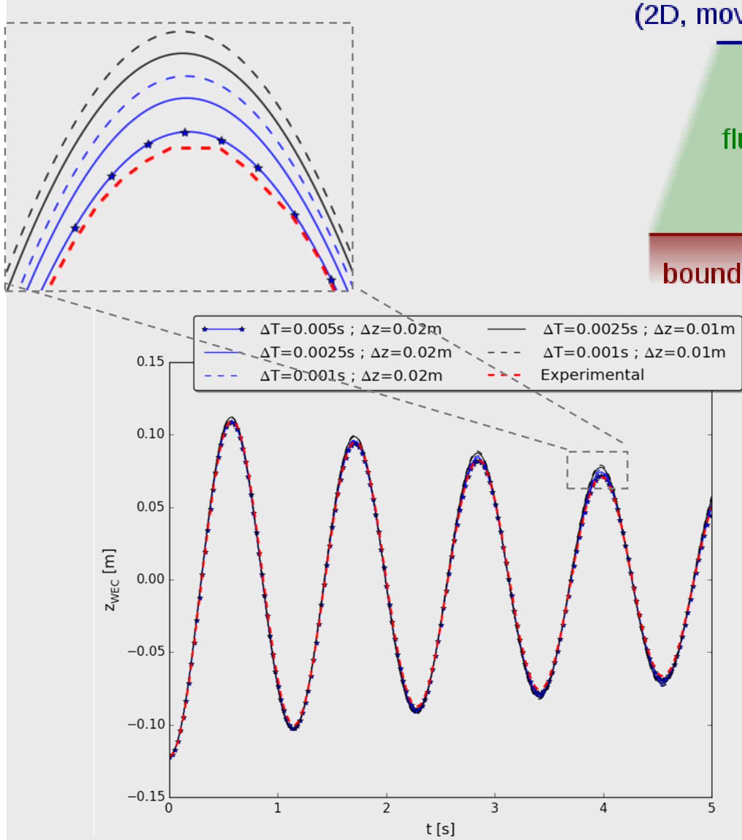
  - Mass (m)
  - $$T_n = 2\pi\sqrt{\frac{m + m_a}{\rho g A_w}}$$
- Use a modified mass!

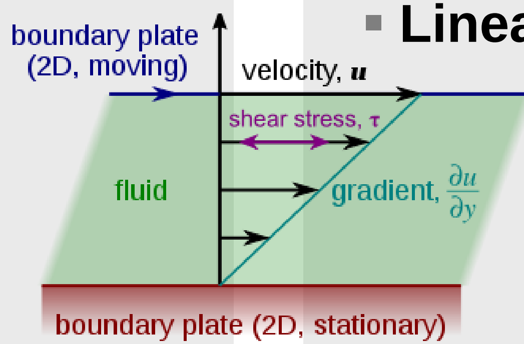


Results: free decay test

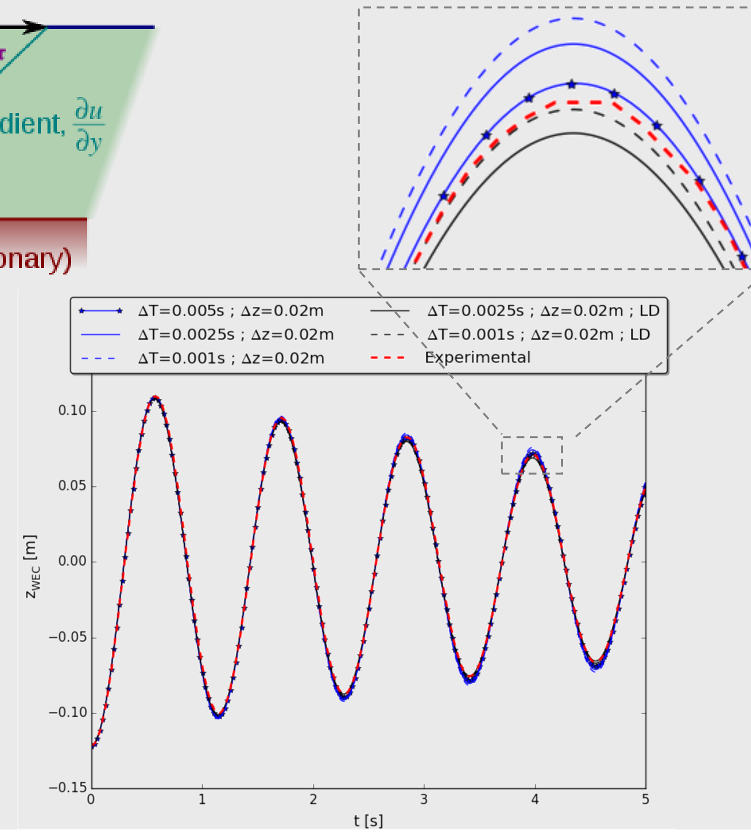
$$c = b_{d,target} - b_{d,num}$$

- **Modified mass**



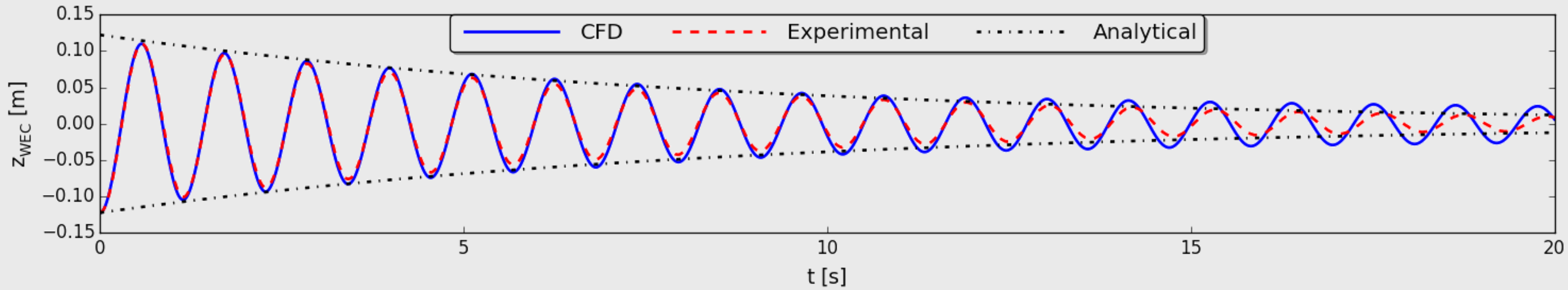


- **Linear damper (*F* = -*c*·*v*)**

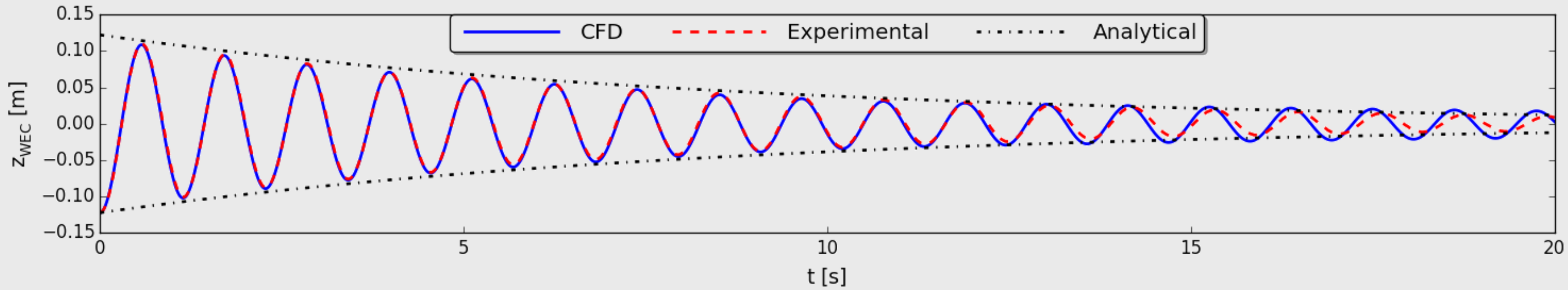


Results: centre of mass

- **Free decay test**
  - No linear damper



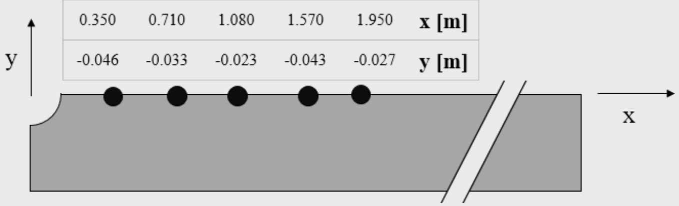
  - With linear damper

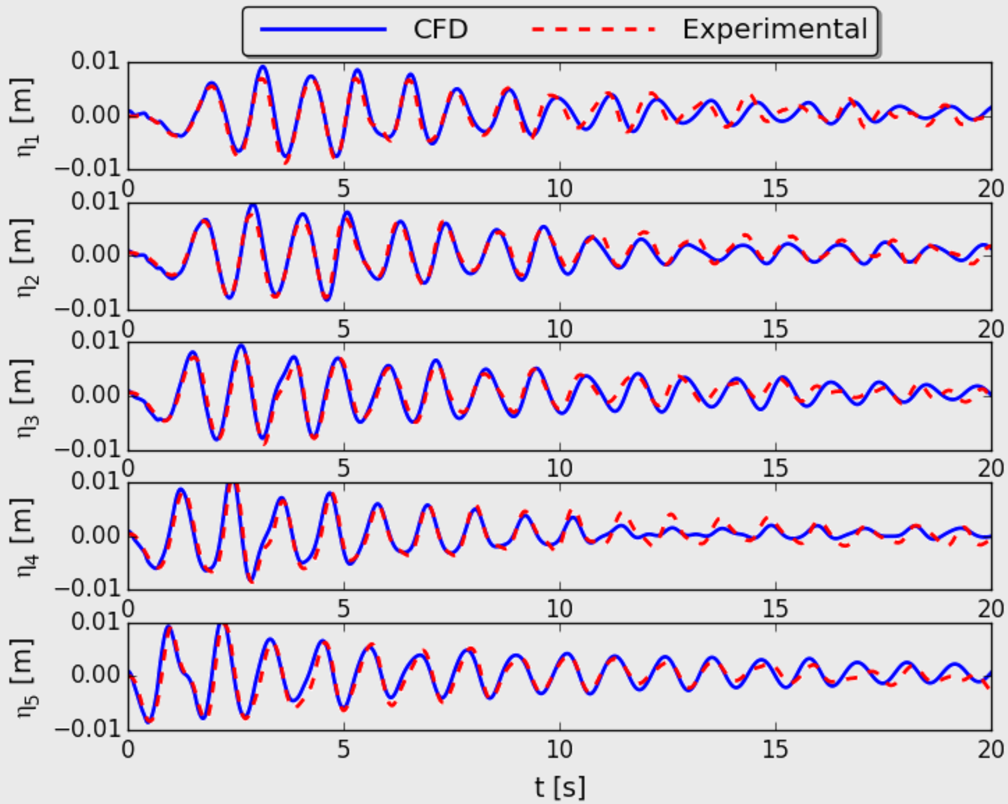


Results: radiated wave field

- **Free decay test**
  - Motion of the buoy generates waves
  - Radiated wave field
  - Important for the interaction between multiple WECs

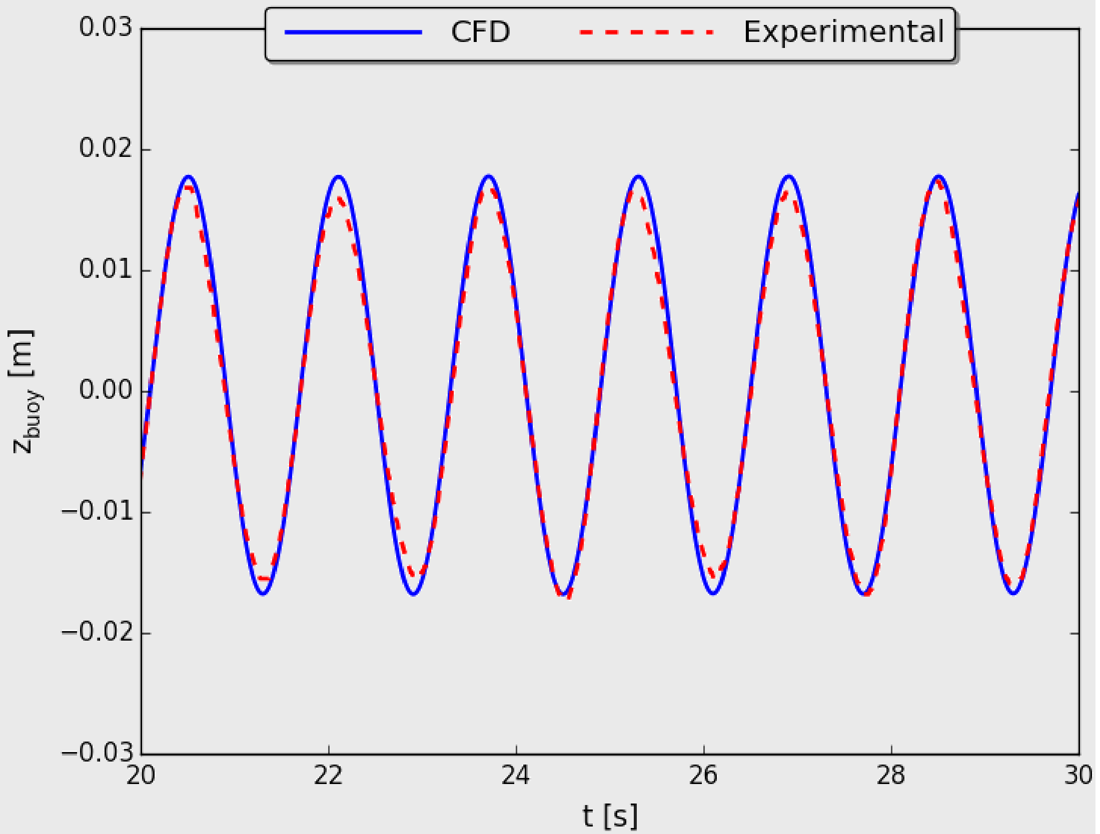
5	4	3	2	1	η_i
0.350	0.710	1.080	1.570	1.950	x [m]
-0.046	-0.033	-0.023	-0.043	-0.027	y [m]





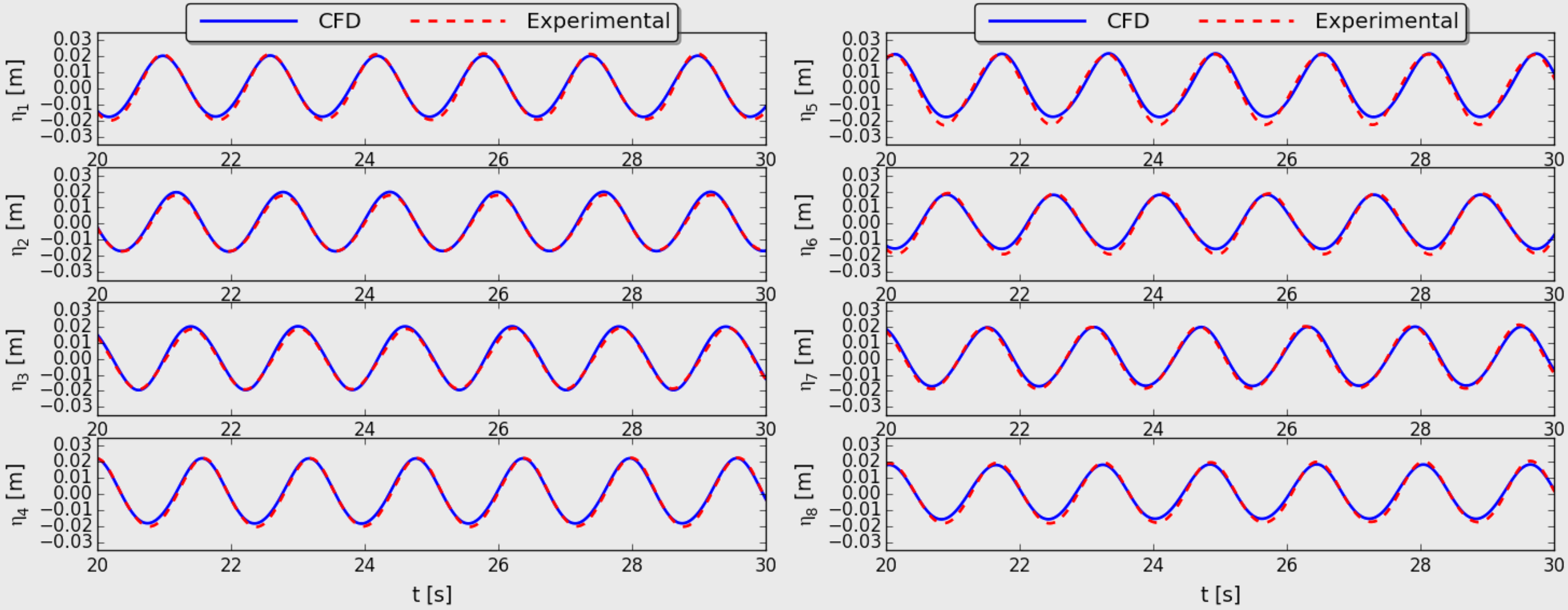
Results: centre of mass

- **Regular wave train**
  - H = 0.04 m
  - T = 1.60 s
  - d = 0.70 m
- **Courant limit of 0.3 instead of fixed time step**
- **Amplitude WEC's motion ~ amplitude waves**



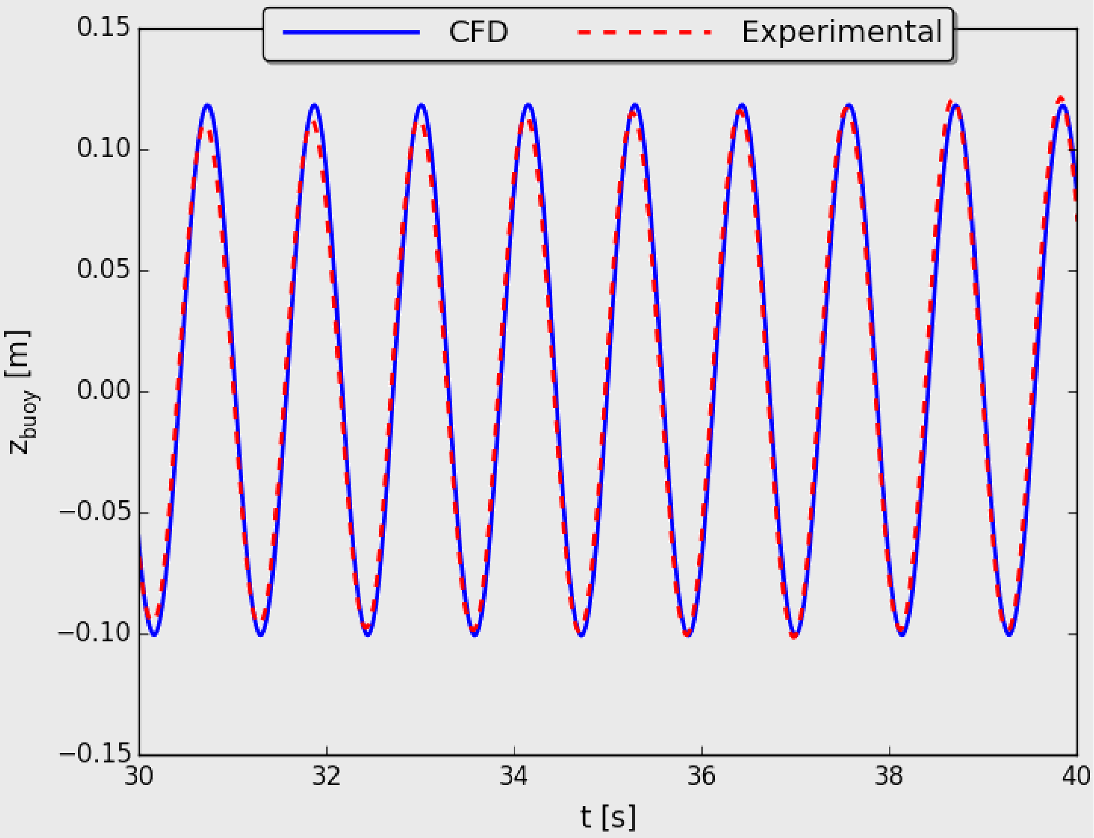
Results: perturbed wave field

- **Regular wave train**
  - H = 0.04 m ; T = 1.60 s ; d = 0.70 m
  - Wave height remains constant for all the wave gauges



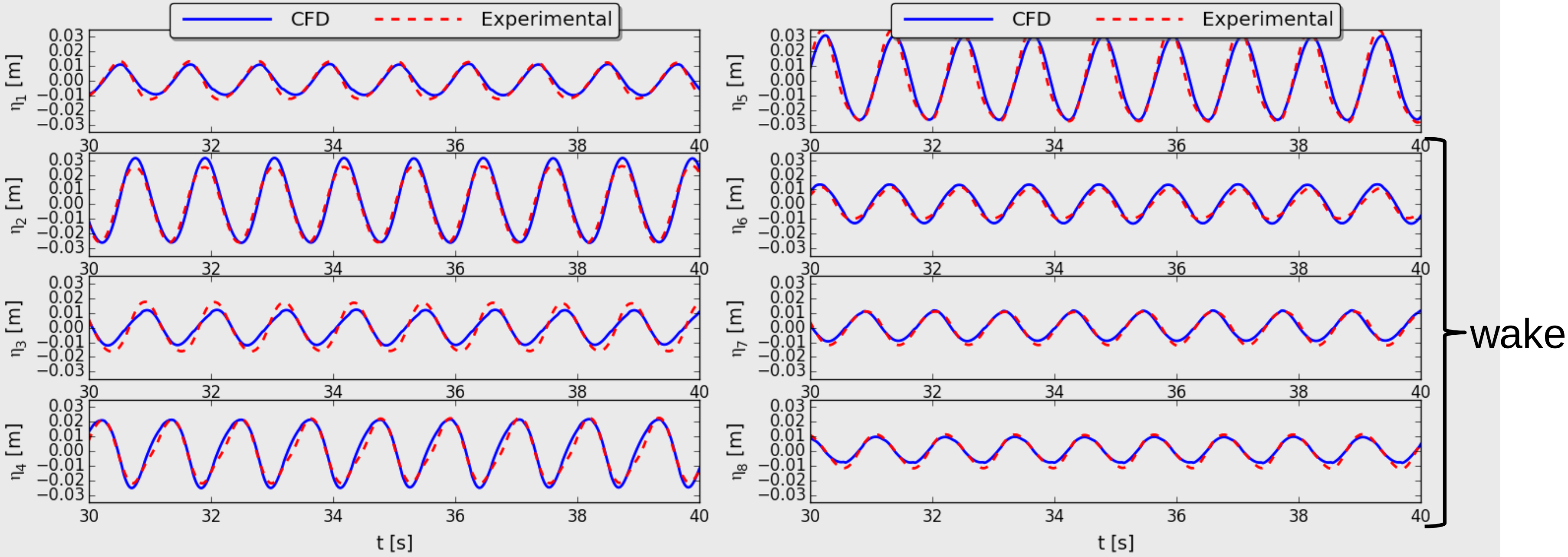
Results: centre of mass

- **Regular wave train**
  - H = 0.04 m
  - T = 1.14 s
  - d = 0.70 m
- **Amplitude WEC's motion >> amplitude waves**
- **Resonance!**

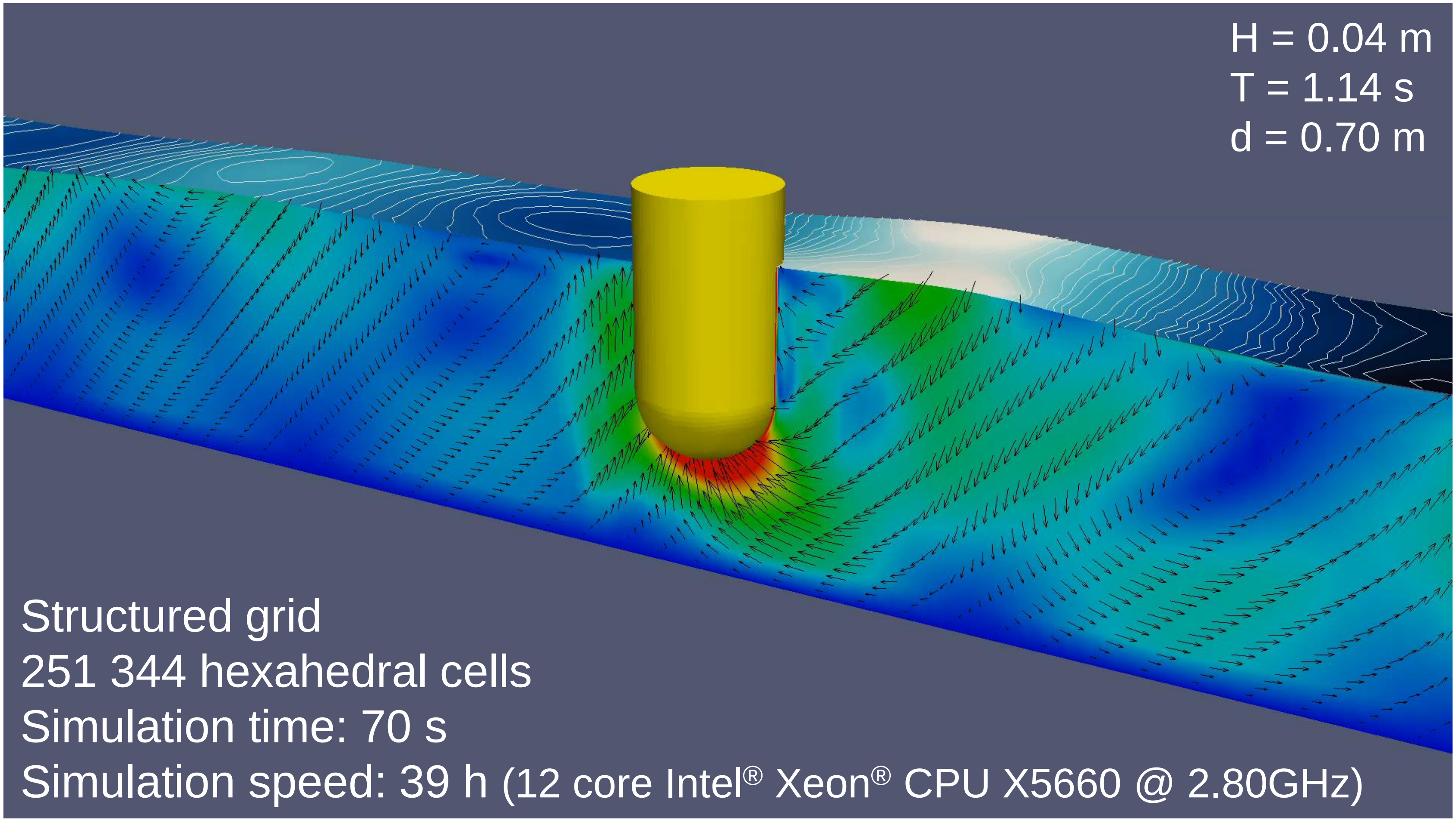


Results: perturbed wave field

- **Regular wave train**
  - H = 0.04 m ; T = 1.14 s ; d = 0.70 m
  - Wave height increases in front of the WEC and decreases behind the WEC



Results: 3D flow field during resonance



Conclusions and further research

- **CFD modelling** of a single heaving WEC in a **numerical wave tank** using **OpenFOAM®**
- Model **validated** against experimental data
- **Free decay test** to obtain motion of WEC and radiated wave field
- Response of a single WEC subjected to a **regular wave trains**
- Both tests: results were very **comparable** to experimental data
- **Further research**
  - Importance of viscous forces and non-linear effects
  - Including turbulent effects

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