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Tool for Distributed Pressure Time-Histories of Marine Structures: Verification and Case Study With a WEC

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ABSTRACT

In this paper we describe the theory and code implementation of a tool to obtain the time-dependent pressure distribution on a marine structure using the results from a boundary element method code (BEM). Here, we present a case study of a floating wave energy converter (WEC) in regular waves. The results are verified by comparison with open-source codes and then used to run a structural simulation (finite element analysis) to showcase a possible application.

TOOL INPUTS & OUTPUTS

Inputs:

- Results from NEMOH boundary element method code
- Time-history of device motion

Outputs:

- Cell-by-cell total hydrodynamic pressure time history
- Added mass, radiation damping, hydrostatic, and excitation cell-by-cell pressure time-histories.

DISTRIBUTED PRESSURE TIME-HISTORY TOOL

Complex cell-by-cell pressure coefficients for a single frequency and wave direction for each cell *(i)* and degree of freedom (*j*)*:*

- Radiation and Diffraction – Parse NEMOH outputs

$$\tilde{\Psi}_{R_{i,j}} \quad \tilde{\Psi}_{D_i}$$

- Froude-Krylov

$$|\tilde{\Psi}_{FK_i}| = \rho g \frac{\cosh(k(z_i + h))}{\cosh(kh)}$$

$$\angle\tilde{\Psi}_{FK_i} = kx_i$$

$$\tilde{\Psi}_{FK_i} = |\tilde{\Psi}_{FK_i}|\cos(\angle\tilde{\Psi}_{FK_i}) + i|\tilde{\Psi}_{FK_i}|\sin(\angle\tilde{\Psi}_{FK_i})$$

Real-valued pressure coefficients for the time-domain implementation:

$$C_{rd_{i,j}} = \Re\{\tilde{\Psi}_{R_{i,j}}\}$$

$$C_{am_{i,j}} = \frac{-\Im\{\tilde{\Psi}_{R_{i,j}}\}}{\omega}$$

$$C_{rex_i} = \Re\{\tilde{\Psi}_{FK_i} + \tilde{\Psi}_{D_i}\}$$

$$C_{iex_i} = \Im\{\tilde{\Psi}_{FK_i} + \tilde{\Psi}_{D_i}\}$$

Pressure time-histories using time-history of device motion:

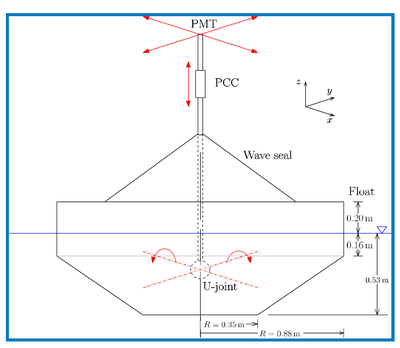
$$P_{rd_{i,j}}(t) = C_{rd_{i,j}}\dot{x}_j(t)$$

$$P_{am_{i,j}}(t) = C_{am_{i,j}}\ddot{x}_j(t)$$

$$P_{ex_i}(t) = A(C_{rex_i}\cos(\omega t) - C_{iex_i}\sin(\omega t))$$

$$P_{hs_i}(t) = \begin{cases} -x_{i3}(t)\rho g & \text{if} \quad x_{i3} < 0 \\ 0 & \text{if} \quad x_{i3} \geq 0 \end{cases}$$

$$P_{T_i}(t) = P_{ex_i}(t) + \sum_{j=1}^{6}(P_{rd_{i,j}}(t) + P_{am_{i,j}}(t)) + P_{hs_i}(t)$$



Device geometry – single body point-absorber WEC

VERIFICATION

Geometry : 1:17 scale single body point absorber

Motion time-history from heave-only WEC-Sim simulation

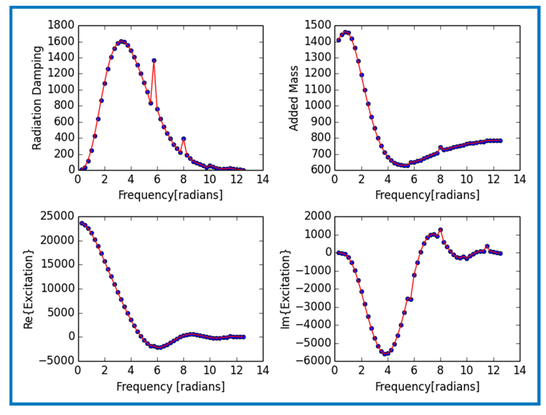
- Regular wave H=0.1m, T=1.57s

Whole-body force coefficients obtained by integrating the real-valued pressure coefficients over the entire body.

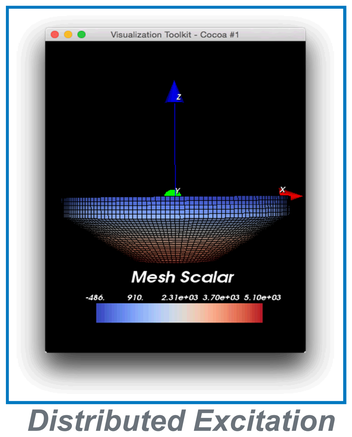
- Compared to NEMOH whole-body force coefficients.

Whole-body force time-histories obtained by integrating the pressure time-histories over the entire body at each time step.

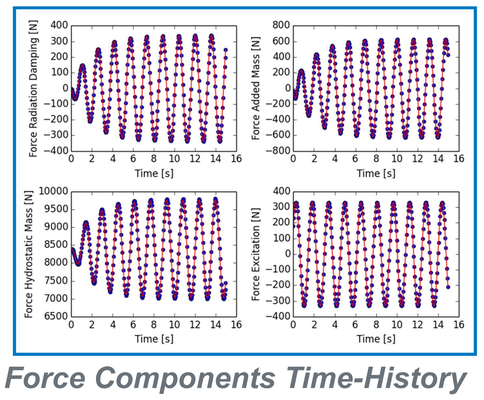
- Compared to WEC-Sim whole-body force time-histories.



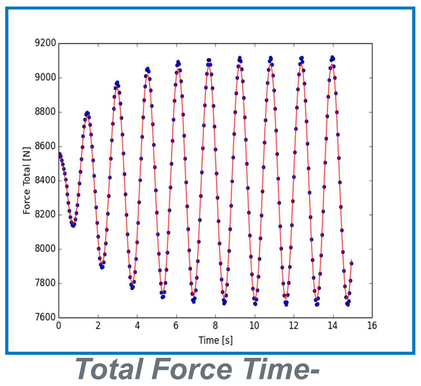
Radiation and Excitation Coefficients Comparison



Distributed Excitation Pressure at t=15s



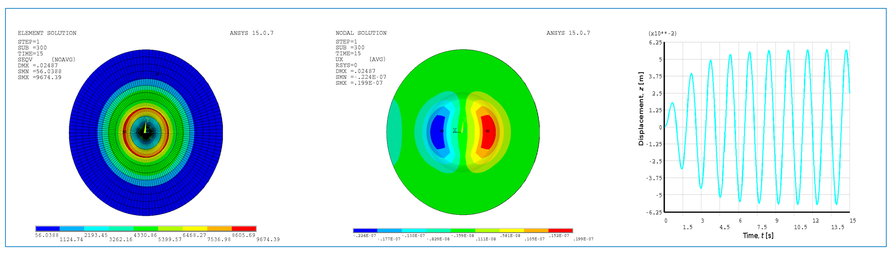
Force Components Time-History Comparison



Total Force Time-History Comparison

APPLICATION: FEA STRUCTURAL ANALYSIS

As a demonstration of a possible application an FEA structural analysis was conducted in ANSYS.



FEA Results: Von Mises Stress At t=15s, X-Displacement At t=15s, Z-Dispalacement Time-History At Bottom Surface

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