VI. MARINE ENERGY CONFERENCE

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WAVE ENERGY EXTRACTION USING A BUOY WEC WITH AN IDEAL PTO

The aim of this poster is to analyse the behaviour of a vertical oscillating buoy on the water in terms of its model and the feedback of the system. First the model will be introduced, describing the forces acting over a submerged body subject to the effects of waves. The dynamical behaviour of the modelled buoy will be analysed looking to how the excitations force created by the incident wave affects the vertical displacement of the buoy. Secondly, the model of an ideal Power Take Off (PTO) energy extraction system will be developed, and the ideal power extracted will be analysed in terms of the variation of the damping parameter which represents the energy extraction. With this objective in mind, regular and irregular sea states will be used as input to analyse the system response in each case. [1]

MATHEMATICAL MODEL OF THE BUOY

The buoy can be represented as a floating body, which has 6 degrees of freedom (Figure 1), being 3 for the vertical, longitudinal and lateral displacement and the other 3 for the rotations over each of the axis. In this case the buoy has been ideally modelled with a degree of freedom, so it is assumed that the buoy oscillates vertically overlooking the rest of freedom degrees. The WEC is attached to the bottom with an energy extraction mechanism, represented according to a damping parameter, B. For this simple model, it can be assumed that the dynamical model can be represented by the Cummins, considering all the forces acting on a submerged body.

Where:

$$F_{exc} + F_{rad} + F_{res} + F_{fon} = m \cdot \ddot{x}$$

- **m** is the **mass** of the device
- **x** is the **vertical displacement** of the device, being $\dot{x}$ and $\ddot{x}$ the vertical velocity and acceleration, respectively.
- F_{exc} represents the **excitation force** caused by the incoming waves. It depends on the height of the wave and on the geometry of the oscillation body.
- F_{rad} represents the **radiation force** over the oscillation body moving on calm water caused by the waves created by the movement of the body itself. It depends on the size and geometry of the body and on the frequency of the oscillations.
- F_{res} represents the **restoring forces**, which are the forces that oppose to the oscillation. They are proportional to the position.
- F_{fon} represents the forces caused by the anchoring system.

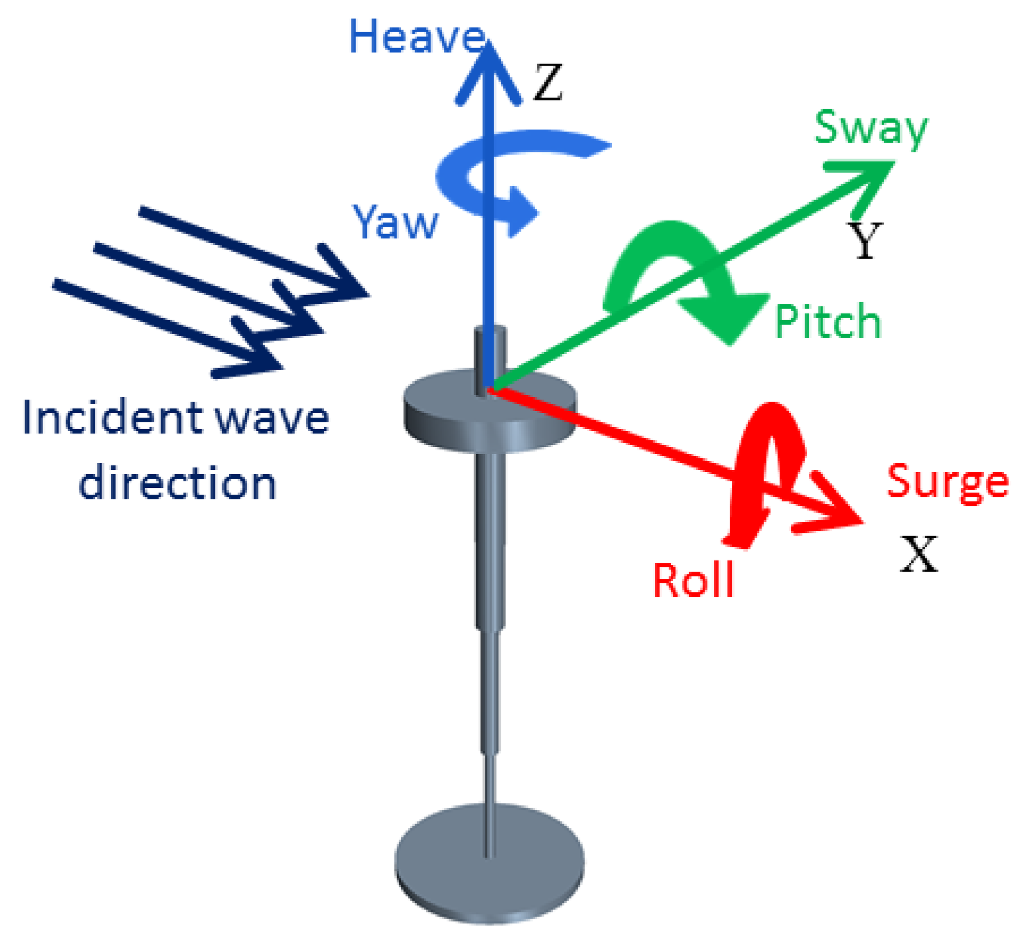


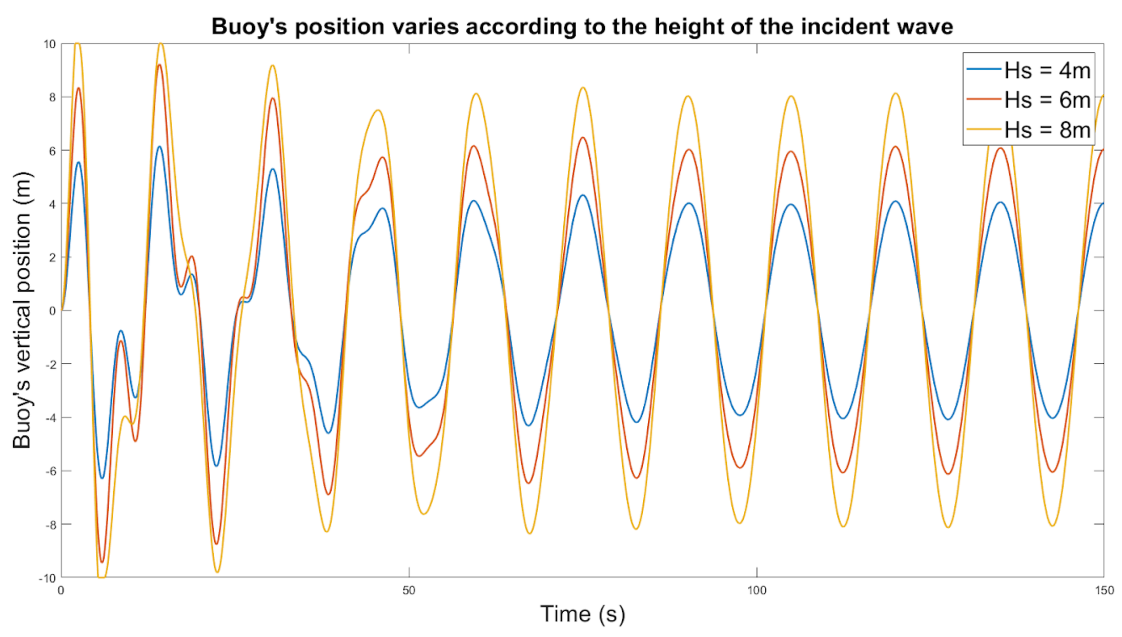
Figure 1: Non-linear model of a floating body on the water [2]

ANALYSIS OF THE BEHAVIOUR OF THE BUOY ON OPEN-LOOP

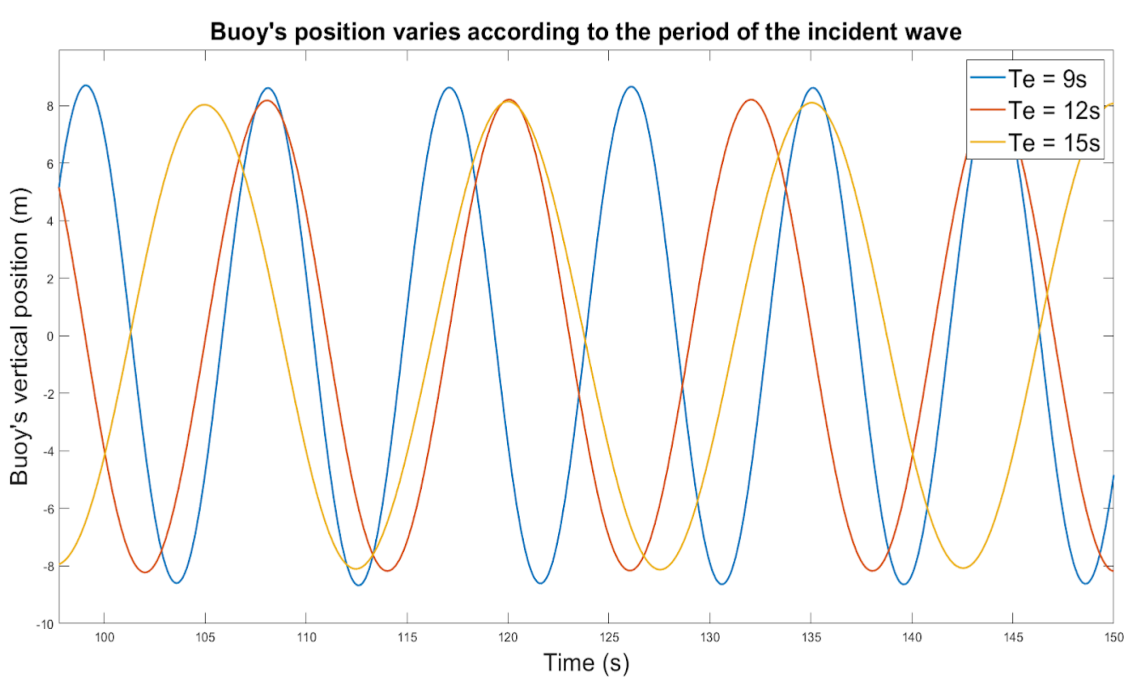
REGULAR SEA STATE

By changing the significant period of the wave (T_e) or the height (H_s), it can be observed the behaviour of the buoy regarding the amplitude and frequency of its vertical displacement.

- **For fixed T_e = 15 s.** For different H_s the frequency is the same while the amplitude increases up to the peak value of H_s. For greater H_s values, the system needs less time to stablish.

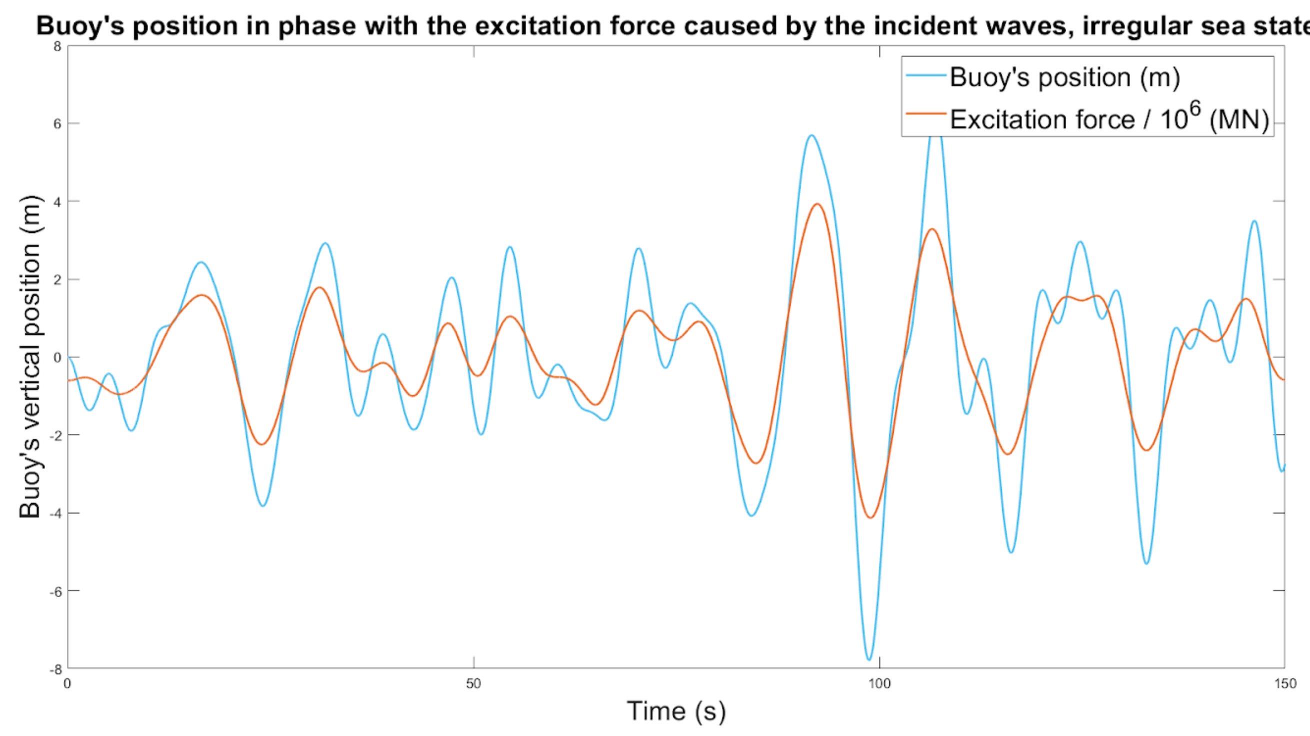


- **For fixed H_s = 8 m.** The amplitude takes similar values to H_s while for greater T_e the frequency decreases.



IRREGULAR SEA STATE

For an irregular sea state, each simulation will give back different results. In the example behind, there are different amplitudes and the frequency is not constant because the system does not get stablished. Note that F_{exc} is in phase with the buoy´s position.



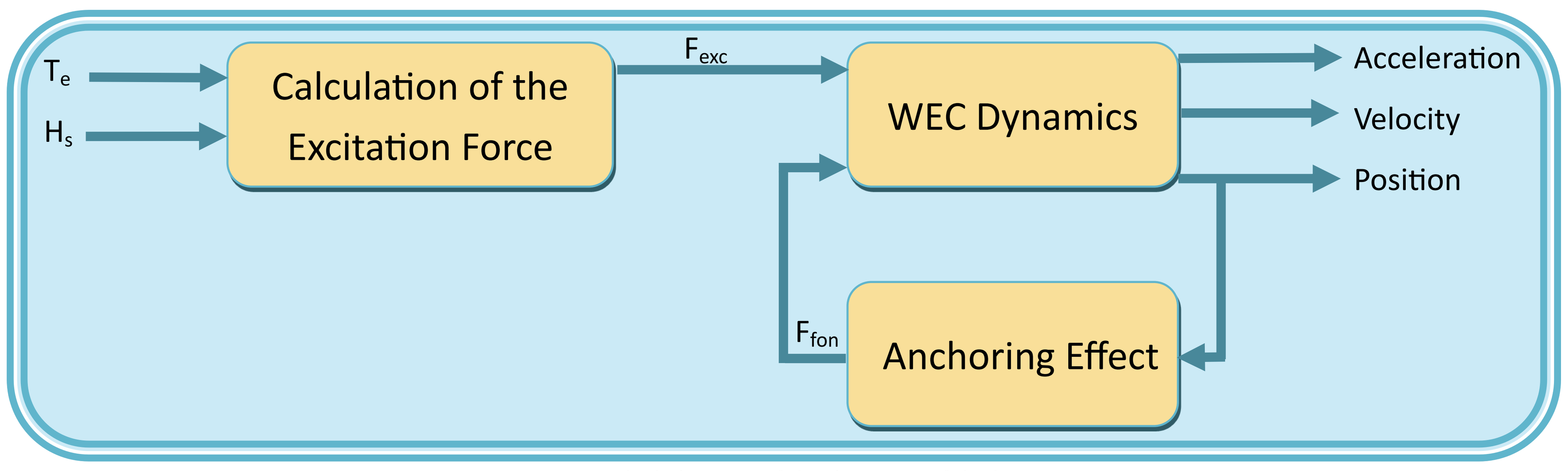


Figure 2: Block diagram of the dynamics of the buoy

FEEDBACK SYSTEM WITH AN IDEAL POWER TAKE OFF

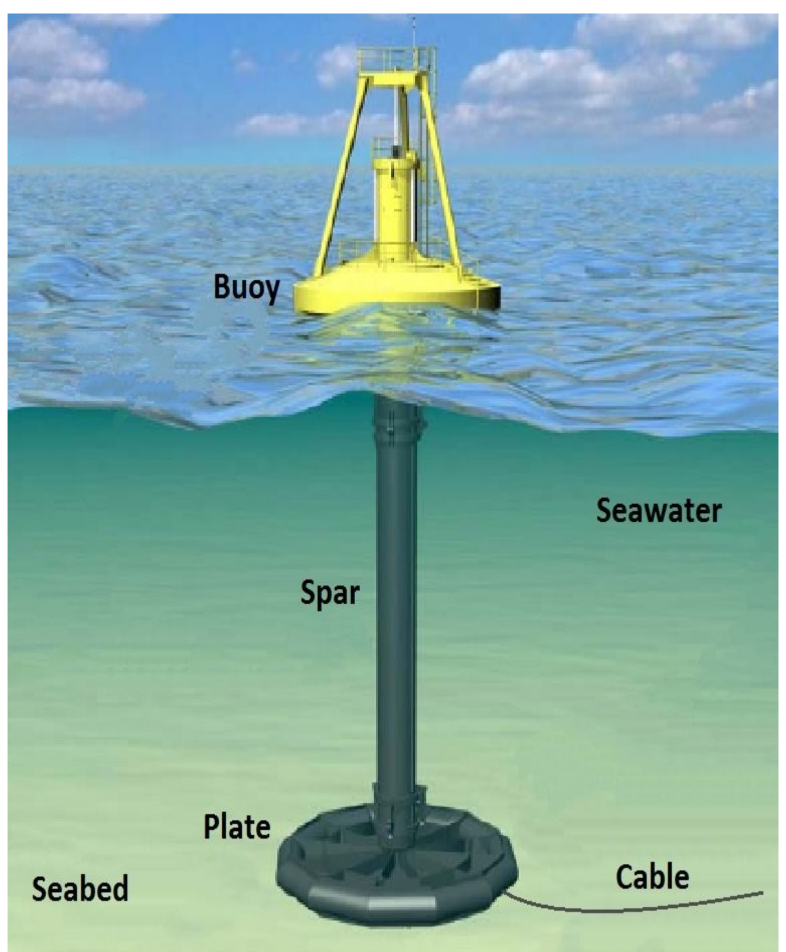
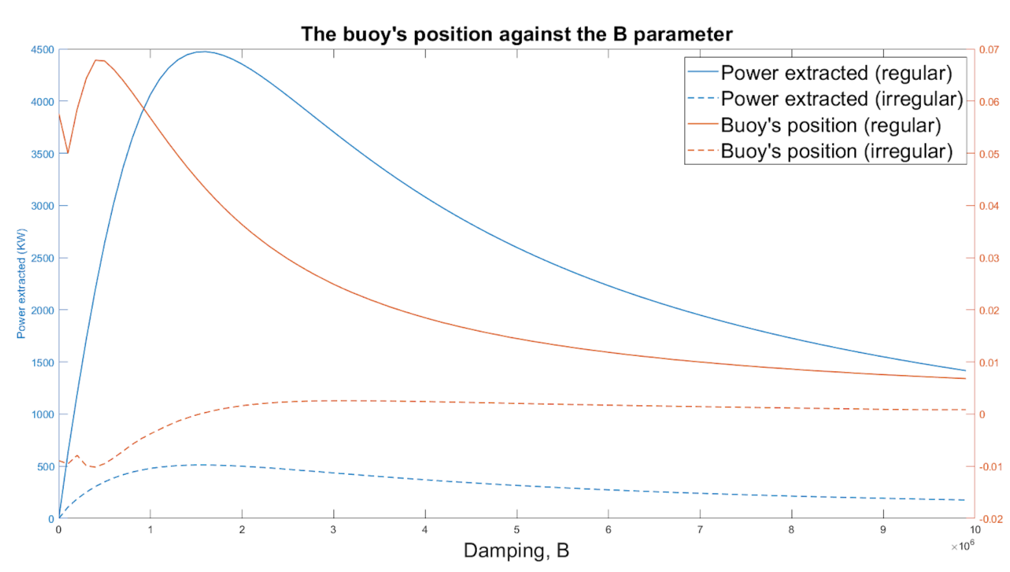
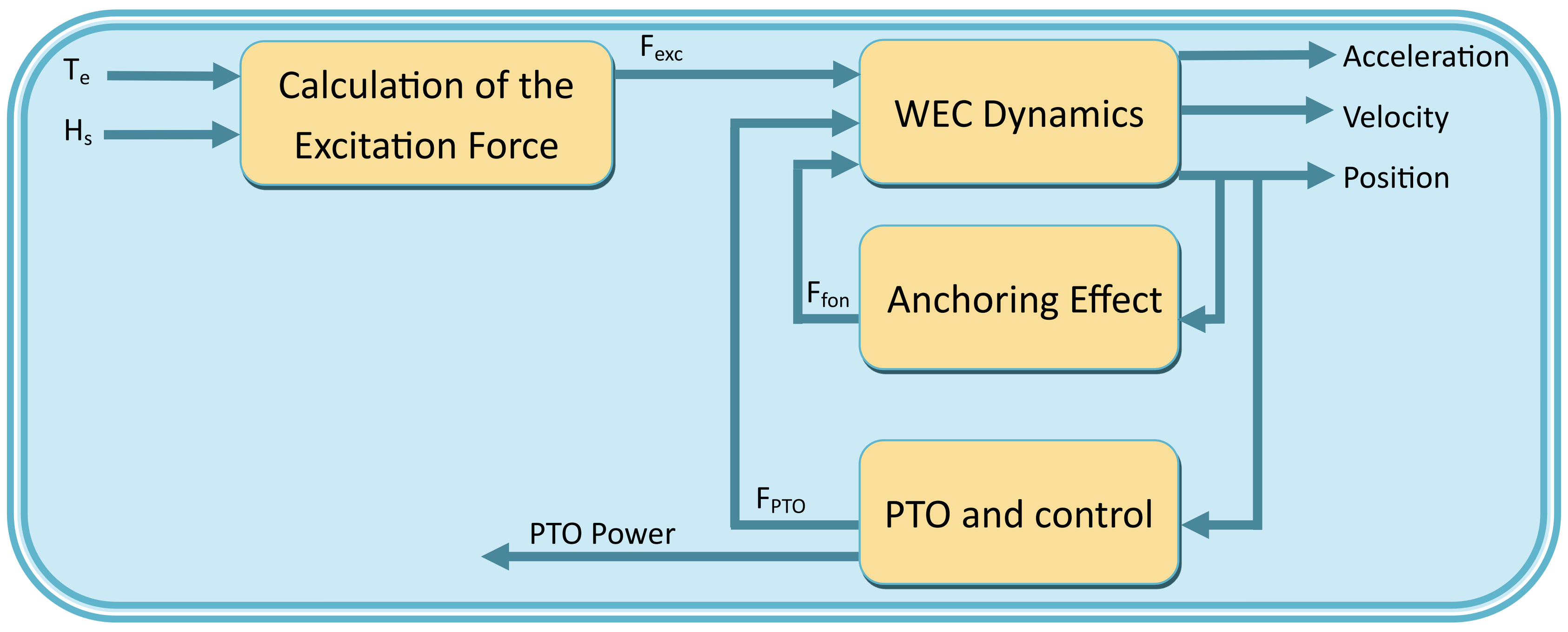


Figure 3: Point absorber [3]



The damping equivalent to the power take off (B_{PTO}) affects the position of the buoy, as well as the extracted power. The power extracted increases as long as the B_{PTO} is increased until it achieves its maximum value; then, it softly decreases.

- The optimal B_{PTO} is around 10^6 kg/s → P = 4063.5 kW and x = 0.0567 m.
- Up to that value → The extracted power increases with the damping.



CONCLUSION

- **Modelling of the buoy:** It is important to have in mind that even if when simulating the behaviour of the buoy under different conditions (e.g. H_s and T_e) a regular sea state is used, in the reality it will always predominate an irregular sea state. So, the results got from the regular sea state serve to get an idea of how the buoy is going to behave, but they are not representative of the final behaviour in real sea state.
- **Ideal power take off:** The approximate optimum value of the damping can be corroborated by looking the point in which the maximum power extraction is got. The maximum power extracted changes in function of the conditions of the sea state, but the optimum value of the damping is always the same.

[1] Wave energy extraction using a buoy Wave Energy Converter (WEC) with an Ideal PTO (Power Take Off) , Wave to control, UPV/EHU
[2] https://www.picswe.com/pics/point-absorber-buoyancy-unit-4b.html
[3] https://www.researchgate.net/figure/A-point-absorber-WEC_fig1_310748251

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