Research to reduce the risk & uncertainty in marine energy development

Time- and Frequency-Domain Modelling

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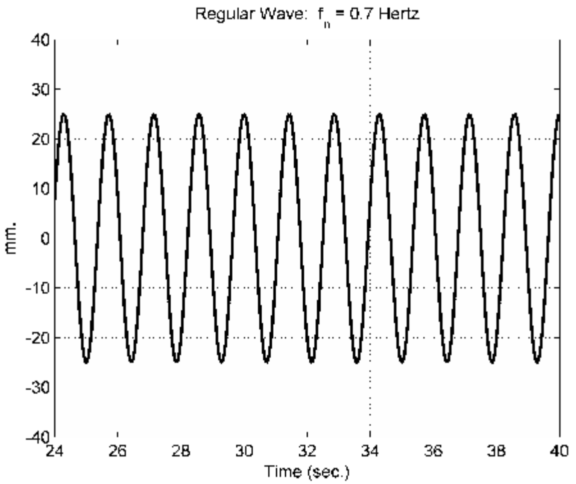
WHAT?

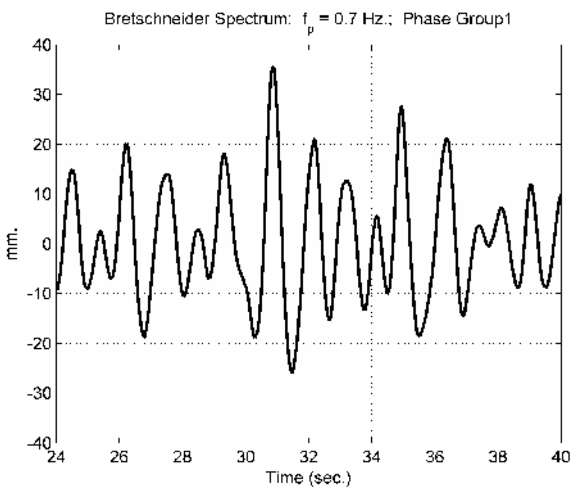
Frequency-Domain:

- Sinusoidal Waves
- Algebraic Equations
- ‘Steady-State’ Solution

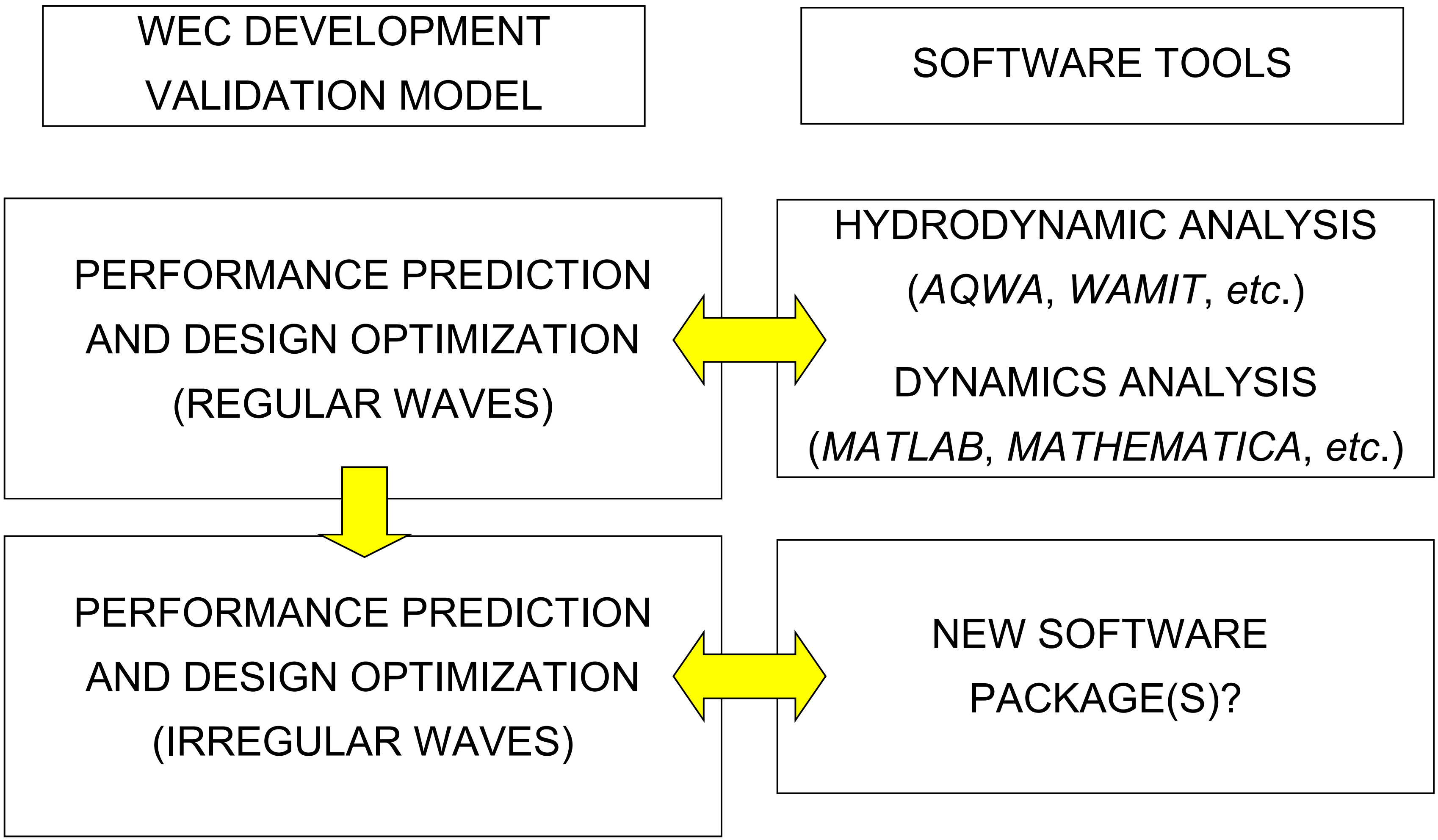


Time-Domain:

- Non-Sinusoidal Waves
- Differential Equations
- Transient Solution



WHY?


WEC DEVELOPMENT VALIDATION MODEL
SOFTWARE TOOLS
PERFORMANCE PREDICTION AND DESIGN OPTIMIZATION (REGULAR WAVES)
HYDRODYNAMIC ANALYSIS (*AQWA*, *WAMIT*, *etc.*)
DYNAMICS ANALYSIS (*MATLAB*, *MATHEMATICA*, *etc.*)
PERFORMANCE PREDICTION AND DESIGN OPTIMIZATION (IRREGULAR WAVES)
NEW SOFTWARE PACKAGE(S)?

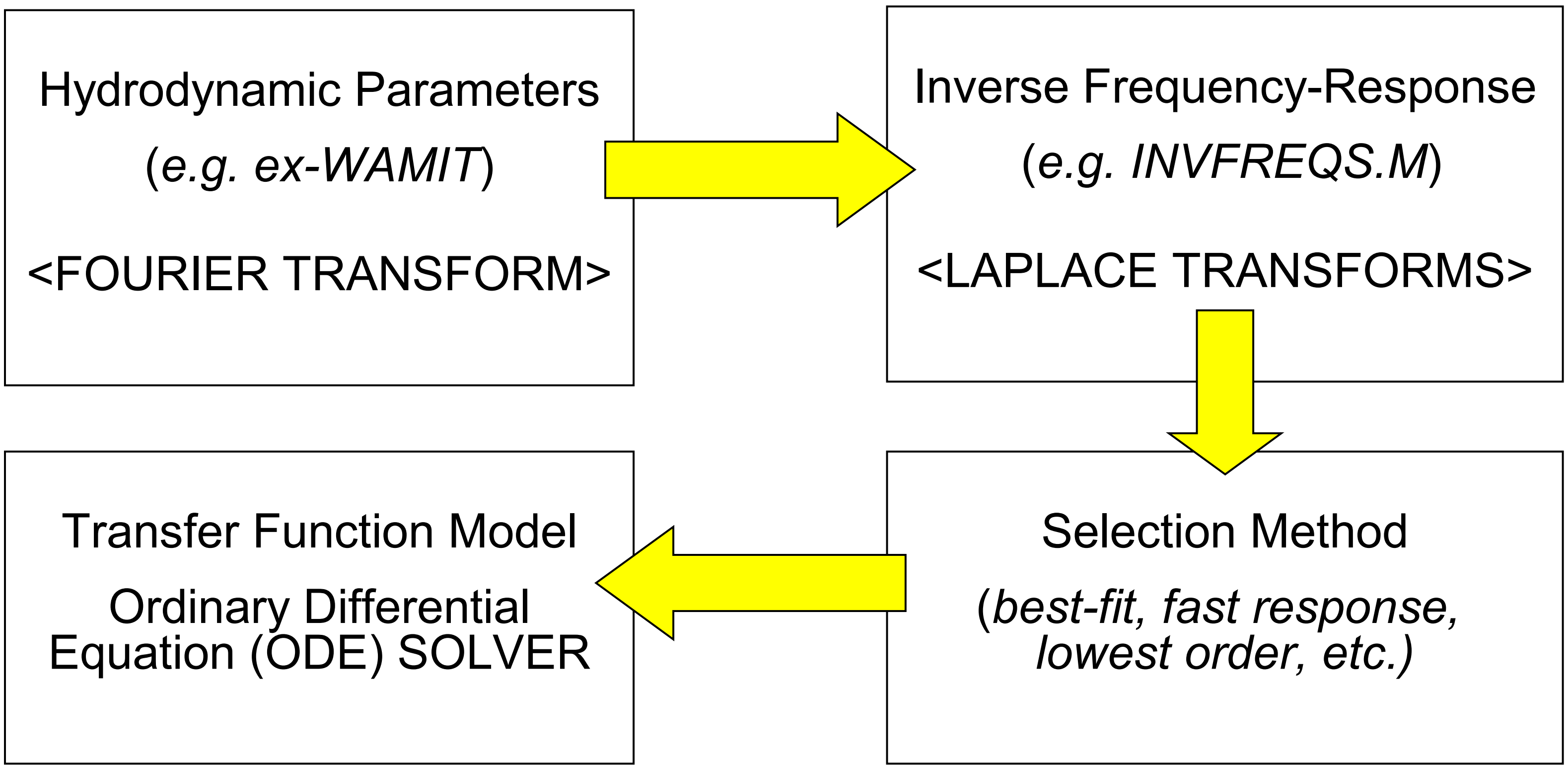
The objective:

Derive a time-domain model:

- using the software tools to hand
- avoiding extensive customized programming
- utilizing the best aspects of the software
- minimize design and run times, where possible

Basic Linear Model:

presented at the 6th European Wave and Tidal Energy Conference (EWTEC 2005)



6-Degrees-of-Freedom Model:

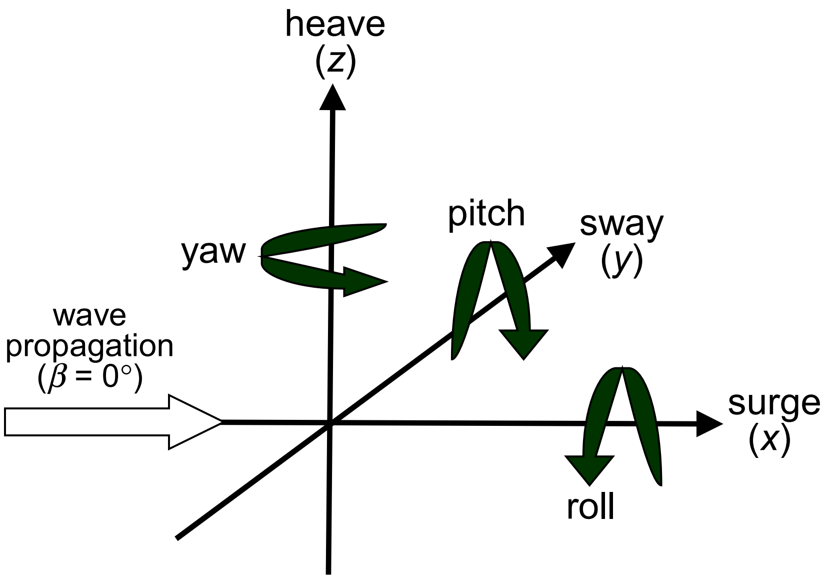
submitted to Ocean Engineering (currently being refereed)

Spread irregular wave model (a):

- Separate input function for each wave heading
- Increased model complexity and run time

Spread irregular wave model (b):

- One input function per mode
- Spreading by processing wave input
- Implication for long-crested wave approximation



Time Scale of Model Design and Run

Transfer Function Derivation:

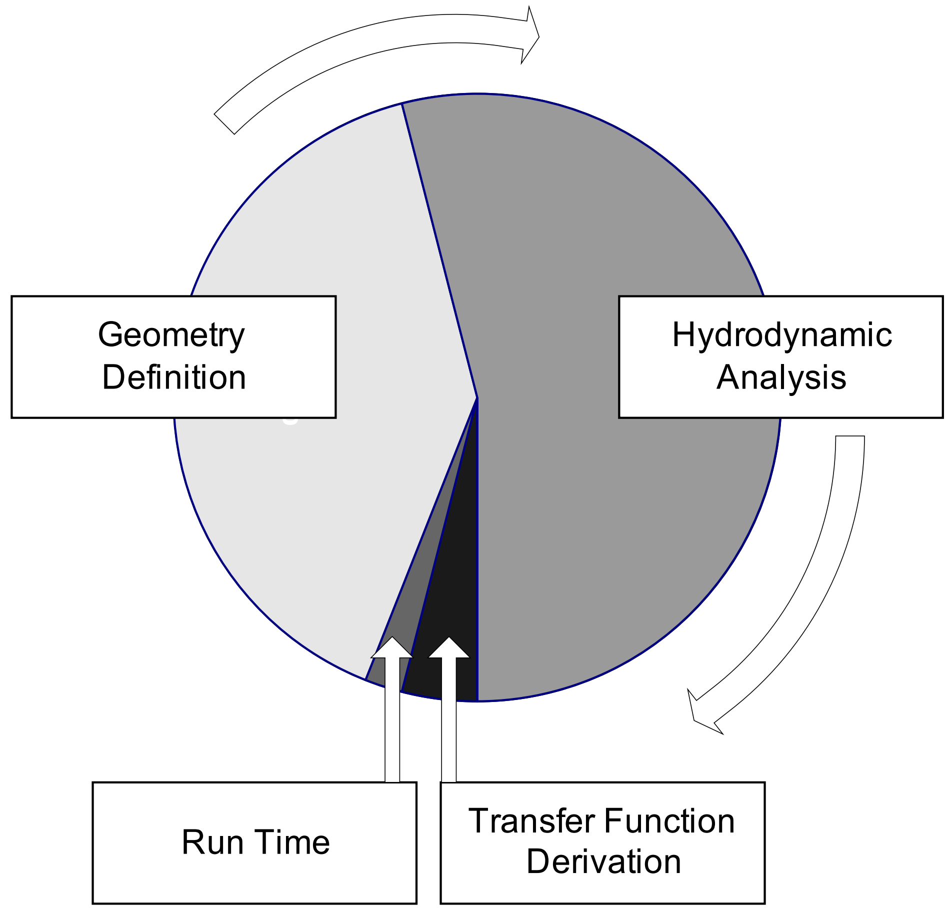
Assesses approx. 200 per minute

Model Run Speeds:

1 d.o.f.: ≈ 100x – 200x

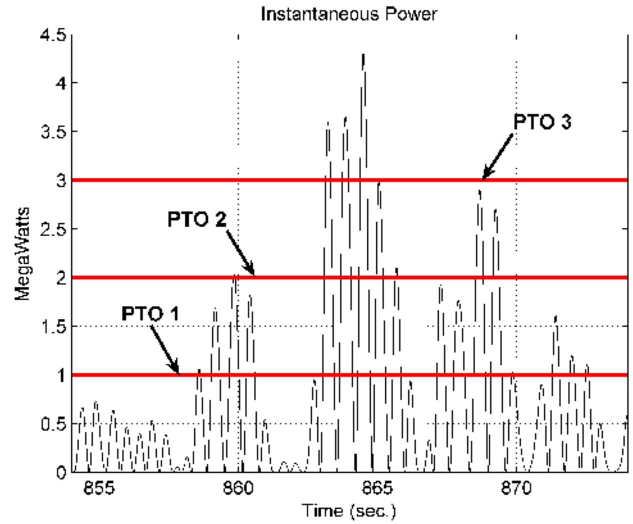
3 d.o.f.: ≈ 30x – 50x

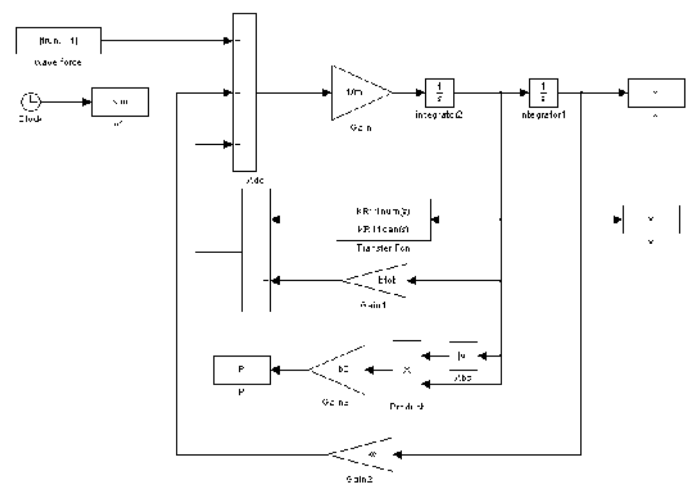
6 d.o.f.: ≈ 5x – 10x



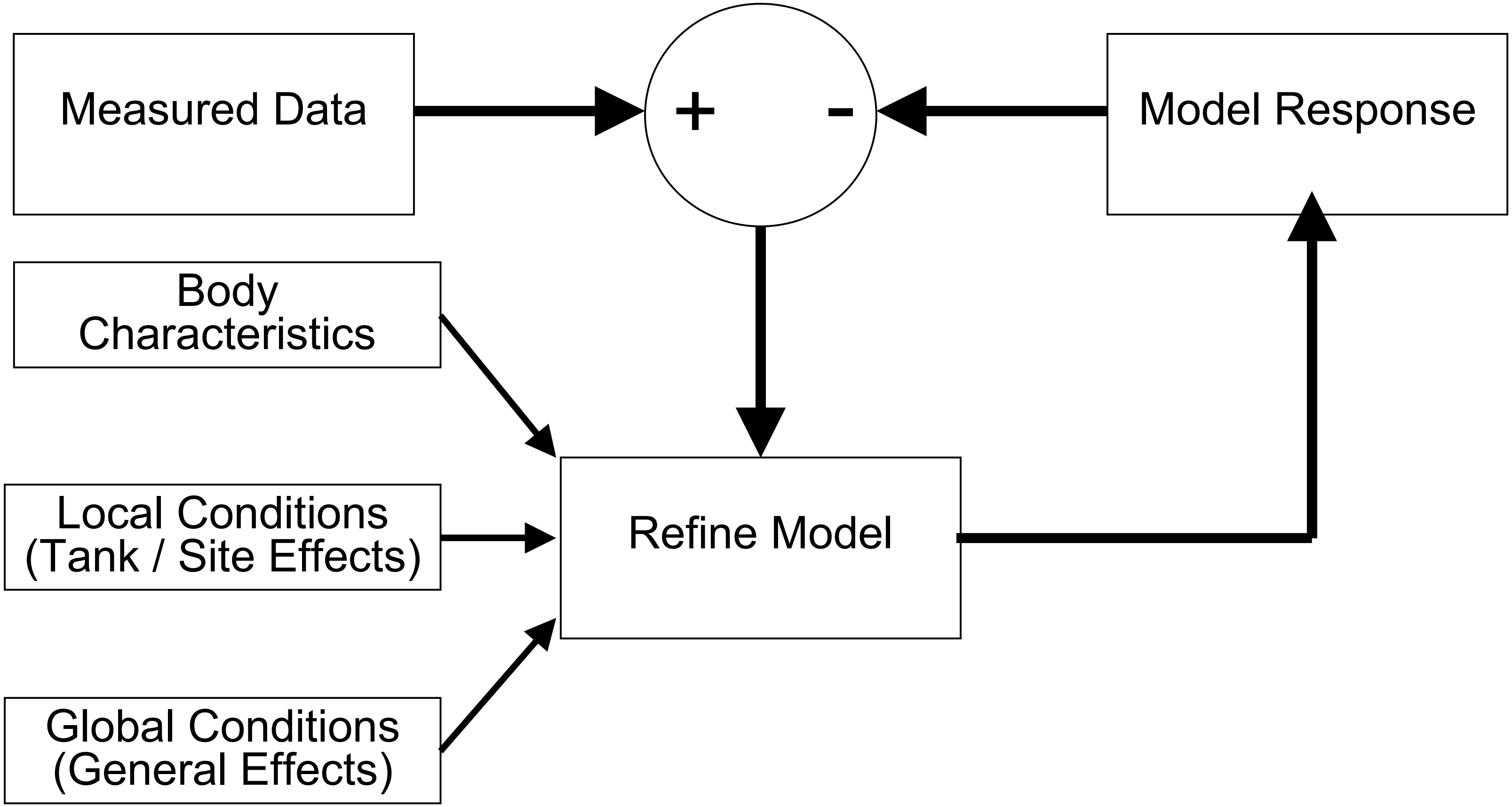
Preliminary Estimates

- Transient Power Flow
- Transient Control Effort
- Controller Optimization
- Structural Requirements





Model Verification

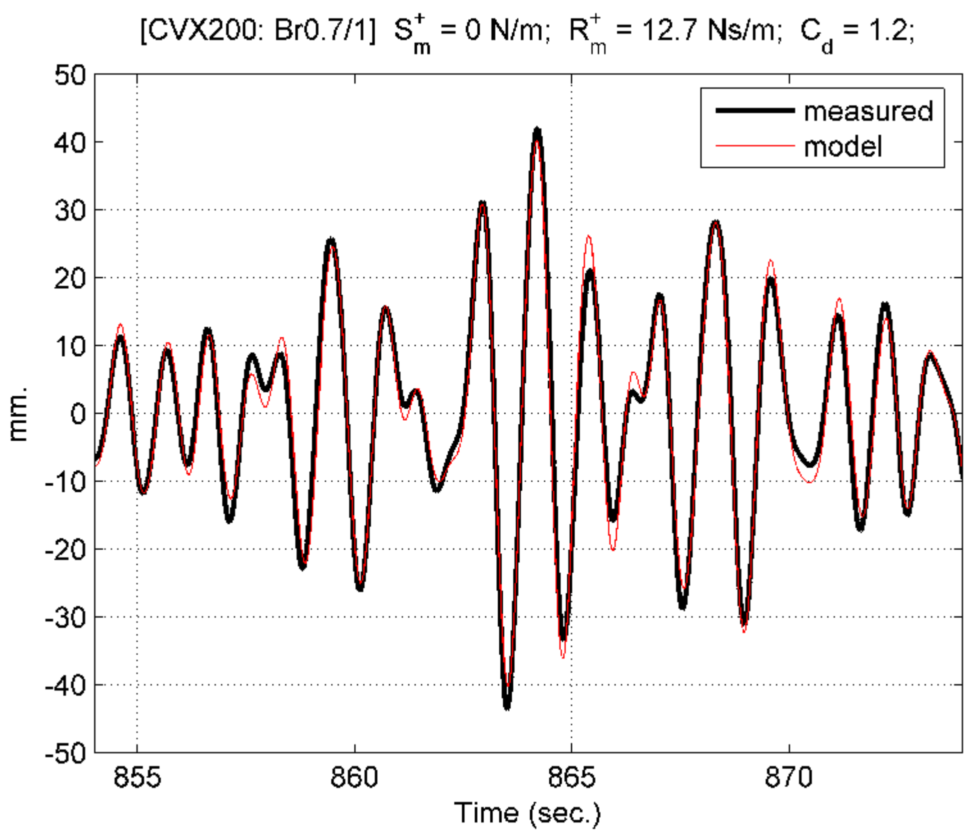


Model Verification - from work to be presented at ICOE (October 2006, Bremerhaven)

1/100th scale tank model
–
Surging Convex Plate

applied stiffness: 295 N/m
applied damping: 10 Ns/m

Basic Linear TD Model
+
Extra Damping
+
Drag



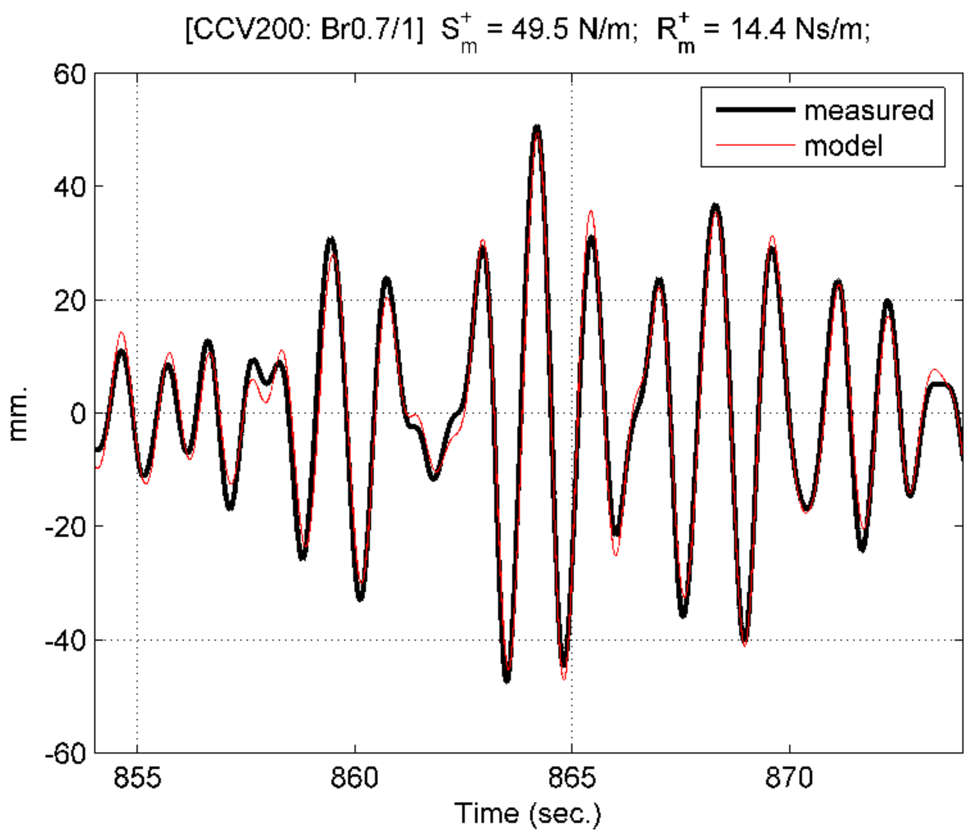
Model Verification - from work to be presented at ICOE (October 2006, Bremerhaven)

1/100th scale tank model
–
Surging Concave Plate

applied stiffness: 325 N/m

applied damping: 10 Ns/m

Basic Linear TD Model
+
Extra Stiffness
+
Extra Damping



Time- and Frequency-Domain Modelling – some papers, etc.

$$\left\{-\omega^2[m + a_{ii} \ldots \right\} \ldots X_i(\omega) = \alpha F_i(\omega)$$

A time-domain model of a floating body using transforms
A. P. McCabe, A. Bradshaw, and M. B. Widden
Presented at the 6th European Wave and Tidal Energy Conference (6th EWTEC),
University of Strathclyde, Glasgow, 30th August – 2nd September 2005.

$$m\ddot{x}_i(t) = F_{E,i} \ldots - \tau)\zeta(\tau)\,d\tau$$

$$F_{R,ii}(t) = a\ddot{x}_i(t) + b\dot{x}_i(t) + c_{ii}x_i(t) + \int_{-\infty}^{t} K_{R,ii}(t-\tau)\dot{x}_i(\tau)\,d\tau$$

Estimation of the responses of axisymmetric bodies in spread irregular waves
A. P. McCabe, T. J. Stallard, N. J. Baker, H. Yavuz
submitted to Ocean Engineering, February 2006

$$\int_0^{+\infty} K_{R,i} \ldots) - a]$$

$$K_{R,ii}(s) = \ldots) = \frac{B_{E,i}(s)}{A_{E,i}(s)}$$

Developing a time-domain model of a small-scale wave energy collector
A. P. McCabe, T. J. Stallard
Paper and poster presentation at the International Conference Ocean Energy,
Deutsches Schiffahrtsmuseum, Bremerhaven, 23rd – 24th October, 2006

$$\mathrm{Re}\left[\frac{B_{R,ii}(\mathbf{i}\omega \ldots}{A_{R,ii}(\mathbf{i}\omega)}\right] \ldots \quad \mathrm{Im}\left[\frac{\ldots}{A_{R,ii}(\mathbf{i}\omega)}\right] = \omega[a_{ii}(\omega) - a_{ii}(\infty)]$$