A 3D FEM model for wind turbines support structures

Alexis Campos; **Climent Molins**; Pau Trubat; Daniel Alarcón
Universitat Politècnica de Catalunya. Escola de Camins

UPC BARCELONATECH

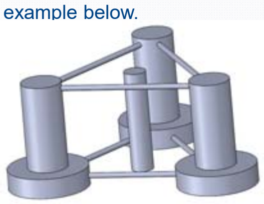
Dynamic co-rotational FE analysis for FOWT's

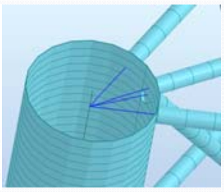
With the aim of improving the tools for the analysis of floating spar type structures for offshore wind turbines, a model which includes the nonlinear FEA for large displacements based on a co-rotational formulation is under development at the UPCBarcelonaTech.

The model is able to take into account the wind loads over the structure, the hydrodynamic loads from the wind turbine, hydrodynamic loads, the elasticity of the full structure and the mooring response in both, in quasi static or accounting for its dynamics. All forces integrated in the time domain. The model assumes one-dimensional beam elements, extended to the 3D domain.

FEM discretization

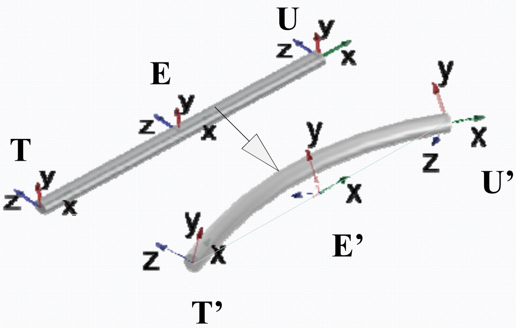
The FE numerical model is based in the Euler beam theory, which in combination with elasticity and one-dimensional finite elements may be used to analyze the most common types of onshore and offshore wind turbines support structures. Also special elements like rigid links are implemented to deal with some limitations of the one-dimensional elements as shown in an example below.





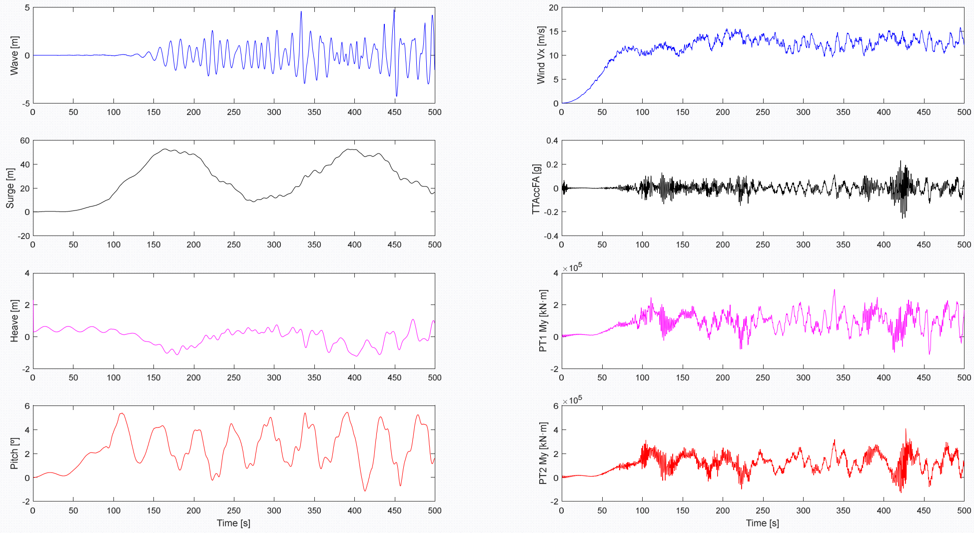
Co-rotational approach

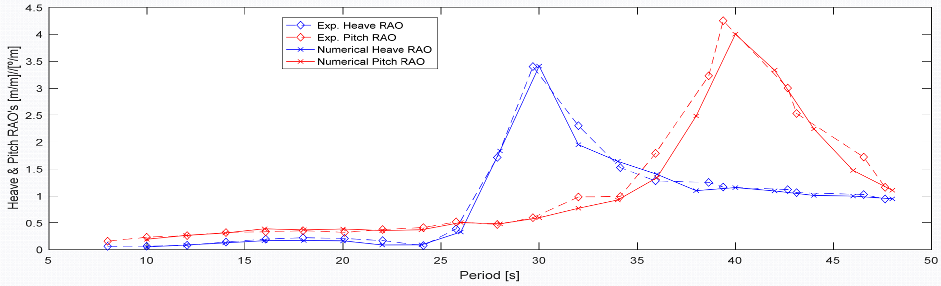
To analyze floating structures with large rigid body motions but small strains, a consistent co-rotational formulation for dynamic analysis proposed by Crisfield [1] is implemented. This formulation allows the computation of the equivalent local angles with respect a co-rotational frame, which is moving attached to the element as shown.



Dynamic Analysis

The dynamic analysis is performed in the time domain by solving the equations of motion of the system, based on the Newton's 2nd law. For the time integration a Hilber-Huges-Taylor [2] scheme is adopted in combination of an iterative Newton-Raphson method to deal with the nonlinearity.





External loads

The external forces considered in the model include the effects of the environmental loads (buoyancy and waves), the mooring system, the wind turbine, the self-weight as well as user defined input forces.

The equivalent buoyancy forces acting over the structure are computed by the 3D integration of the pressures over the structure at each time step from the global position of the mesh elements centroids to finally compute the hydrostatic pressures to compute the resultant force at each element.

The drag forces and the wave loads are computed with the Morison's equation, from where the water particle kinematics can be computed with regular or irregular Airy waves theory or the Stokes 5th order non-linear wave theory. For the irregular waves the kinematics can be computed from a defined sea spectrum or from a wave data record.

For the mooring system loads, the model allows to compute in a quasi static way or considering the full mooring dynamics, based in the Garret [3] and Kim [4] works.

Validation and Numerical Results

The results obtained during the Windcrete concept experimental campaign [5] have been used to validate the numerical results of the model. The results from a simulation under normal operation conditions in combination with the NREL 5MW WT and the adjusted numerical model of Windcrete are shown in the upper part while a RAO comparison between simulations and experimental results is shown below.

Acknowledgements

We would like to express our gratitude for the financial support obtained from the Catalan government, Generalitat de Catalunya, through its AGAUR agency and from the KIC InnoEnergy.

References

[1] Crisfield,M. A., Non-linear finite element analysis of solids and structures, vol. 2. John Wiley & Sons Inc, 1991.

[2] H. M. Hilber, T. J. R. Hughes, and R. L. Taylor, "Improved numerical dissipation for time integration algorithms in structural dynamics," Earthq. Eng. Struct. Dyn., no. 5, pp. 283–292, 1977.

[3] D. L. Garrett, "Dynamic Analysis of Slender Rods," J. Energy Resour. Technol., vol. 104, no. 4, pp. 302–306, 1982.

[4] Y.-B. Kim, "Dynamic Analysis of multiple-body floating platforms coupled with mooring lines and risers," Texas A&M University, 2003.

[5] Campos,A.;Molins,C.;Gironella,X.;Trubat,P.;and A Alarcón,D., "Experimental RAO's analysis of a monolithic concrete spar structure for offshore floating wind turbines," in Proceedings of the 34th International Conference on Ocean, Offshore and Arctic Engineering OMAE2015, 2015.