WEC-Sim Technical Training Course

PRESENTED BY

WEC-Sim Development Team

Advanced Features – Body-to-Body Interactions

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WEC-Sim Theory

- Uses the radiation and diffraction method and calculates the hydrodynamic forces from frequency-domain Boundary Element Method (BEM)
- Dynamics simulated by solving time-domain equation of motion (Cummins, 1962)

$$m\ddot{X}(t) = \boxed{F_B(t)} + \boxed{F_{ext}(t)} + \boxed{F_{rad}(t)} + \boxed{F_v(t)} + \boxed{F_{PTO}(t)} + \boxed{F_m(t)}$$

- $F_B(t)$: Hydrostatic Restoring force
- $F_{ext}(t)$: Wave excitation & diffraction force (BEM)
- $F_{rad}(t)$: Radiation force: added mass and radiation damping (BEM)
- $F_v(t)$: Viscous force
- $F_{PTO}(t)$: Power take-off force
- $F_m(t)$: Mooring force

$$F_{ext}(t) = \Re\left[R_f \int_0^{\infty} \boxed{F_x(\omega_r)}\, e^{i(\omega_r t + \phi)} \sqrt{2S(\omega_r)d\omega_r}\right]$$

BEM

$$= \int_{-\infty}^{\infty} \eta(\tau) \boxed{f_e} (t-\tau)d\tau$$

BEM

$$F_{rad}(t) = \boxed{-A_\infty} \ddot{X} - \int_0^t \boxed{K_r}(t-\tau)\dot{X}(\tau)d\tau$$

BEM BEM

WEC-Sim Theory

- For a two body system consisting of a buoy and spar/plate the forces on bodies are given by:
  - Buoy Forces

$$F_{e_1}(t) - F_{r_{11}}(t) - F_{r_{12}}(t) = K_{hs}x_1 + b_{v_1}\dot{x}_1 + \big(m_1 + A_{11}(\infty)\big)\ddot{x}_1$$

  - Spar/Plate Forces

$$F_{e_2}(t) - F_{r_{22}}(t) - F_{r_{21}}(t) - F_m(x_2, \dot{x}_2) = b_{v_2}\dot{x}_2 + \big(m_2 + A_{22}(\infty)\big)\ddot{x}_2$$

    - Radiation force created by each body's motion

$$F_{r_{11}} = \int_{-\infty}^{t} k_{r_{11}}(t-\tau)\dot{x}_1(\tau)d\tau \qquad F_{r_{22}} = \int_{-\infty}^{t} k_{r_{22}}(t-\tau)\dot{x}_2(\tau)d\tau$$

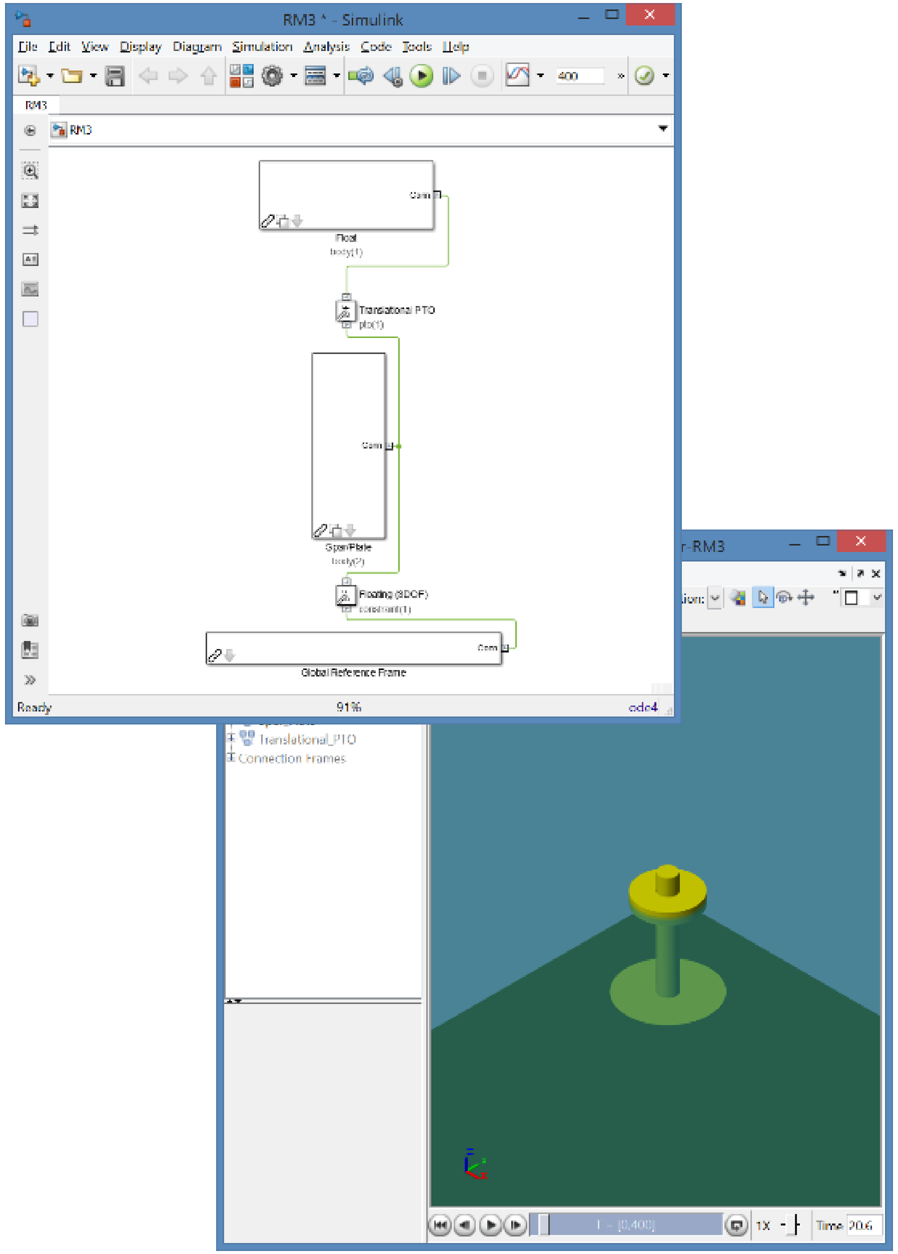
Buoy Radiation IRF — Plate Radiation IRF

    - Coupled radiation forces:

$$F_{r_{12}} = \int_{-\infty}^{t} k_{r_{12}}(t-\tau)\dot{x}_2(\tau)d\tau + A_{12}(\infty)\ddot{x}_2$$

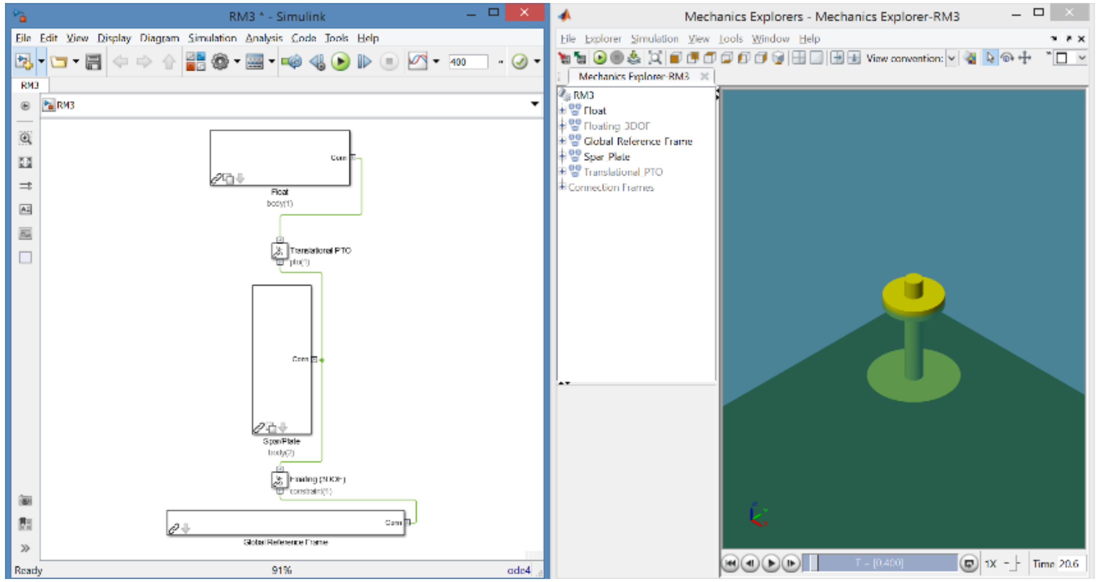
$k_{12} = k_{21}$

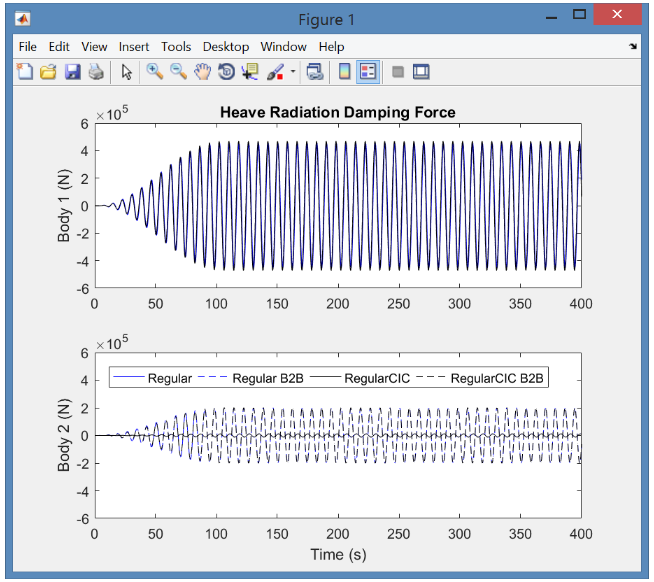
$$F_{r_{21}} = \int_{-\infty}^{t} k_{r_{21}}(t-\tau)\dot{x}_1(\tau)d\tau + A_{21}(\infty)\ddot{x}_1$$



Body-to-body (B2B) Interactions Examples

- **Body-to-Body_Interactions Application:**
  - https://github.com/WEC-Sim/WEC-Sim_Applications/tree/master/Body-to-Body_Interactions
  - Models RM3 with B2B on/off
  - Compares different B2B numerical implementations
    - *Regular* uses coupled radiation coefficients for each body based on incident wave period
    - *RegularCIC* uses Impulse Response Function (IRF) formulation of coupled radiation forces





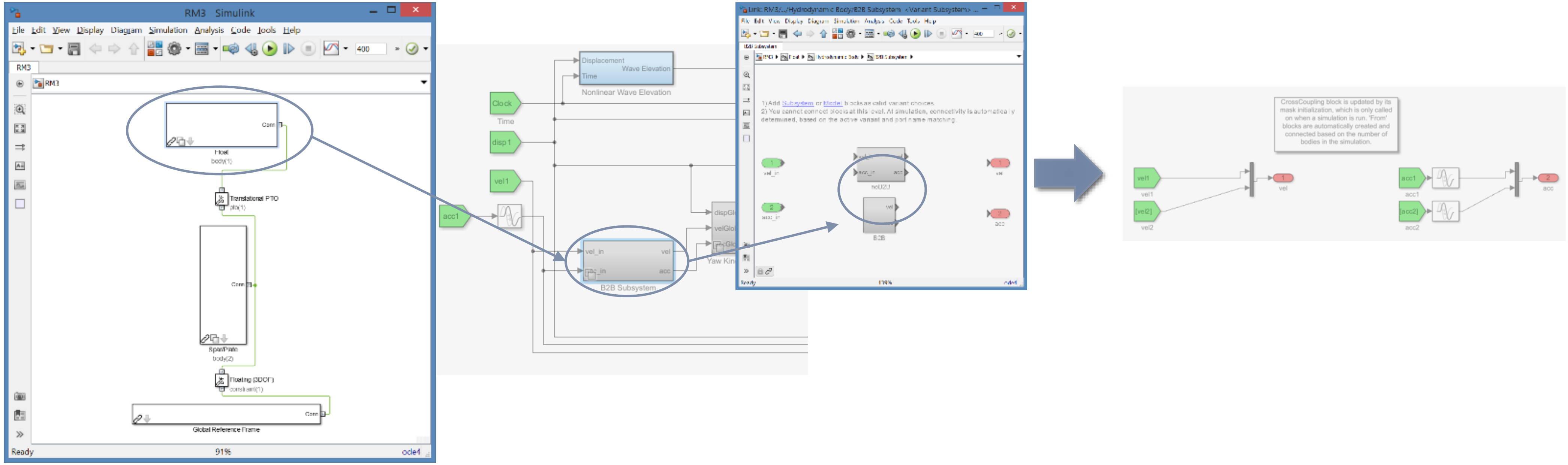
Body-to-body (B2B) Interactions Examples

- **Body-to-Body_Interactions Application:**
  - https://github.com/WEC-Sim/WEC-Sim_Applications/tree/master/Body-to-Body_Interactions
  - Input File
    - Initialize simulation class as usual
    - Set *simu.b2b = 1;*

```
%% Simulation Data
simu = simulationClass();
simu.simMechanicsFile = 'RM3.slx';
simu.solver = 'ode4';
simu.explorer='off';
simu.startTime = 0;
simu.rampTime = 100;
simu.endTime=400;
simu.dt = 0.1;
simu.b2b = 1;                                 % Turn B2B interactions 'on'
```

Body-to-body (B2B) Interactions Examples

- **Body-to-Body_Interactions Application:**
  - https://github.com/WEC-Sim/WEC-Sim_Applications/tree/master/Body-to-Body_Interactions
  - Simulink Model
    - *simu.B2B = 1;*
    - Turns on *B2B* variant subsystem
    - Merges each body's velocity and acceleration signals into one velocity and acceleration vector, e.g. for 2 bodies [6x1] → [12x1]



Thank you!

All previous webinar materials and recordings are available online:

http://wec-sim.github.io/WEC-Sim/webinars.html

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