Preliminary stability assessment of Marine Power Systems marine renewable energy devices

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Introduction and aim of the work

The design of an offshore renewable energy platform requires sufficient stability during all the stages of the device life, both in floating and operating conditions. The stability assessment is a very important step to check the suitability of the device and it will determine the feasibility of the design. Stability curves are widely used to check the equilibrium of a floating structure as a function of the angle of heel. The angle of heel is supposed to be generated by the wind loading. The aim of this work is to compare the open source WEC-Sim [1] and the commercial code Orca3D [2] for the calculation of the stability curve of a preliminary configuration of a floating marine renewable energy platform under development by MPS [3].

Computational model set-up

Orca3D is a plugin of the commercial code Rhino that can simulate the hydrostatic stability of floating structures user friendly interface. On the other hand WEC-Sim is open-source and the code is more accessible but less user friendly. WEC-Sim could be considered as a plugin of MATLAB/Simulink for the simulation of Wave Energy Converters (WECs). The main difference between the codes is that Orca3D is limited to the hydrostatic computation while WEC-Sim can compute a time domain simulation of the device. The following inputs are common between Orca3D and WEC-Sim:

- Mesh file (See Figure 1).
- Fluid properties.
- Position of the Center of Gravity (CoG) of the structure.
- Mass of the structure.
- Heeling angles.

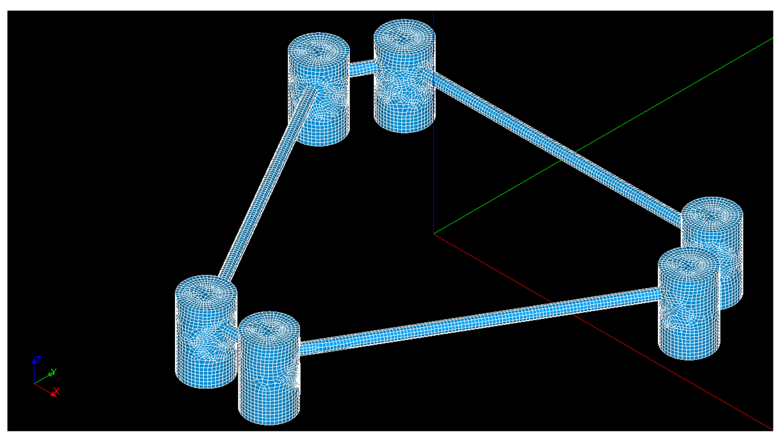

Figure 1: The fine mesh of the platform in Salome-Meca [4]

Methodology

The methodology of the hydrostatic simulation in Orca3D is quite simple and it follows the definition of the input described in the computational set-up. WEC-Sim instead requires a more complex methodology because the hydrostatic stability simulation is not set-up. However, WEC-Sim is already capable of computing the non-linear hydrostatic torque. The restoring torque in roll at the beginning of the time domain simulation is the most important output used for the calculation of the stability curve. Two WEC-Sim Simulink models have been created to assess the hydrostatic stability:

- The sinkage assessment model to determine the vertical equilibrium position due to the application of the heeling angle. This model considers the structure connected with a constraint of one translational vertical degree of freedom.
- The stability model to address the calculation of the hydrostatic stability curve. The structure in this case is connected with a constraint of 6 degrees of freedom.

The calculation of the wind loading is also important to test if the structure is stable and finally the post-processing compares the stability curves between the 2 different software.

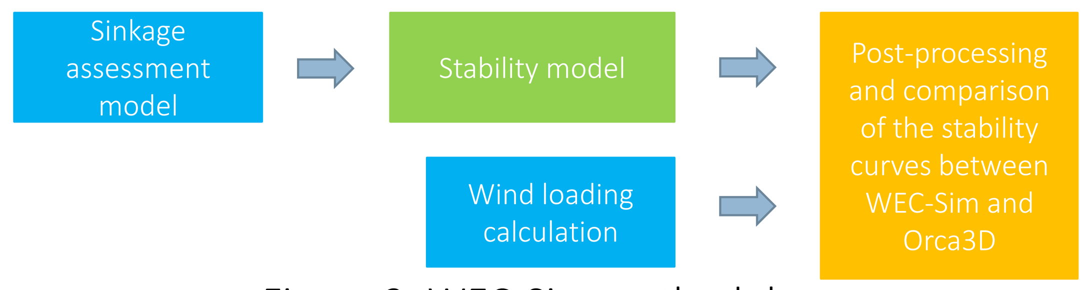

Figure 2: WEC-Sim methodology

Results

- Good mesh convergence both for WEC-Sim and Orca3D. Stability curves are very similar.
- The wind loading torque is obtained as the sum of the moment of the tower (M_{Tower}) and the blades (M_{Blades}) [5-9]:

$$M_{WindHeeling} = M_{Tower} + M_{Blades} = \left(\frac{1}{2} \cdot \rho \cdot \int_{Hmin}^{Hmax} c_{D_{Tower}} \left(V(H)\right)^2 H\, D(H)\, dH + \frac{1}{2} \cdot \rho \cdot C_{D_{Blades}} \cdot V_{H_{Rotor}}^2 \cdot WA \cdot H_{Rotor}\right) \cdot \cos(\alpha_{Heel})$$

Where ρ is the air density, $Hmin$ and $Hmax$ are the vertical distance from the COG of the structure to the bottom and top positions of the tower, c_D is the drag coefficient, $V(H)$ is the wind profile power law, $D(H)$ is the tower diameter profile, α_{Heel} is the angle of heel and WA is the total wing area of the 3 blades calculated from the chord profile and the blade length.

- A successful stability has been evaluated using the following stability criteria [10]:

$$\int_0^{\alpha_{Heel_{SI}}} M_{RestoringTorque} \geq 1.4 \cdot \int_0^{\alpha_{Heel_{SI}}} M_{WindHeeling}$$

Where $\alpha_{Heel_{SI}}$ is the angle of heel of the second intercept between the stability curve and the wind loading.

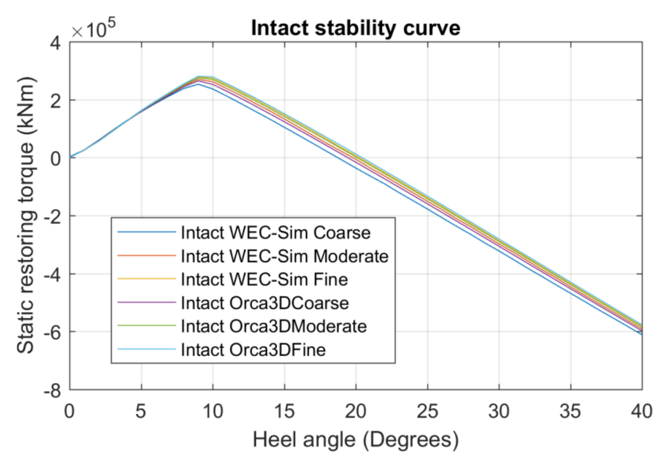

Figure 3: Mesh convergence

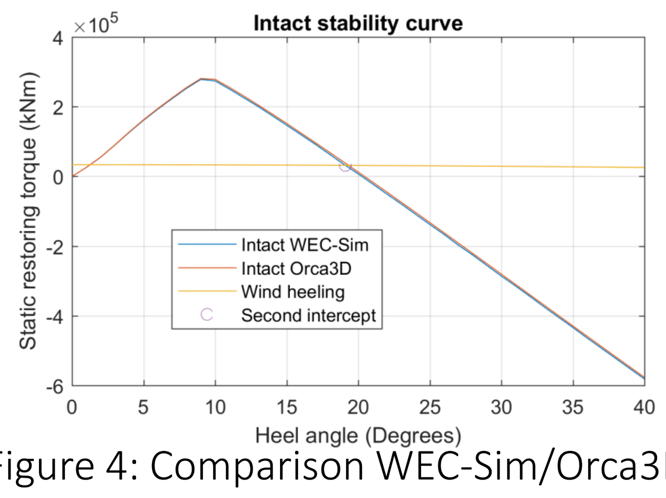

Figure 4: Comparison WEC-Sim/Orca3D

Conclusion and further work

- Very similar intact stability curve between Orca3D and WEC-Sim.
- Successful hydrostatic floating stability of the intact preliminary configuration of the platform.
- Computational time of WEC-Sim is larger because of the time domain simulation. However, only the initial timestep is used for the calculation of the restoring torque and so the simulation time can be very short.
- Further work will include a simulation option in WEC-Sim for the calculation of the stability curve without being necessary to run the time domain simulation.

References

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