Resolute Marine Energy
Clean Water From Ocean Waves

Winner MassChallenge 2011
Runner up Global Ideas Competitions 2011
Winner Startup Open 2010
World Top 100 Marine Technology Company, 2009 & 2010

Extreme Conditions Modelling Workshop
Developer Experience: RME

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13th of May 2014

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Overview of the Development of SurgeWEC™

- RME est. 2007, Boston, MA.
- SurgeWEC™: an Oscillating Wave Surge Converter
- Prototypes deployed in North Carolina (2011, 2013)
- **Physical scale model tests (March 2014)**
- Hybrid electric/desalination plant (2015)
Extreme Conditions Modelling

- **Extreme Response**
  - Resonance
  - End stop limits

- **Extreme Excitation**
  - Foundation/mooring loads
  - Structural loads
  - PTO loads
Extreme Conditions Modelling

- **BEM based numerical model (WAMIT)**
  - ✔ Cheap
  - ✗ Unsuitable for non-linear wave conditions
  - ✗ Viscous damping accounted for using empirically determined coefficient
  - ✗ Requires physical validation

- **Physical scale modelling**
  - ✔ All relevant physical processes represented (provided scale factor is large enough)
  - ✗ Expensive

- **CFD simulation**
  - ~ Not cheap
  - ✗ Requires physical validation
Limitations of BEM based Numerical Model

Limitations inherent to WAMIT
- Linear potential flow: valid for small wave/body amplitudes;
- Inviscid fluid: viscous shear/vortex effects not accounted for.

Limitations specific to OWSCs:
- Free surface fixed at still water level;
- Dependence of hydrodynamic loads & coefficients on angular position not recognised.

✓ Operational wave conditions
❗ Extreme wave conditions
Validation: Oyster 800

- Compared excitation moment applied by waves incident on stationary flap estimated according to various numerical methods
- Oyster800: 26m wide flap in 13.4m water depth, physically modelled at 1:25 scale.

\[ H = \{0.5, 1, 2, 3, 4\} \text{m} \]
\[ T = \{5, 15\} \text{s} \]
\[ h = 13.4 \text{m} \]
\[ S = Hk/2(kh)^{\frac{1}{2}} \]

**Figure 6:** Comparison of normalised torque moment obtained from WAMIT simulations (light blue) and experimental data (dark blue) for different Stoke parameters; \( T = 5 \text{ s} \).

**Figure 7:** Comparison of normalised torque moment obtained from WAMIT simulations (light blue) and experimental data (dark blue) for different Stoke parameters; \( T = 15 \text{ s} \).
Physical Model Tests

- Orion Energy Centre, Inverness, Scotland
  - Shallow water, piston wave-makers
- 1:20 scale
  - Approaching limits of wave-maker capabilities
  - Accommodation of instrumentation
  - Scale effects associated with viscous drag/surface tension not expected to be significant
- Extreme seas across range of water depth & angular incidence
- Rotation, pressure, and foundation loads measured
- PTO not simulated
Physical Model Tests: OEC Wave Tank
Resonant Response

- Natural Period (14.7s) measured from free decay tests in still water
- Amplitude of rotation response measured in monochromatic waves
Extreme Seas in Shallow Water: Depth Limited Wave Height

- **3 water depths**
  - HWL: 8.36m
  - MWL: 7.36m
  - LWL: 6.36m

- **4 Sea states**
  - $H_s = 4m$ (target)
  - $T_p = 12s; 15s; 18s; 20s$ (target)

- **Depth limited wave height suggests limit to extreme excitation loads**
Extreme Seas in Shallow Water: Wave Parameters

- $H_{1/3}$ rather than $H_{m0}$ used to calculate significant wave height ($H_s$)
- $T_p$ rather than $T_{02}$ used to characterise wave period

![Wave parameter graphs](image-url)
Impact Loads

- Pulsating load: Froude scaling appropriate
- Impact load: partial Froude scaling?
Impact Loads: Scaling of water/air properties


Figure 20. Local flows for the Froude-similar global flows obtained with large scale test L121 (top) and full scale test M62 (bottom). Time step is 10 ms.

(a) Large scale test L119 and full scale tests M51, M52 and M53
(b) Large scale test L121 and full scale tests M61, M62 and M60

Figure 23. Pressures in the air pockets at large (red) and full (blue) scale. Pressures at large scale have been Froude-scaled.
Impact Loads: Structural Rigidity

- **Model's structural stiffness**
  - Scaling of material stiffness not considered
  - Instrumentation (load cells) introduce flexibility in foundations
Conclusions

- BEM numerical model unsuitable for extreme conditions modelling
- Physical modelling completed at Orion Energy Centre
- SurgeWEC’s resonant response not problematic
- Extreme loads limited by depth limited wave height in shallow water
- Extreme loads categorised as pulsating loads & impact loads
- Partial Froude scaling of impact loads considering:
  - Incorrect scaling of water/air properties between model & prototype
  - Structural rigidity of model and prototype
THANK YOU!

“Whiskey’s for drinking
Water’s for fighting over”
Attributed to Mark Twain