Research to reduce the risk & uncertainty in marine energy development

Validated mooring responses

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Background

“We know all about moorings”

- Moorings have long been developed for their application to vessels station keeping and offshore floating structures (FPSO’s/ mooring and offloading buoys ..).

However

- Their design is almost completely concerned with “station-keeping”.
- The response period of the mooring system is designed to be far from that of the wave excitation force on the floating structure.
- The purpose is generally to minimize the response of the floating structure.

Challenge

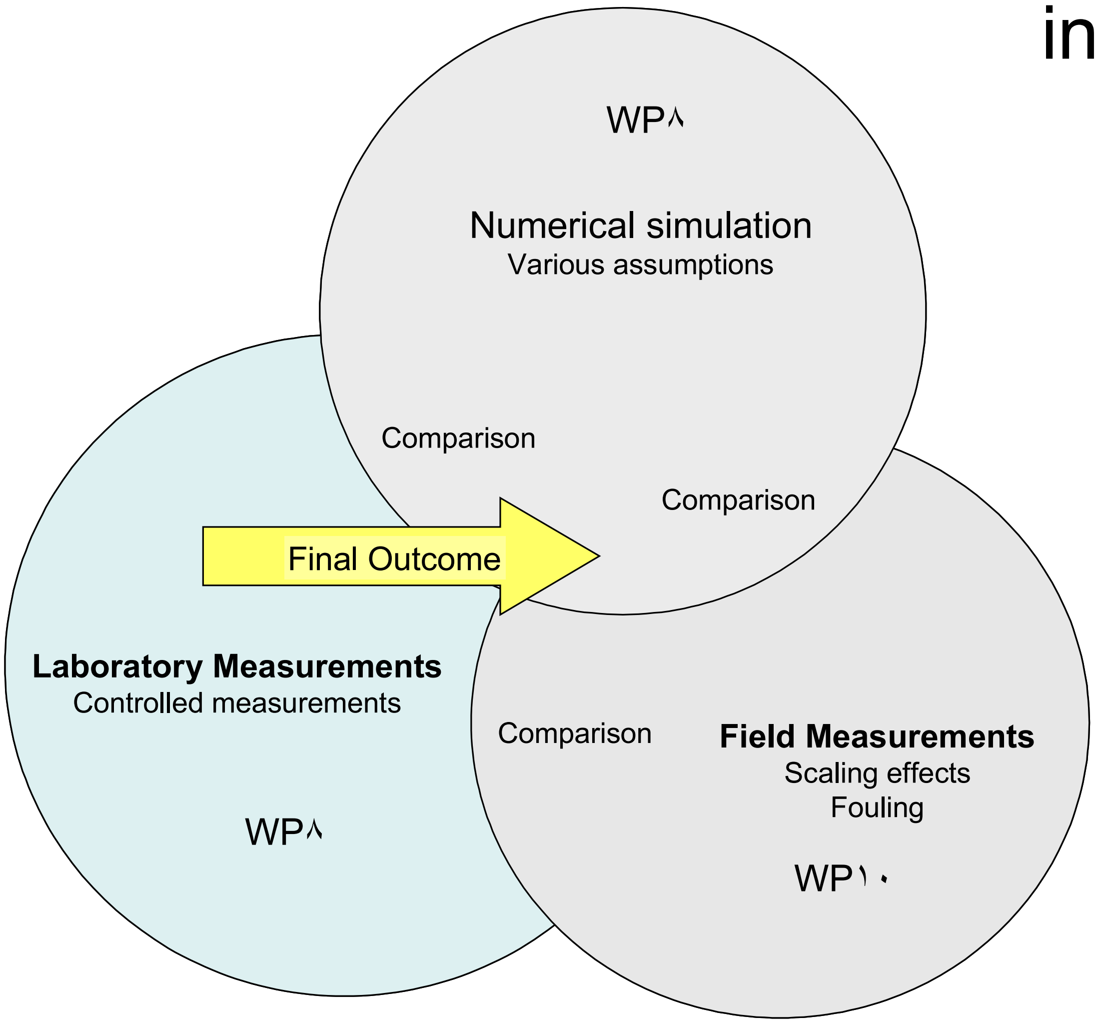
- How (if necessary) must we adapt mooring analysis to improve it’s application to floating wave energy converters?
- For a WEC, the mooring:-
  - MUST provide station keeping under extreme wave and current conditions.
  - *WILL have a strong influence on the structure motions and MAY affect the power conversion of the particular devices.*
  - *“Active” mooring systems to improve energy conversion efficiency have been suggested.*

The objectives

- To extend knowledge of the application of mooring design to the restraint of floating marine energy converters.
  - perform experimental tests at various scales and derive hydrodynamic parameters, particularly damping.
  - compare with previous work and with numerical models.

Supergen Approach

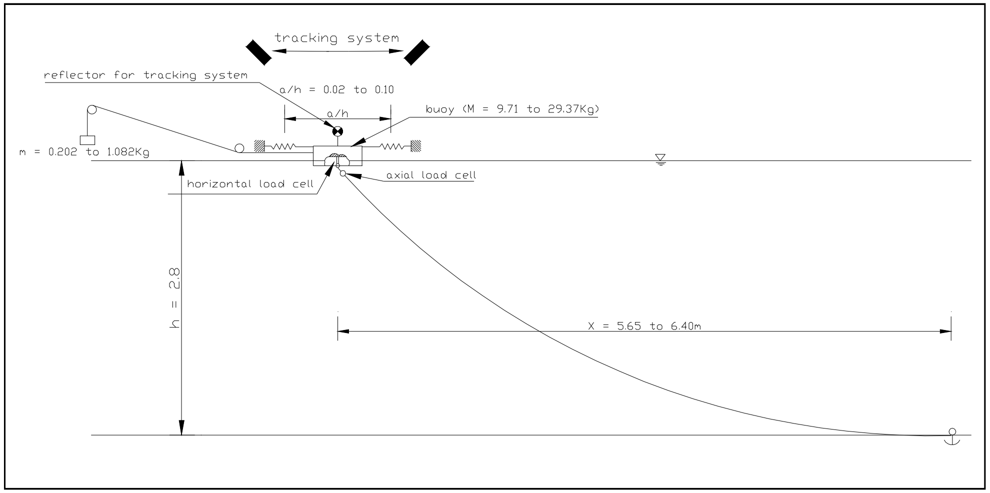
integrated research!



Laboratory tests

- A carefully designed series of laboratory tank tests have been undertaken to determine dynamic response and damping coefficients:
  - Extinctions tests
  - Harmonically (sinusoidal) driven tests

Laboratory tests

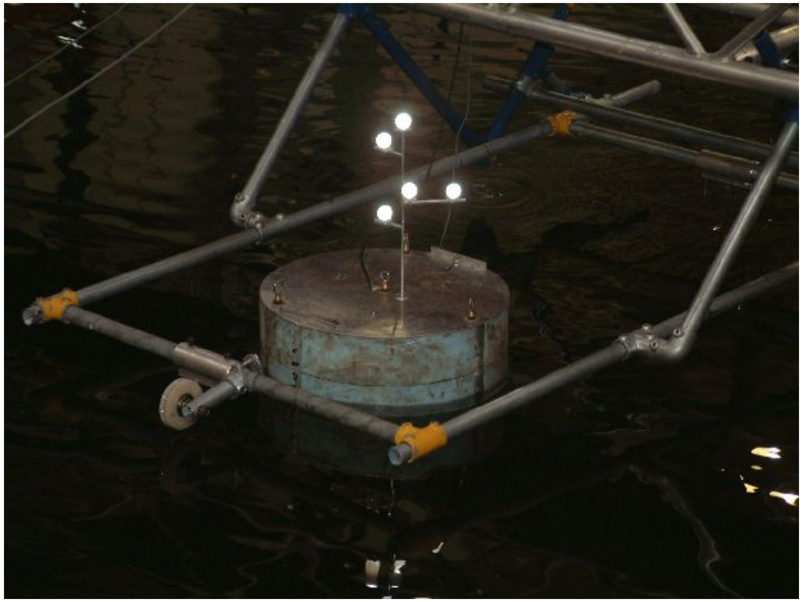


Non-dimensional parameter:

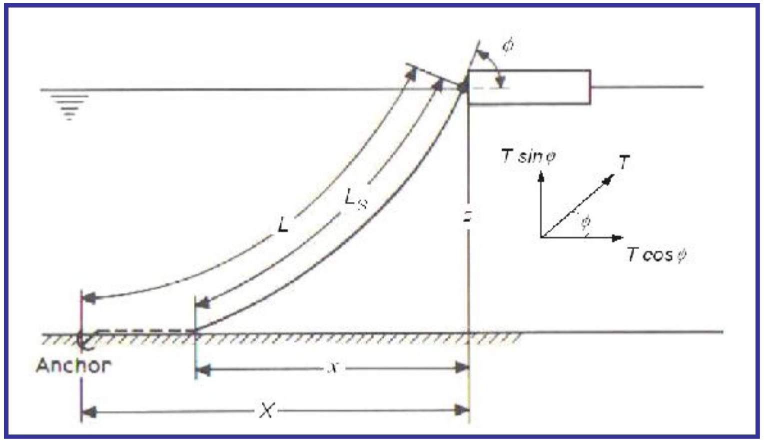
- EA/wL = 78500
- L/h = 2.5
- a/h = 0.02, 0.04, 0.05
- D/h = 8.9 10^{-4}

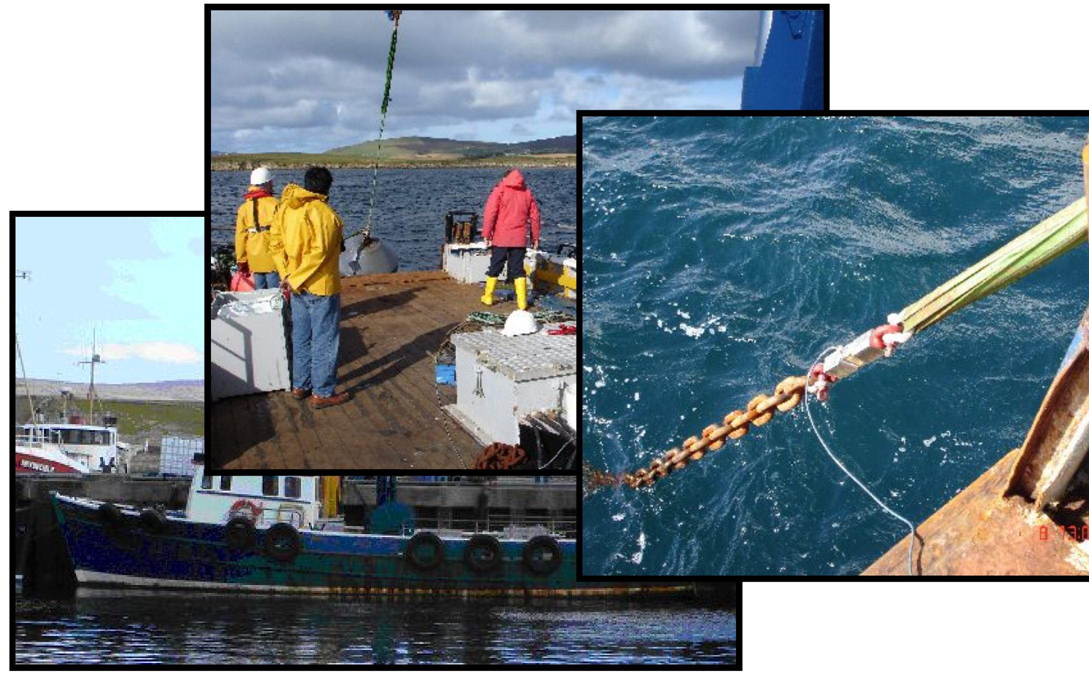
Mooring Arrangement

- Single catenary chain D = 2.5mm
- Chain length L = 6.98 m
- Submerged weight w = 1.036 N/m
- Water depth h = 2.8 m
- Axial stiffness AE = 562.5kN



Full scale mooring line tests





<u>Mooring Arrangement</u>

- Single catenary chain D = 22mm
- Chain length L = 80 m
- Submerged weight w = 75.12 N/m
- Water depth h = 24.4 m
- Axial stiffness AE = 43,560kN

<u>Non-dimensional parameter:</u>

- EA/wL = 7248
- L/h = 3.3
- a/h = 0.02
- D/h = $9.0\ 10^{-4}$

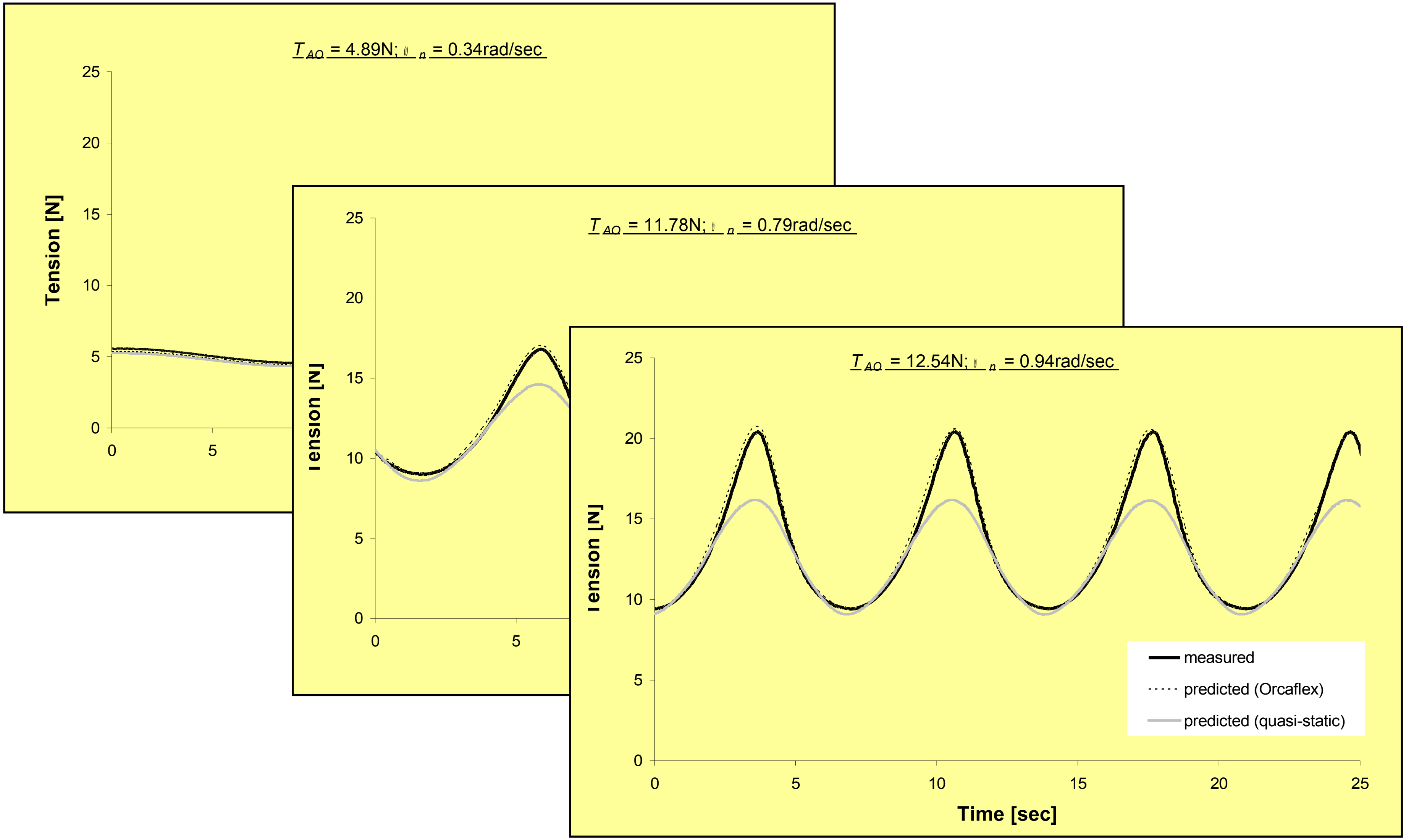
Numerical model comparison

- Comparison with physical tests
  - Ran comparisons with the laboratory scale tests
  - Investigated dynamics and damping results
  - Will repeat this with full scale results this year

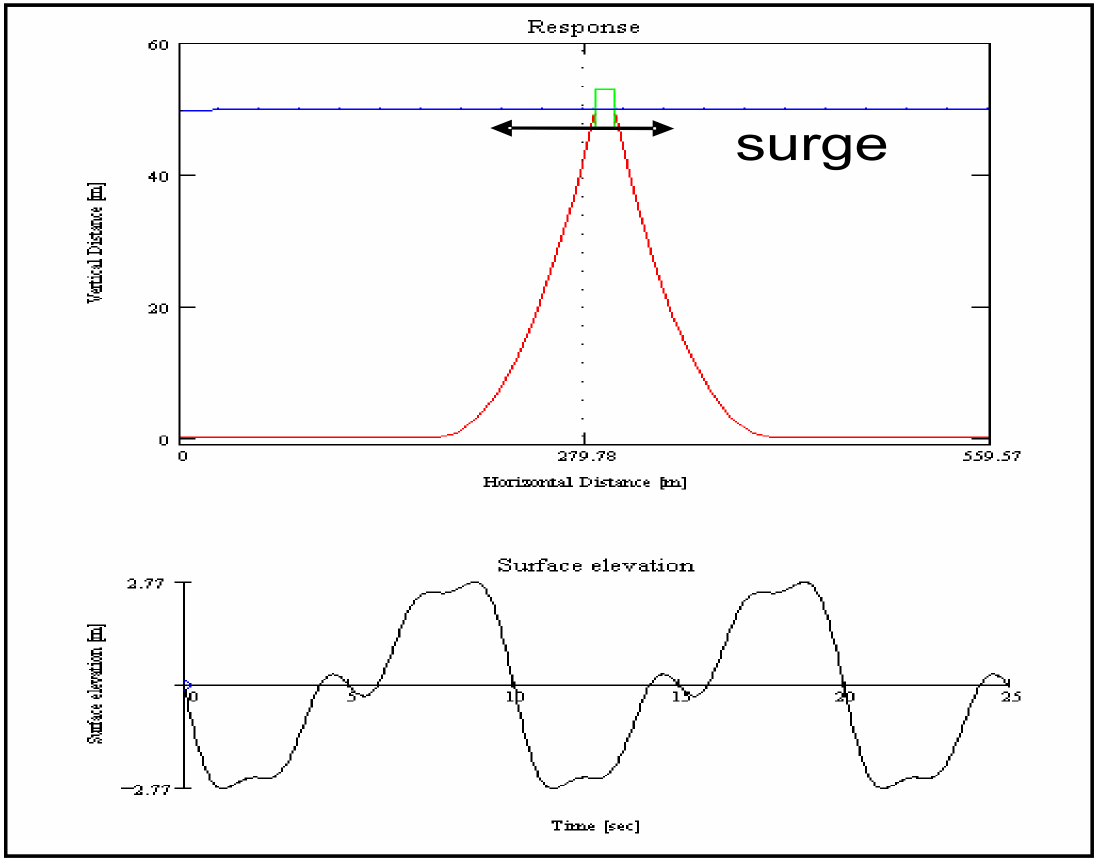
Many thanks to Orcina Ltd for the supply and their support in using Orcaflex

Important Results and Conclusions

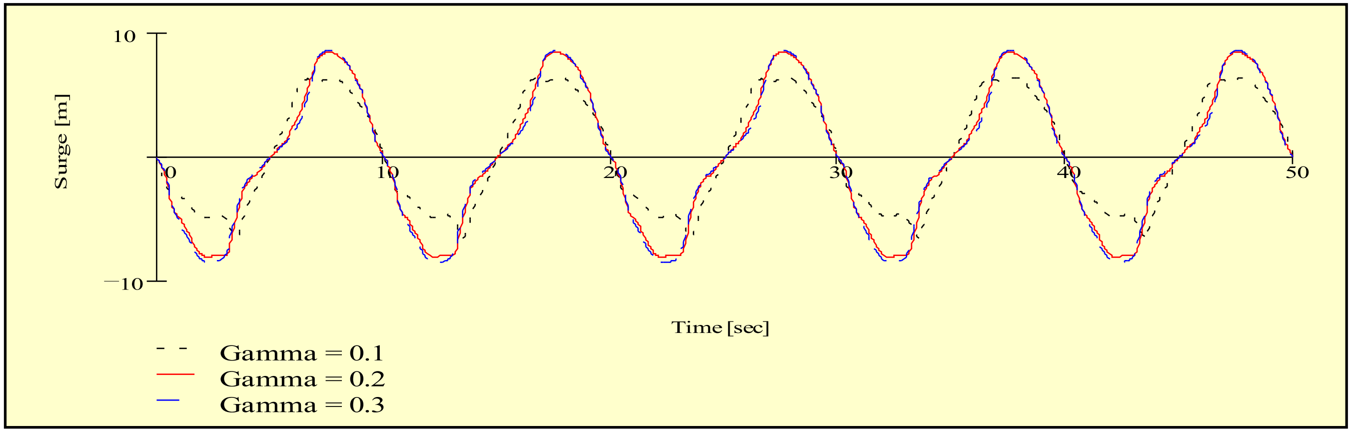
Effect of increasing surge on peak tension

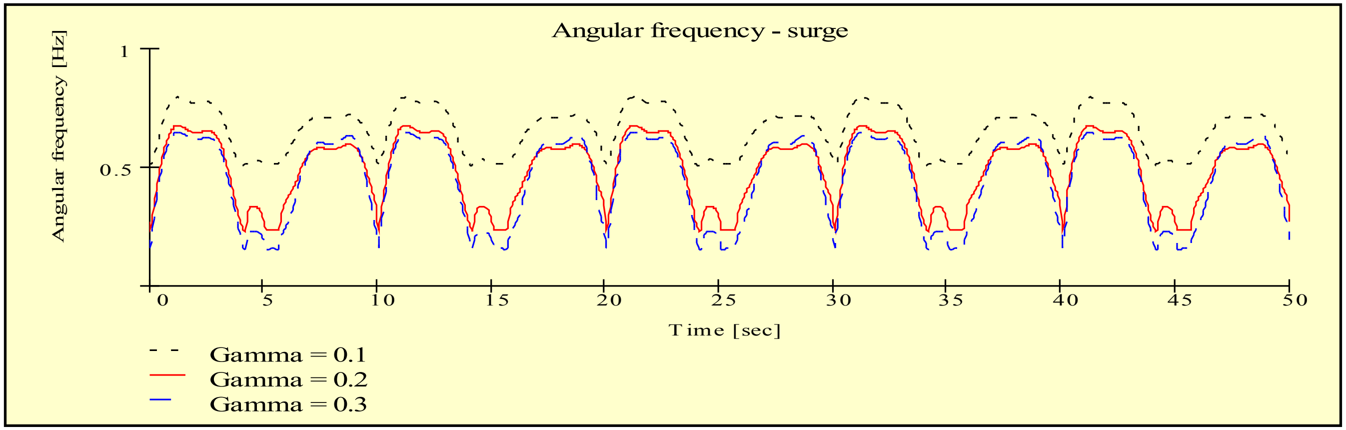


Effect of increasing surge on frequency



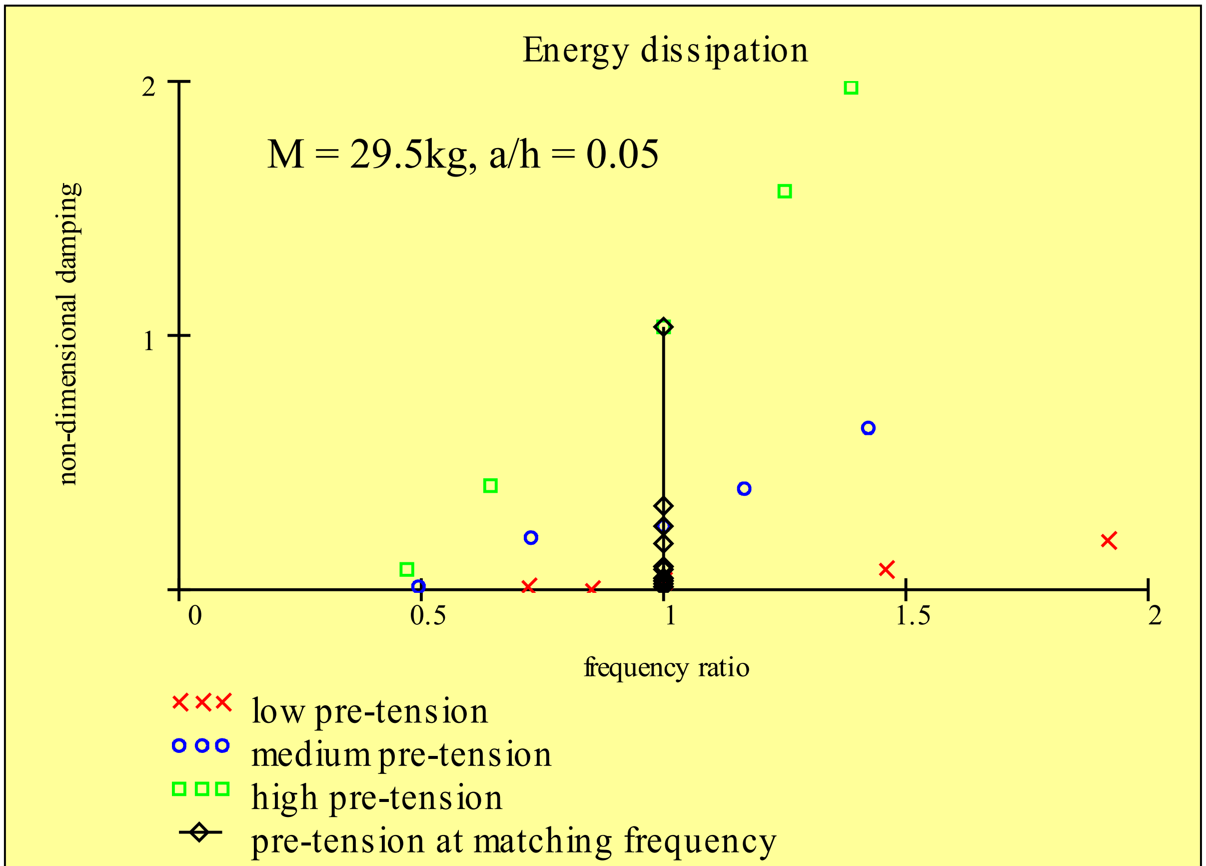
Effect of increasing surge on frequency





Variation in damping with frequency ratio

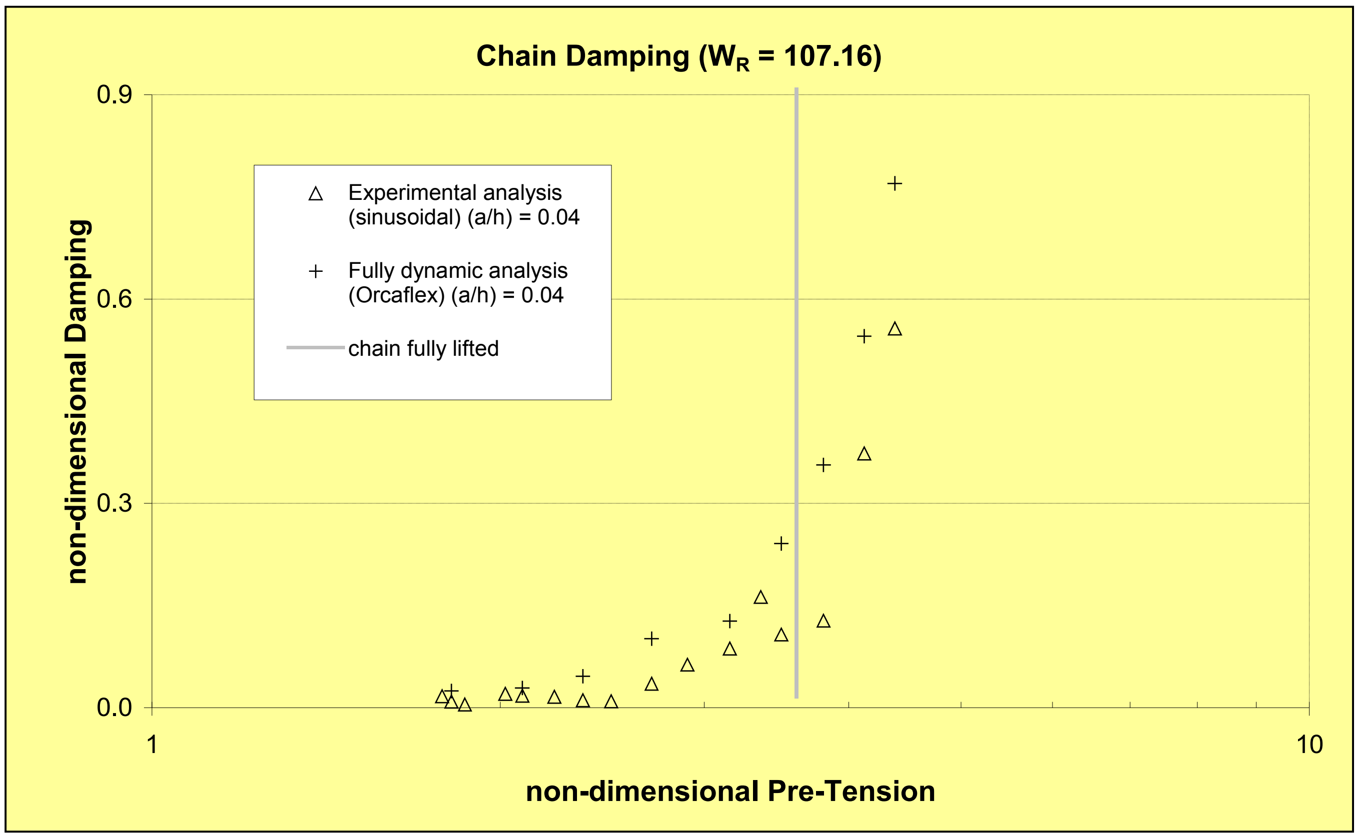
Damping values measured from horizontal pre-tension and surge motion for pre-tension with non-matching natural frequencies.



- Damping increases with pre-tension
- Damping increases approximately linearly with frequency ratio

Comparison between experimental and numerical results

Horizontal damping values as calculated from indicator diagrams laboratory tests and from corresponding dynamic simulation (Orcaflex).



Achievements - Design

- For “motion dependent” WECS the mooring will be subject to many more fatigue cycles.
- If the surge is also large (due to design or extreme wave and current conditions – wave groups?) then significant cycles will occur at large dynamic loads.
- Water depth and tidal variation will be more important
- Effects of dynamics must be considered:
  - “top-end” dynamics of mooring.
  - Frequency changes and their effect on damping.
- For a WEC the “quasi-static” approach is often not appropriate, and a fully dynamic analysis should be performed, early in the design cycle.

Achievements - Experimental Method

- Development of test methodology to measure response and damping both at full-scale and lab-scale.
- Designed and proved specific load cell and position measurement system for full-scale.
- Lab and full-scale results now being integrated with a numerical model.
- Recommend using “driven” tests at lab scale to establish damping characteristics rather than conventional “extinction” tests.

Achievements

- Numerical Results
  - To date the numerical model has agreed well with laboratory results. Require more accurate measurements at full-scale for an equitable comparison.
- Arrays – a thought!
  - to utilise the sea space effectively one would wish for “tight” packing. In this case a catenary moorings can be operating at the “high end” of the surge, where dynamic effects are most prominent.

=> de-couple “wave active” devices from mooring by use a taught mooring.

Year 4 (and beyond)

- Improved instrumentation for next full-scale tests.
- Examination of the effect of fouling on damping coefficients.
- Further full-scale tests on different mooring line materials.
- Comparison with other model WEC data would be extremely beneficial!
- Design of moorings for arrays and wave-current interaction.

Thank You