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Scaling Relations for Model Scale Testing of Hydrokinetic Ocean Renewable Energy Systems

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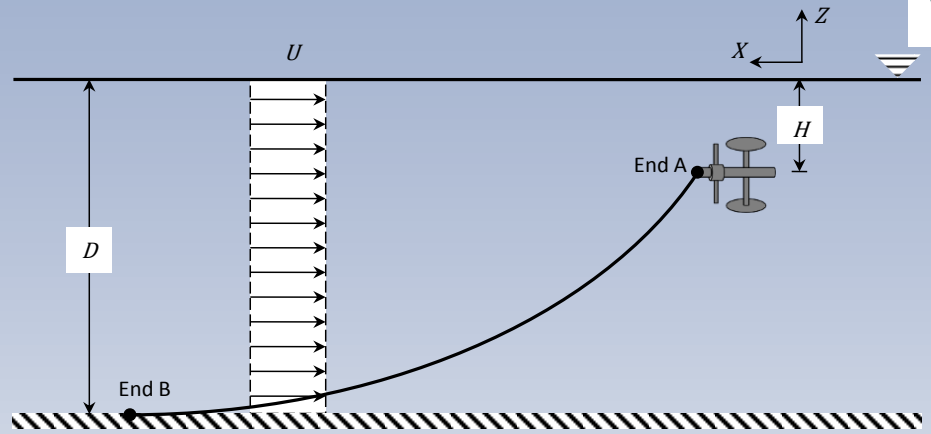
Motivation

- Most energy-dense portions of strong ocean currents (e.g. Florida Current, Kuroshio Current, Agullas Current) found offshore in deep water (Duerr & Dhanak 2012)
  - Florida Current: ~25-40 km, 320-560 m deep water
  - Systems likely positioned at 50-200 m depths
  - Complex mooring and anchoring systems required
  - Little experimental and practice experience with mooring systems
  - Lab studies of complete moored systems in controlled conditions more cost-effective than offshore field tests

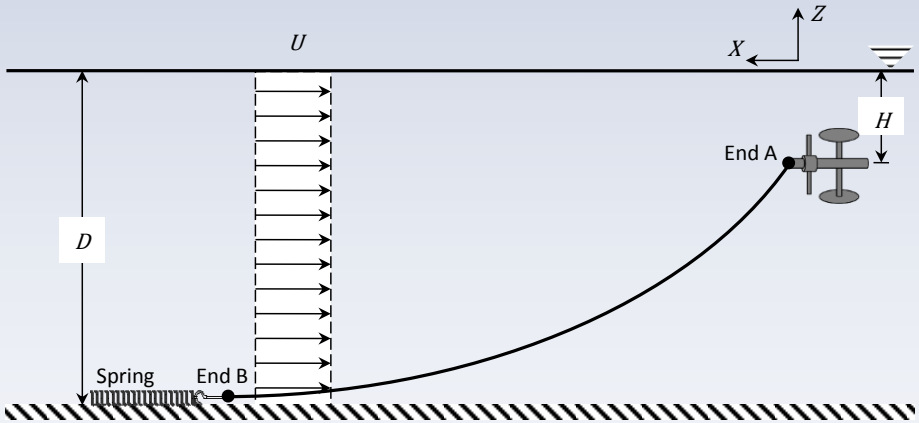
Approach

- Model Scaling Procedure of Mavrakos et al. (1995) modified for Froude rather than Reynolds number scaling
- 3 DoF Numerical Simulations Performed in Orcaflex (v9.4 e)
- "Numerical Experiments" performed to evaluate effectiveness of scaling procedure on submerged systems having a single catenary mooring line
  - Prototype: 400m depth; Models: $^{1}/_{40}$ scale and $^{1}/_{10}$ scale

23 m Horizontal Axis Ocean Current Turbine

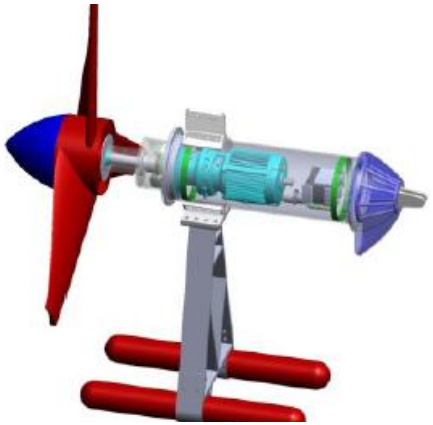


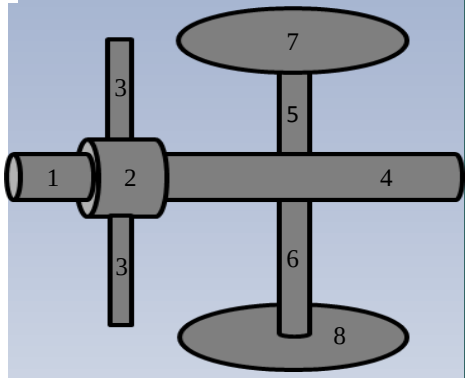
Prototype System



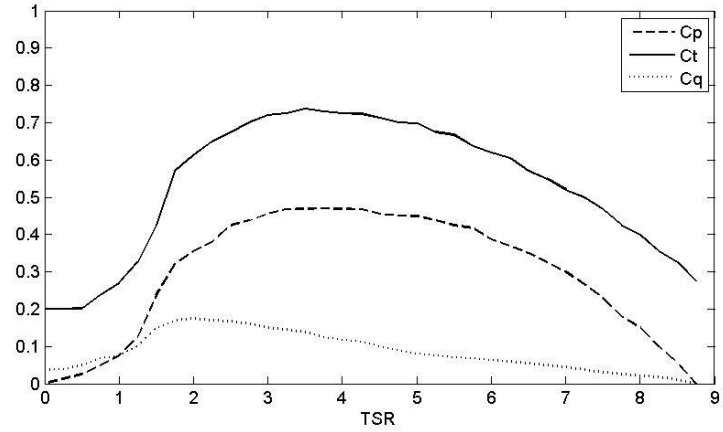
Model System

Van Zweiten et al. 2013





Lumped Parameter Turbine Model

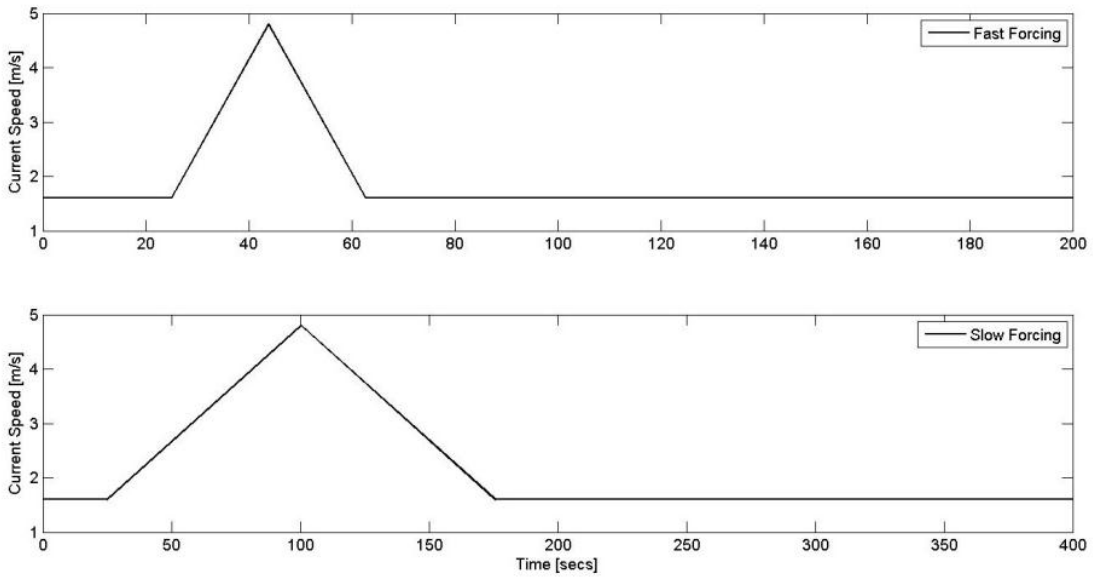


Excitations

Waves

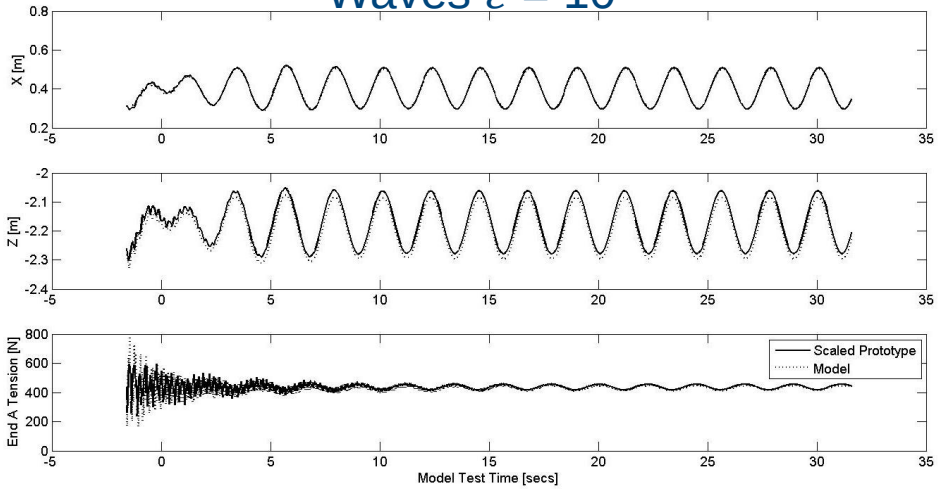
Parameter	Prototype	1/40th Model $\varepsilon = 40$	1/10th Model $\varepsilon = 10$
Wave Amplitude ς_a [m]	0.675	0.016875	0.0675
Wave Period T_0 [sec]	7.00	1.107	2.214
Surface Current Speed U_0 [m/s]	1.6	0.253	0.506

Current Perturbations

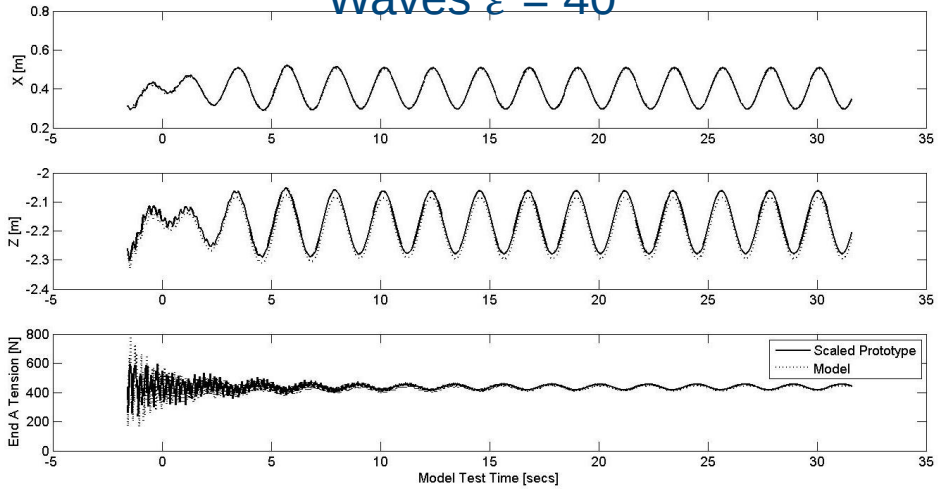


Parameter	Prototype	1/10th Model $\varepsilon = 10$
Water Depth D [m]	400	40
Water Density ρ_w [kg/m^3]	1026.9	999.7
Kinematic Viscosity υ_w [m^2/s]	1.35x10^{-6}	1.31x10^{-6}
Surface Current Speed U_0 [m/s]	1.6	0.506
Surface Current Perturbation [m/s]	3.2	1.012
Fast Forcing Duration [sec]	37.68	11.92
Slow Forcing Duration [sec]	150.7	47.66
Seabed Stiffness [kg/m^3]	100x10^3	100x10^3

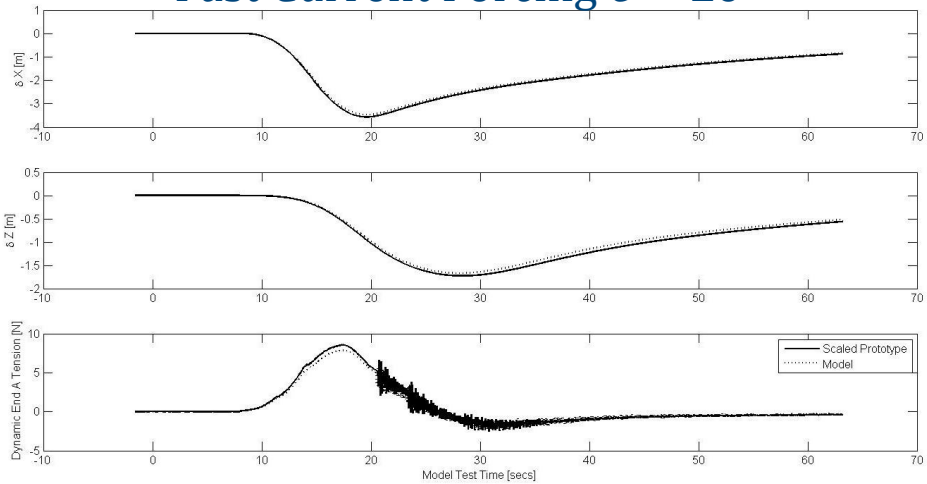
Waves ε = 10



Waves ε = 40



Fast Current Forcing ε = 10



Slow Current Forcing ε = 10