COMPASS
www.compassis.com

SeaFEM - Validation Case 18

Analysis of the response amplitude operator (RAO) of a spar buoy wind turbine

SeaFEM

Version
15.1.0

Compass Ingeniería y Sistemas http://www.compassis.com
Tel.: +34 932 181 989 - Fax.: +34 933 969 746 - E: info@compassis.com - C/ Tuset 8, 7o 2a, Barcelona 08006 (Spain)

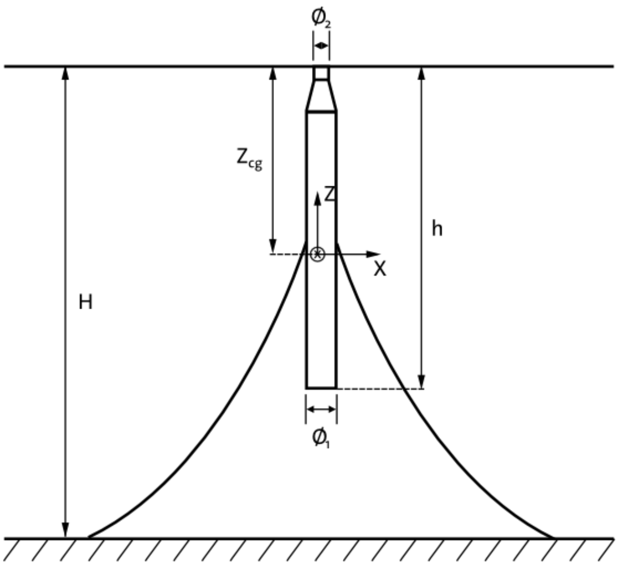
http://www.compassis.com
info@compassis.com
November 2018

Table of Contents

1 Validation Case 18 - Response amplitude operator for a spar buoy wind turbine

This test case concerns the calculation of the response amplitude operators (RAOs) of a spar buoy wind turbine system. Results are compared againsts those obtained with WAMIT and FAST [1].

The problem's geometry is sketched in the figure below, where just the portion of the buoy located below the water line is represented. Mooring lines are also sketched although in this case they are not modelled explicitly. Instead, mooring effects are taken into account in the form of additional damping and stifness matrices.



H = 320 m

h = 120 m

Z_{cg} = -76.81 m

Φ_1 = 9.4 m

Φ_2 = 6.5 m

Problem description

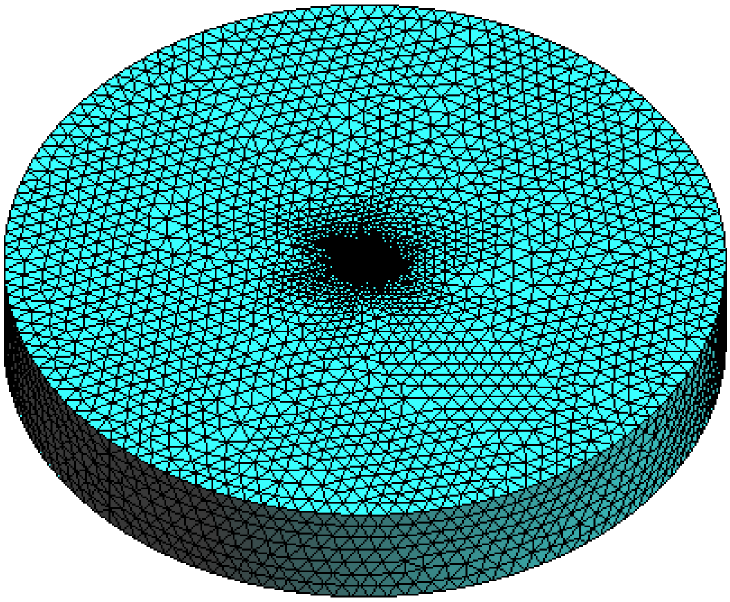
For the purpose of results validation, the problem under analysis considers a rigid floating wind turbine without wind excitation. The analysis is applied to a floating sytem composed of the OC3-Hywind spar buoy and NREL 5-MW wind turbine [1]. RAOs are computed within SeaFEM through white-noise wave excitation and studying the associated time-domain reponse. To this aim, the wetted part of the geometry is directly modeled in SeaFEM (see figure 1) while the influences of the turbine and mooring lines are considered through additional stiffness and damping matrices.

Mesh

Mesh properties for the present analysis are summarized in the following table:

Mesh properties	
Min. element size	0.5
Max element size	50
Mesh size transition	0.3
Number of elements	488238
Number of nodes	82512

Next picture shows an isometric view of the mesh used for the present analysis and a close view of the region next to the surface of the spar buoy.



Results

In this section, RAO's results obtained with SeaFEM are compared with those obtained with WAMIT and FAST and reported in [1]. For the sake of comparison, it must be taken into account that the results provided by SeaFEM are referred to the center of gravity of the body. On the contrary, results in [1] are referred to the origin of coordinates. Therefore, SeaFEM results must be also translated to the origin for a correct comparison. To this aim, RAO's phases results must be considered to adequately compose the different degrees of freedom contributions.

Transformation of surge results in order to be referred to the origin can be performed as follows:

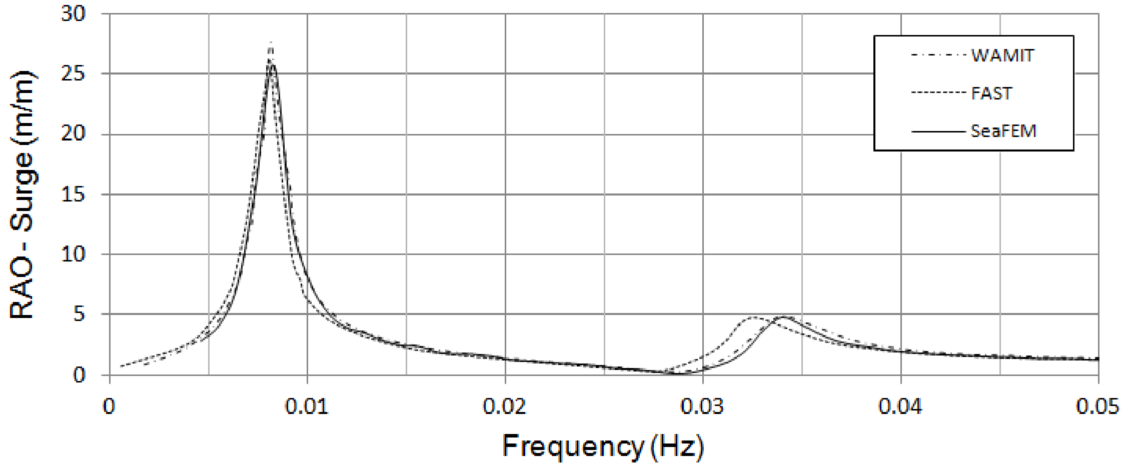
$$RAO\_X_o = [(RAO\_X_{cg}*\cos\Phi_s - Z_{cg}*RAO\_\Theta_y*\cos\Phi_p)^2 + (RAO\_X_{cg}*\sin\Phi_s - Z_{cg}*RAO\_\Theta_y*\sin\Phi_p)^2]^{(1/2)}$$

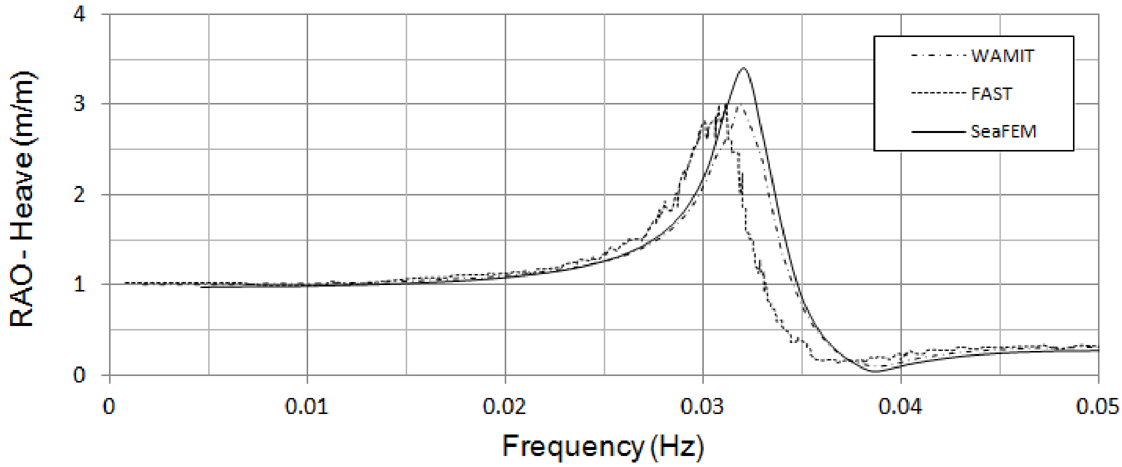
where Φ_s andΦ_p are the surge and pitch phases respectively, and Z_{cg} is the Z coordinate of the center of gravity. Similarly, heave results can be transformed as follows:

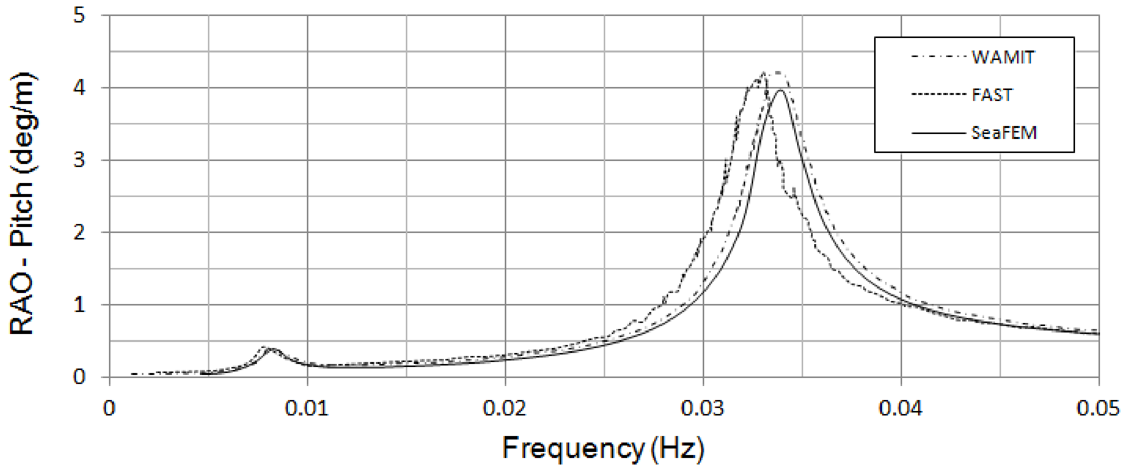
$$RAO\_Z_o = [(RAO\_Z_{cg}*\cos\Phi_h + X_{cg}*RAO\_\Theta_y*\cos\Phi_p)^2 + (RAO\_Z_{cg}*\sin\Phi_h + X_{cg}*RAO\_\Theta_y*\sin\Phi_p)^2]^{(1/2)}$$

where Φ_h and Φ_p are the heave and pitch phases respectively, and X_{cg} is the X coordinate of the center of gravity.

In the following graphs, RAO's results obtained with SeaFEM (and already transformed to be referred to the origin) are compared againsts the results obtained with WAMIT and FAST [1]. It can be observed that SeaFEM results are in very good agreement with WAMIT.







References

[1] Ramachandran G.K.V., Robertson A., Jonkman J.M. and Masciola M.D., Investigation of Response Amplitude Operators for Floating Offshore Wind Turbines, National Wind Technology Center, National Renewable Energy Laboratory, Boulder, CO, USA, Conference paper NREL/CP-5000-58098 at www..nrel.gov/puclications.

Validation Summary

CompassFEM version	15.1.0
Tdyn solver version	15.1.0
RamSeries solver version	15.1.0
Benchmark status	Successfull
Last validation date	27/11/2018