Expanding ISWEC Modelling with a Lumped-Mass Mooring Line Model

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Abstract— **The mooring system is a vital part of a wave energy converter. Nowadays no specific regulations exist about mooring design for these devices. Therefore the interaction between mooring and wave energy converters is still an interesting research topic in order to properly design a mooring line. This paper presents first results for the mooring system study and design of the ISWEC device. A mooring line layout is proposed according to the ISWEC requirements and then models are presented. Since the interaction with the mooring system is important for the correct evaluation of the forces acting on the hull, the research goal is to find the best balance between model accuracy and computational efficiency. Firstly, a simple quasi-static model has been implemented for testing the coupling with the already developed ISWEC numerical model. Later on, the lumped-mass mooring line model MoorDyn is introduced. Eventually, within the hypotheses done and the discussed limits, a comparison of the two different models is done with experimental data obtained in a tank test session on a 1:20 scaled device at Cork.**

***Keywords*— ISWEC, MoorDyn, Mooring, Lumped-mass mooring, Numerical modelling of mooring interactions, Model validation**

I. INTRODUCTION

For a wave energy converter (WEC) device, mooring requirements represent an important design consideration. Device survivability depends on the mooring. Generally speaking, a WEC needs to be kept in position by a station-keeping system in order to realize its functionality and ensure its safety. For floating devices, the station-keeping system is required to limit the excursion and orientation of the structure itself under the action of environmental forces from waves, currents and wind, even in the most severe storm conditions. In addition, the mooring system has to be cost effective so that the overall economics of the device remain viable. Nevertheless, in many cases moorings should be designed as an integral element of the system that contributes to power extraction efficiency (e.g. to keep devices at optimum orientation relative to the waves) [1].

Various authors have addressed the design of suitable mooring systems for WECs [2]-[7] but there is still no specific regulation for WEC moorings and research in the field is still maturing. At present, a starting point is represented by a range of rules, guidelines and regulations related to oil and gas platforms, published by various authorities such as DNV (Det Norske Veritas), API (American Petroleum Institute), and RINA (Registro Italiano Navale ed Aeronautico). These references are less than ideal, however, since they take into account stringent risks such as environmental pollution and even loss of life, which are not necessarily relevant to small unmanned devices like WECs.

In terms of WEC mooring design, several mooring types have been developed and different classifications can be found in literature [1],[6] based on the WEC's functionality and geometric characteristics. According to Harris et al. [1], the most suitable configurations for floating WECs are:

- Catenary Anchor Leg Mooring (CALM): the floating structure is linked to a catenary-moored buoy and it is able to weathervane around said buoy;
- Single Anchor Leg Mooring (SALM): the floating structure is linked to a single-anchored buoy and it is able to weathervane around it.

In order to improve the mooring line flexibility and compliance, particular layouts could be used that include risers and multiple catenary lines. The layout is influenced by the kind of motion that the device should be free to perform in order to extract energy and, where necessary, the requirement of orienting the WEC to the main wave direction.

Depending on the loads and on the installation costs it is possible to determine the necessary number of lines. Furthermore, a single line can be composed of different parts linked by springs, floats and clump weights, which can help to reduce loads and increase a WEC's vertical range of motion. Regarding the material of the mooring line, the choice is between synthetic rope, wire and chain. The latter is the most common because of its known reliability, resistance and cost characteristics. Lastly, anchors provide the fixed connection to the seabed.

During the first design stage, modelling is essential to setting up a suitable layout for a WEC's mooring system. This paper describes mooring modelling for ISWEC, a WEC design being developed at Politecnico di Torino based on a rocking hull and gyroscopic power take-off (PTO) mechanism. The ISWEC mooring system has to have specific characteristics in order to be compliant and to allow highly dynamic motion of the hull along the pitch degree of freedom (DoF). One of the main challenges with this system is finding a suitable mooring line model, in terms of accuracy and the corresponding computational expense of the simulation.

The aim of the paper is to add the mooring part of the model to the existing ISWEC Simulink model to obtain the *wave to wire* model useful in the pre-design of new devices. The objective is to develop a model capable to simulate at best the device behaviour experimentally verified.

After a brief description of the ISWEC device and its mooring requirements (II), the model description is done step by step, starting with a very simple quasi-static approach (III). Then MoorDyn (IV) is introduced and its validation with some experimental results is proposed. Section (V) is dedicated to the ISWEC model expansion, underlining the difficulties met at this stage. Eventually conclusions (VI) are discussed highlighting the needs of future work.

II. ISWEC AND ITS MOORING SYSTEM

A. System description

ISWEC (Inertial Sea Wave Energy Converter) [8], [9] is a system that exploits the gyroscopic reactions provided from a spinning flywheel for wave power conversion. The flywheel works inside a sealed hull floating body in order to be protected from the outer environment and to grant reliable and durable operation. An action torque is provided from the PTO on the gyroscope frame, allowing the energy conversion, while a reaction torque is given from the gyroscope to the hull. In this way the power transfer from the floater to the PTO is obtained. An illustration is provided in Figure 1.

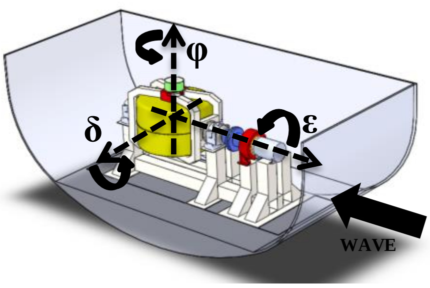

Figure 1. ISWEC layout concept

B. Hydrodynamics

In this paper the attention will be focused on the hydrodynamics model of ISWEC, developed by using the Cummins matrix equation in time domain, without gyroscopic contributions [11], [12]:

$$(M_F + A_\infty)\ddot{X} + \int_0^t h_{r\dot{X}}\,(t-\tau)\dot{X}(\tau)d\tau + KX = F_w + F_m, \quad (1)$$

In this equation the hydrodynamics of the floater is considered to be linear and its interaction with the external environment are represented by the wave forces F_w and the mooring forces F_m.

C. Mooring system

The ISWEC mooring system has been designed in order to match these characteristic needs:

- to ensure device survivability
- to restrain the maximum hull excursion within its reserved sea area
- to assure the hull self-orientation with the incoming wave direction
- to not interfere with the hull pitching motion which is opportunely controlled to harvest the wave energy

Basically, the full scale prototype mooring system belongs to the single point type, however it presents some peculiarities. From bottom to top it is composed as follows. Four anchors are positioned on the seabed over a circumference such that the angular distance among them is equal to 90 degrees. From each anchor a chain extends to reach a connection point placed upward with respect to the seabed, identifying a sort of virtual seabed; in this way the seabed abrasion of the chain is avoided and the working angle for the anchors is granted. From the virtual seabed a single chain line goes up vertically to a submerged buoy (referred to as the *jumper*), then a second chain links the jumper to a clump weight. A third chain segment, which present a symmetric bifurcation, links the line to the ISWEC through two hawseholes placed at the hull bow, symmetric to the centerline. The system from the virtual seabed upward is shown in Figure 2.

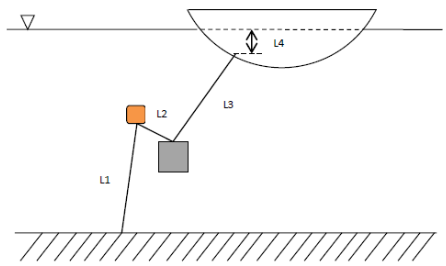

Figure 2. ISWEC mooring system concept

This configuration presents different advantages: the load on the main line is distributed among four different lines and so four anchors; the single line system allows the hull rotation around the jumper and its positioning toward the incoming wave direction. However, the most important part is the single line going from the jumper to the clump and then to the hull: this line acts as a spring that increases its restoring force as the hull displacement increases, limiting the hull excursion. On the other hand, it can absorb extreme waves' actions, avoiding snap loads on the mooring line.

III. Quasi-static Model

In the quasi-static model, hydrodynamics of the hull is still modeled by using Cummins equation, while the restoring force of the mooring line is given by a steady state response varying the surge displacement along different equilibrium conditions. This simplified model even though its limits is useful in order to have a first response on how the system works apart from an order of magnitude of its stiffness.

The mooring line is modeled starting from the virtual seabed that ideally represent a fixed point. The problem is considered to be two-dimensional and so it is studied on the x-z plane as shown in Figure 3. The remaining three parts of the mooring line are modeled as three different rigid bodies. The jumper and the clump weight are respectively represented by a buoyancy restoring force and a weight force.

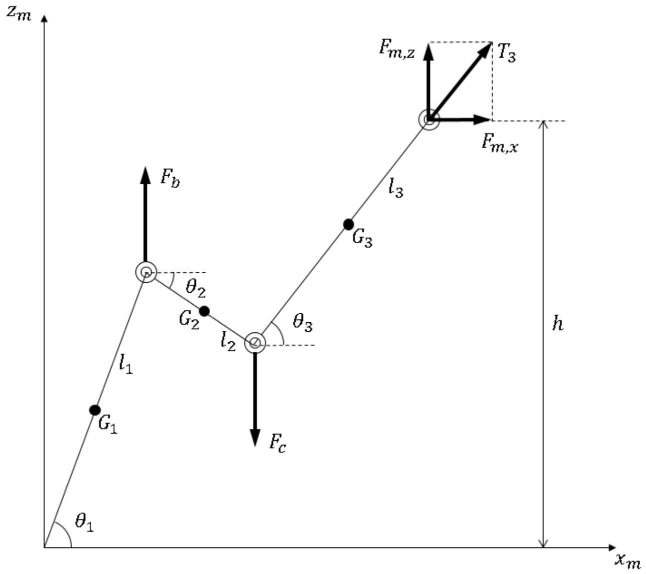

Figure 3. Quasi-static model scheme

The maximum hull distance from virtual seabed is given by the geometrical properties of mooring:

$$x_{max} = \sqrt{(l_1 + l_2 + l_3)^2 - h^2}, \qquad (2)$$

For each possible surge displacement value the potential energy is calculated as a function of θ_1. The equilibrium condition is found where the potential energy U reach its minimum value and so the mooring line geometric configuration. Referring to Figure 3, the U function can be easily written as:

$$U = F_c * z_B - F_b * y_A + m_1 g * \frac{l_1}{2} sin\theta_1 + m_1 g * \left(l_1 sin\theta_1 - \frac{l_2}{2} sin\theta_2\right) + m_3 g * \left(l_1 sin\theta_1 - l_2 sin\theta_2 + \frac{l_3}{2} sin\theta_3\right), \quad (3)$$

Once θ_1 is known, one can calculate other angles (θ_2 and θ_3) and tensions (T_1, T_2 and T_3). The tension on the last chain line T_3 is eventually decomposed on the x-z plane in order to be inserted in the Simulink model. The resulting behaviour of the two components $F_{m,x}$ and $F_{m,z}$ for the 1:20 scaled model are displayed in Figure 4.

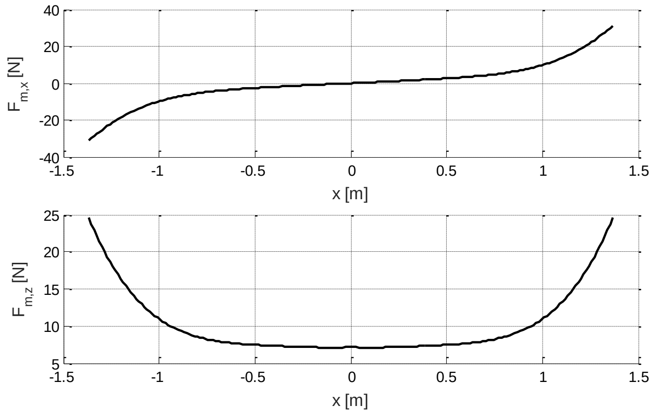

Figure 4. Quasi-static surge-forces characteristics

IV. Dynamic Mooring Model

A. MoorDyn Model Description

The dynamic mooring model used in this work is MoorDyn, an open-source lumped-mass model, developed at University of Maine, that supports dynamic simulation of interconnected mooring lines along with weights and floats in the mooring system. It has previously been validated for catenary chain moorings of a floating wind turbine tested at 1:50-scale.

MoorDyn models individual mooring lines as concatenations of point masses connected by spring-damper elements, as shown in Figure 5. The masses represent the distributed mass of the line, the springs represent the axial stiffness of the line, and the dampers represent a small internal damping force that, while not corresponding to a physical characteristic, provide necessary damping to the model's discretization.

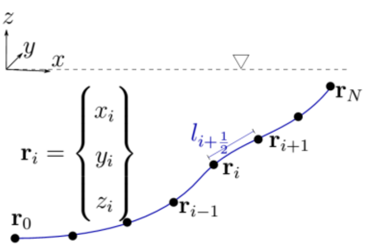

Figure 5. Mooring discretization and indexing

A given line has N elements, connecting N+1 node points including the bottom ("anchor") node and the top ("fairlead") node. Each line is represented as a cylinder with diameter d, total unstretched length L, and density ρ. The stiffness is then determined by Young's modulus, E, and the internal damping is determined by coefficient B, which relates stress to strain rate and has units of Pa-s. The unstretched length of each segment is $l_0 = L/N$ and the net weight (subtracting buoyancy) is

$$W = \frac{\pi}{4} d^2 l(\rho - \rho_w), \qquad (4)$$

where ρ_w is the water density.

The model is designed to represent mooring systems where bending and torsional stiffnesses are of negligible importance, such as chain-based systems; therefore, only axial stiffness is considered and compression is not modelled. In other words, the axial force in each line segment i is calculated as

$$T_i = \begin{cases} EA\left(\frac{l}{l_0} - 1\right), & l > l_0 \\ 0, & l \le l_0 \end{cases}, \qquad (5)$$

Hydrodynamic forces, including drag and added mass, are accounted for using Morison's equation in both transverse and tangential directions. These forces are calculated at each node. The line tangent direction at each node, $\hat{\mathbf{q}}_i$, is approximated to be the average direction of the two connected line segments. If C_{dn} is the transverse drag coefficient and C_{dt} is the tangential drag coefficient, then the transverse and tangential drag forces are, respectively

$$\mathbf{D}_{pi} = \frac{1}{2}\rho_w C_{dn} dl \|(\dot{\mathbf{r}}_i \cdot \hat{\mathbf{q}}_i)\hat{\mathbf{q}}_i - \dot{\mathbf{r}}_i\| [(\dot{\mathbf{r}}_i \cdot \hat{\mathbf{q}}_i)\hat{\mathbf{q}}_i - \dot{\mathbf{r}}_i], \quad (6)$$

$$\mathbf{D}_{qi} = \frac{1}{2}\rho_w C_{dt} dl \|(-\dot{\mathbf{r}}_i \cdot \hat{\mathbf{q}}_i)\hat{\mathbf{q}}_i\| [(-\dot{\mathbf{r}}_i \cdot \hat{\mathbf{q}}_i)\hat{\mathbf{q}}_i], \qquad (7)$$

The added mass matrix for each node is constructed as

$$\mathbf{a}_i = \rho_w \frac{\pi}{4} d^2 l \, [C_{an}(\mathbf{I} - \hat{\mathbf{q}}_i\hat{\mathbf{q}}_i^T) + C_{at}(\hat{\mathbf{q}}_i\hat{\mathbf{q}}_i^T)], \qquad (8)$$

Where C_{an} and C_{at} are the transverse and tangential added mass coefficients.

Bottom contact, while a modelling option in MoorDyn, is not encountered in the present work.

Assembling the various forces gives the following 3-by-3 matrix equation of motion for each node:

$$(\mathbf{m}_i + \mathbf{a}_i)\ddot{\mathbf{r}}_i = \mathbf{T}_i + \mathbf{C}_i + \mathbf{W}_i + \mathbf{D}_{pi} + \mathbf{D}_{qi}, \qquad (9)$$

where $\mathbf{m}$ is mass matrix, $\mathbf{T}$ is tension force, $\mathbf{C}$ is damping force, and $\mathbf{W}$ is net weight.

The equation matrix for a connection node is simply the summation of the equations of motion for the end nodes of each connected line. The right-hand-side terms of this equation are all functions of $\mathbf{r}_i$ and/or $\dot{\mathbf{r}}_i$. Accordingly, the second-order system of ordinary differential equations can be reduced to a larger system of first-order ordinary differential equations with the substitution $\mathbf{y}_i = \dot{\mathbf{r}}_i$. MoorDyn represents the entire mooring system as a system of equations with the following form:

$$\begin{bmatrix} [\mathbf{m}_1 + \mathbf{a}_1] & 0 & 0 & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 & 0 & 0 \\ 0 & 0 & [\mathbf{m}_N + \mathbf{a}_N] & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{I} & 0 & 0 \\ 0 & 0 & 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & 0 & 0 & \mathbf{I} \end{bmatrix} \begin{Bmatrix} \dot{\mathbf{y}}_1 \\ \vdots \\ \dot{\mathbf{y}}_N \\ \dot{\mathbf{r}}_1 \\ \vdots \\ \dot{\mathbf{r}}_N \end{Bmatrix} = \begin{Bmatrix} \mathbf{RHS}_1(\mathbf{r}_1, \dot{\mathbf{r}}_1, t) \\ \vdots \\ \mathbf{RHS}_N(\mathbf{r}_N, \dot{\mathbf{r}}_N, t) \\ \mathbf{y}_1 \\ \vdots \\ \mathbf{y}_N \end{Bmatrix}, \quad (10$$

Each 3-by-3 mass sub-matrix can be inverted independently, and the resulting system of differential equations is solved numerically using a second-order Runge-Kutta integration scheme with constant time step.

B. Comparison with experimental data

This section compares mooring tension predictions made with MoorDyn with experimental data from tank testing of a scale-model ISWEC device. In the experimental campaign, both the hull motion and mooring forces were measured. For this analysis the Simulink model of the ISWEC hull is not used; rather, the hull motions measured from the experiment are prescribed to MoorDyn. Time-histories will be shown, showing the good capabilities of the model but also some problems encountered with the validation.

All waves given to the system are regular. The first case is shown in Figure 6. The calculated tensions match very well the experimentally measured ones, including both frequency and amplitude of the load peaks.

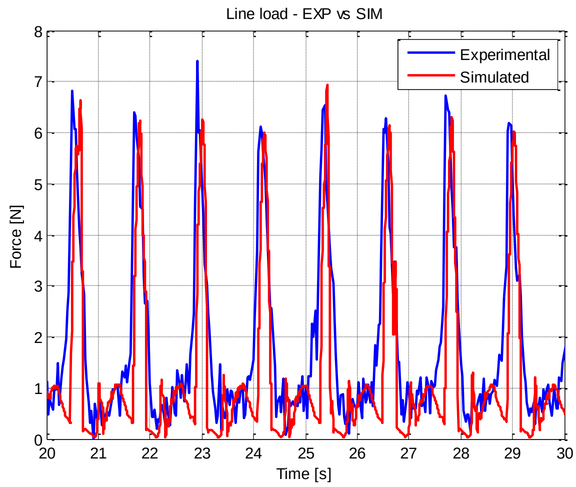

Figure 6. Wave: regular, period 1s, amplitude 100mm.

These kind of results suggest that the model is adequate for taking into account the complex dynamics of the mass-jumper mooring system.

Some problems were encountered with the test data comparison. These tests were not originally planned for this kind of comparison, but only for scaling up considerations, so some of the parameters useful to the model are not measured from the experiments but instead identified after the fact in data analysis, especially those concerning the absolute position of the fixed anchor point. Accordingly, since the input of MoorDyn is the position of the joints, it is clear that a bad starting offset positioning influences the simulated results. This effect is especially emphasized when high surge values arrive, and the highly nonlinear part of displacement-load characteristic of mooring system is encountered.

To demonstrate this, Figure 7 shows a test in which simulated forces actually overestimate experimental values. This is due to the yaw hull's motion starting position which is not accurate. It causes tensions rise and fall following this tilting movement. Simulated results don't show this behaviour.

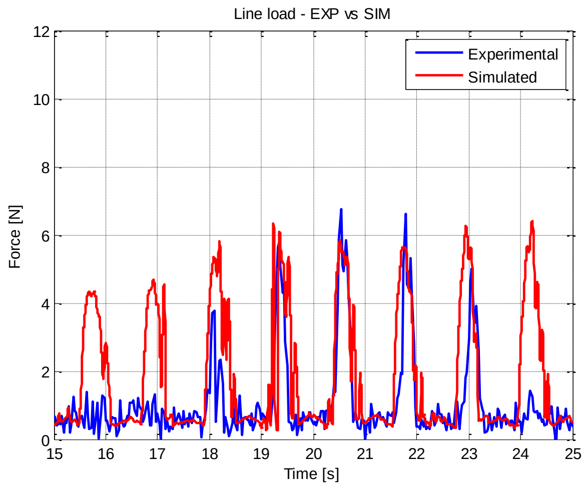

Figure 7. Wave: regular, period 1.5s, amplitude 140mm.

At the end of this comparison phase, MoorDyn has been considered suitable for modelling purposes. In the following part of the paper, its implementation in the ISWEC numerical model will be described.

V. Expanding ISWEC modelling

The MoorDyn software was coupled with the ISWEC hydrodynamic model. In Figure 8 the new functional diagram is presented. The Cummins equation model receives as input two forces: the first from incoming waves and the second from the mooring system. As output, it gives kinematic of the hull, which serve as input to MoorDyn.

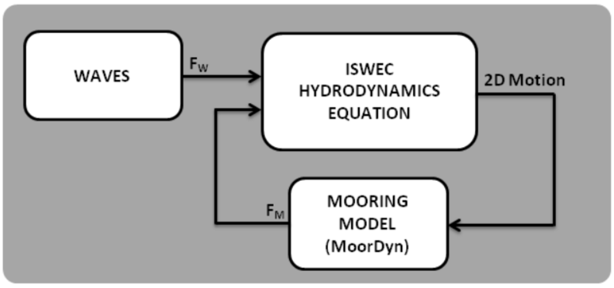

Figure 8. ISWEC hydrodynamic expanded model functional diagram.

The ISWEC numerical model is implemented in Matlab/Simulink environment. MoorDyn is a compiled dynamic link library (dll), with an internal integrator. For coupling procedure, it is necessary that this subsystem be called at a constant coupling time. This is done by a triggered subsystem, while integration with dll is achieved with an embedded Matlab function. This guarantees some flexibility in management of code, but for faster time simulations, an S-function could be used as well.

The first step of model expansion involves considering the entire planar problem. To the initial model which considered only pitch, heave and surge are added. In the next two sub-sections, surge and pitch degrees of freedom are examined.

A. *Surge*

In the first part of the work, the planar problem is considered and some simulations are carried out. With these it is possible to illustrate limitations of this hydrodynamic model with surge motion. Two different situations are presented.

In first case excitation forces are computed with next formula:

$$F_{EXC\ ii}(t) = H \sin(|f_{ii}|\omega t + \langle f_{ii} \rangle)\ , \qquad (11)$$

where: H and ω are wave amplitude and frequency, ii is desired DOF, f_{ii} is ii^{th} DOF Froude-Krylov coefficient. In Figure 9 results are shown. According to our system of reference, surge motion, x, direction is coherent with the incoming wave direction. This can be seen clearly in the first plot, where x continuously moves in the positive direction.

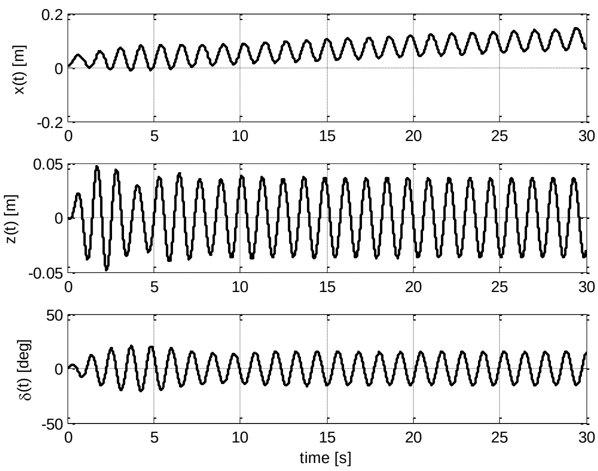

Figure 9 . Planar problem without mooring model. Wave: regular, period 1.2 s, amplitude 80mm. Starting with positive values.

The test is now repeated, with the only difference of adding one more extra phase equal to π to the excitation force, in this way, at initial time, the force starts with negative values. As can be seen in Figure 10, this causes the hull to move in the opposite direction, contrary to empirical observations. The main information which is missing in this hydrodynamic model is wave direction, that in case of surge DOF brings to the presented catastrophic results.

There is a lack of modelling; this is clear since Froude Krylov force hypothesis is that the hull does not disturb the waves. So the surge excitation force is symmetrical with mean around zero. The introduction of second-order terms as already studied in literature will be integrated into the model in future works.

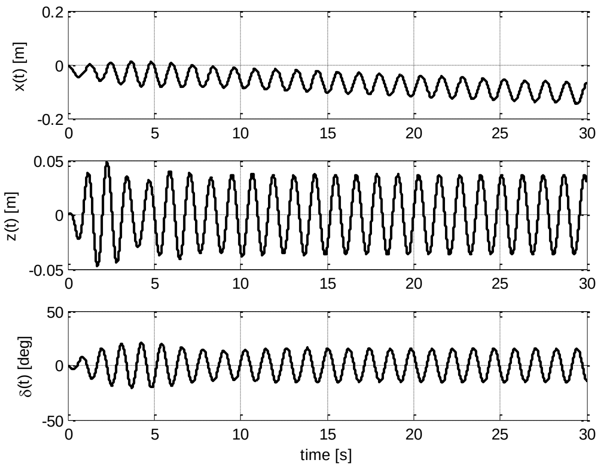

Figure 10. Planar problem without mooring model. Wave: regular, period 1.2 s, amplitude 80mm. Starting with negative values.

For the purpose of this paper, thanks to empirical data taken in a previous experimental campaign at the HMRC (Cork, IRL), it is possible to identify some mean surge loads which push the hull.

For introducing the hull wave interaction in this model, a coefficient that is a function of wave height and period is proposed. This brings excitation force on surge DOF to have the next expression:

$$F_{EXC\ surge}\,(T) = H\,|f_{ii}(T)|\sin(\omega T + \langle f_{ii}(T)\rangle) + \sigma_{fkc}(H,T), \qquad (12)$$

where σ_{fkc} is surge Froude-Krylov correcting factor.
This assumption can be supported also with experimental data. In Figure 11 the steady state surge position has been reported as a function of wave height. The four curves represent four different wave periods. Provided that, there is a linear relation between surge and x fairlead tension, an assumption acceptable in a certain range as shown with quasi static model characteristic (Figure 4), it can be seen that steady state force is increasing linearly with wave height. The modification of forcing period changes the slope of the regression but not its linear nature.

A linear approximation is not possible, since F(H=0) is not equal to zero. For this reason an exponential term is multiplied to the equation. It yields a function of the type hereafter shown :

$$f' = \left(1 - \frac{1}{e^{x/T_c}}\right)\cdot(mx+q), \qquad [mm] \qquad (13)$$

With this correction all curves have the F(H=0) = 0 N point (Figure 13).

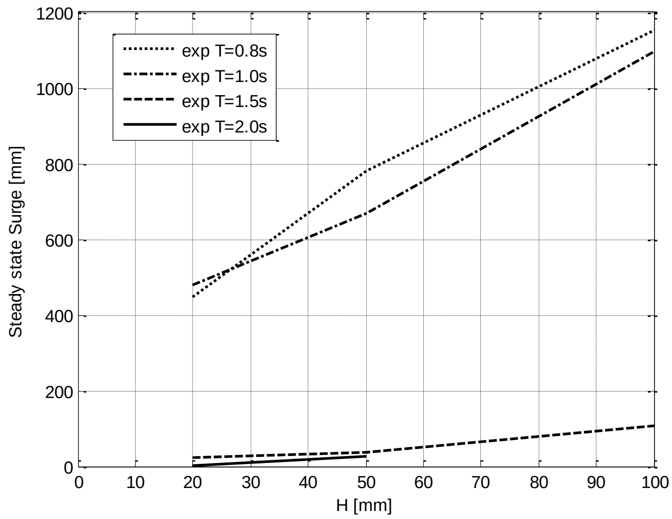

Figure 11 . Experimental data, ISWEC 1:20 scale model. Steady state surge position in function of wave height H and wave period T.

Then, since this parametric curve is only a function of wave height, another dependency is introduced, in order to take into account the effect of the period. The most natural parameter choice seems to be the surge radiation damping coefficient. This is normalised over the parameter of the curve on which the parameter is fitted. In our case it is T=0.8s. The equation becomes:

$$f'' = f' \cdot \frac{|B_{ii}(T)|}{\left|B_{ii}(T)_{Texp}\right|} \quad [mm], \qquad (14)$$

Now, looking at the quasi-static mooring model force-displacement characteristic and linearizing it, using this linear stiffness (K_{QS}), the relationship between steady state surge position and forces can be made:

$$\sigma_{fkc} = \left(1 - \frac{1}{e^{x/T_c}}\right)\cdot(mx+q)\cdot K_{QS}\cdot\frac{|B_{ii}(T)|}{\left|B_{ii}(T)_{Texp}\right|}, [N] \quad (15)$$

In Figure 12 the relation between wave period and surge damping coefficient is shown.

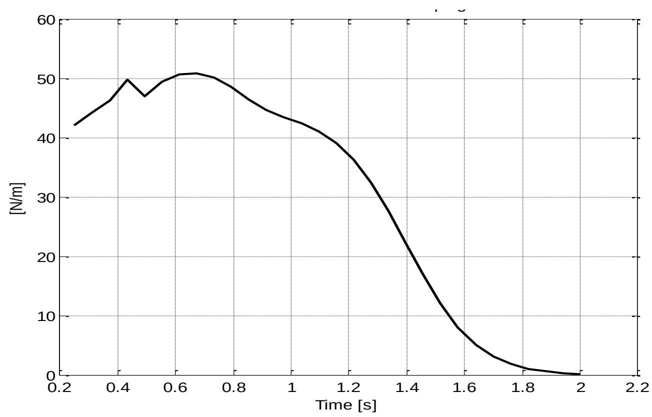

Figure 12. ISWEC 1to20 surge damping coefficient. Evaluated with Ansys AQWA.

Then, m and q parameters are identified starting from the curve of period equal to 0.8 seconds. Using this analytical relation, other curves are calculated and shown in Figure 13.

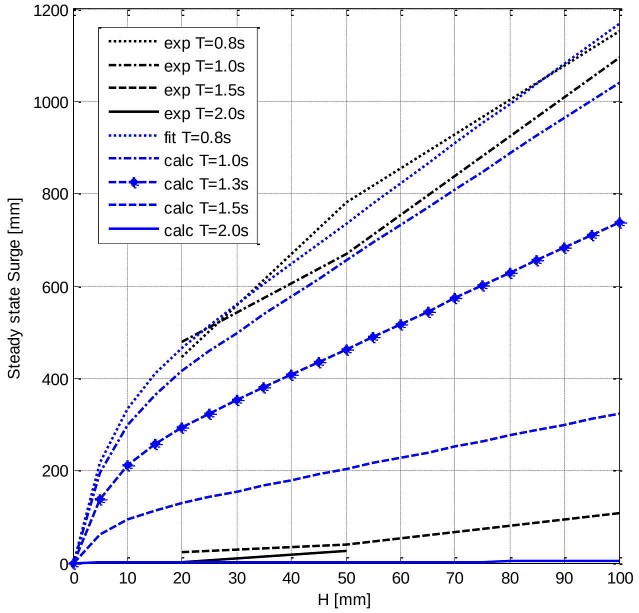

Figure 13. Comparison between experimental and calculated steady state surge curves

Some considerations are needed. The general trend of the curve appears as good. Looking to the actual values, only the upper curves seem to approximate well, meanwhile the T=1.5 seconds curve seems to be not so good. This identification and modelling procedure will be also object of further study.

Anyway the most important thing is that in this way, the ISWEC model is upgraded and can be coupled with MoorDyn, which is the main objective of the current work.

In Figure 14, time simulations are shown with the ISWEC expanded model, including MoorDyn mooring model.

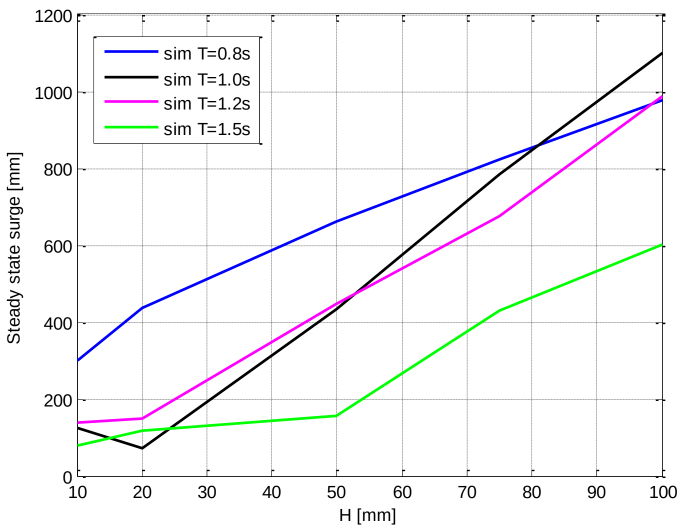

Figure 14 . Simulink model coupled with MoorDyn. Surge steady state curves.

From the results it appears that the curve with T=0.8s, with which parameters are identified, gives surge steady state positions in accordance with experimental data, while other curves presents different kind of problems. Probably there is a lack of modelling, or some functional relationship is not linear. This problem will be investigated, also with the help of specific experimental test campaign. One of the possibility could be the develop of a test rig for measuring the mean surge excitation force acting on the hull, so that mooring lines nonlinear effects can be excluded.

B. *Pitch*

The most important degree of freedom of ISWEC device is pitch. This is in fact responsible for the forces exchanged between the mechanics and the waves. At his point, after the surge DOF has been introduced into the model, a comparison between one degree of freedom model and expanded models is possible.

The first series of simulation are carried out with a one degree of freedom system. The model with pitch only is the actual model that is used in other work for analysis of the entire electro-mechanical ISWEC model. The second kind of simulations consist of the complete planar problem, with three DOFs: surge(x), heave(z) and pitch(δ). This is coupled with the quasi-static (QS) mooring model. In the third set of simulations, the planar problem is coupled with MoorDyn as previously described.

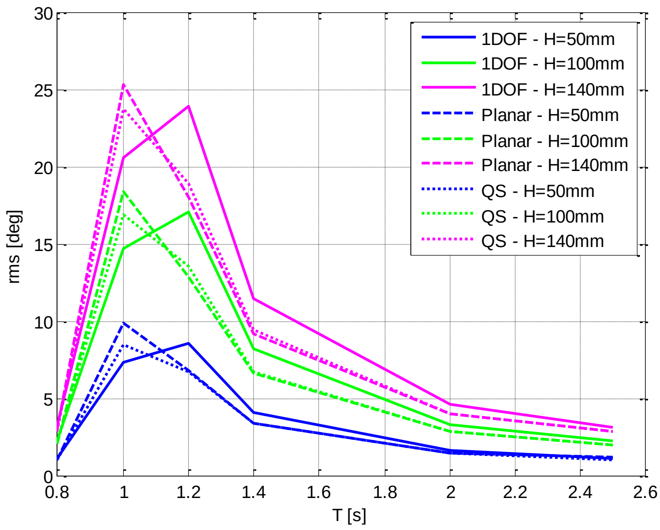

Figure 15. Comparison between steady state rms pitch values, pitch DOF model, ISWEC planar model coupled with quasi-static model and ISWEC planar model coupled with MoorDyn.

An interesting result is seen by evaluating the effect of mooring system on the system's most important DOF, pitch. In Figure 15 root mean square value of pitch at steady state condition is presented. A few observations can be made. Both mooring models dampen the RAO peak period and bring it to lower periods. The mooring system dampens pitch motion in almost the complete working period range, but seems to not dampen the pitch motion at low periods. Some more work should be done for a more accurate understanding of this behaviour, but it must be remembered that the opening of new DOFs also implies more excitation forces incoming into the system. This fact is relevant because of the high Froude Krylov coefficient for surge at low periods.

C. *Examples of time history results*

In this section, some time-domain simulation examples are presented. The MoorDyn mooring model is used.

In Figure 16, the simulation data obtained with an excitation force of period 0.8s and height 75mm is presented. The first transient is shown. The wave starts at the starting time of the simulation and is ramped with a slope of ten seconds. The behaviour of surge, heave and pitch is shown.

In Figure 17 the entire time record of the surge is shown. It can be seen that the mooring system causes the hull to move like a classical second order system. This is confirmed also by experimental data.

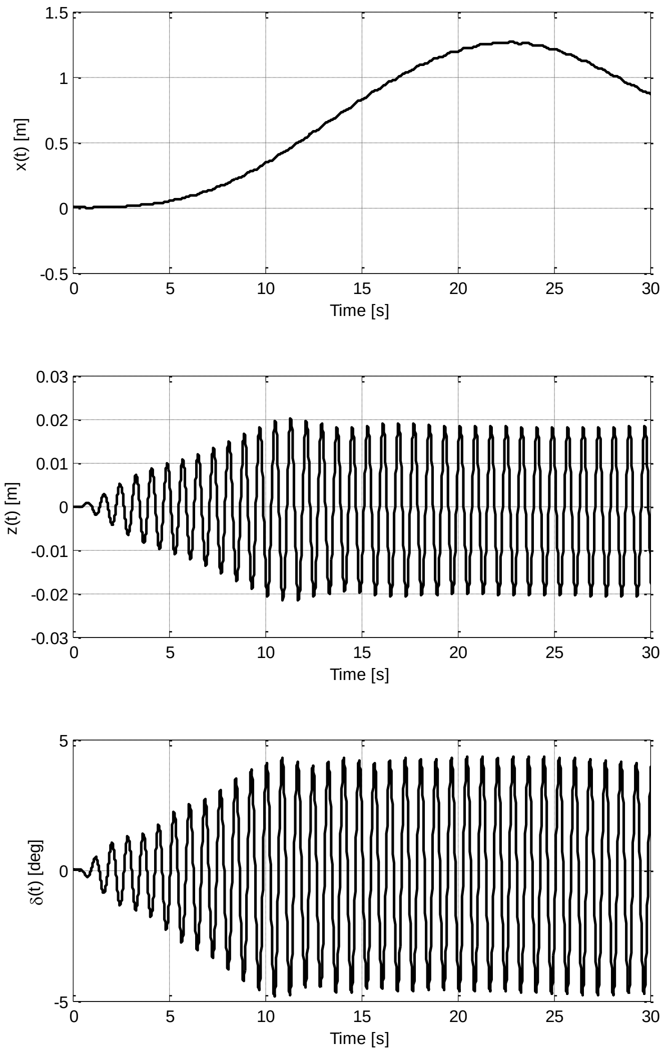

Figure 16. Time history results. Excitation wave: period 0.8 s height 75 mm.
The first transient is shown.

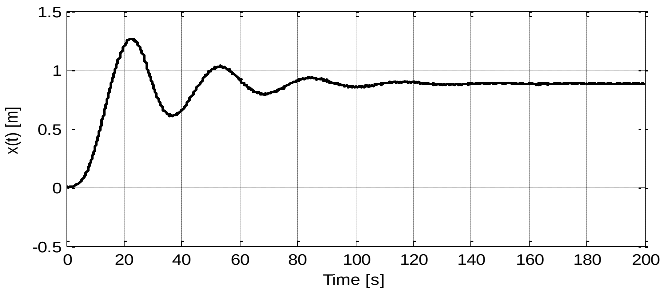

Figure 17 . Time history results. Excitation wave: period 0.8 s height 75 mm. Surge is presented over the entire time record.

VI. CONCLUSIONS

With this work, the ISWEC hydrodynamics model and MoorDyn have been coupled, with ISWEC Matlab/Simulink as the master of the numerical model and MoorDyn as a dynamic-link library.

Some comparisons with experimental data verified the suitability of the MoorDyn model for representing the complexities of the ISWEC mooring system. However, the addition of two new degrees of freedom to the ISWEC model, especially surge, brought new problems to the full-system modelling. A new function is proposed in order to make up for the missing surge force modelling; only qualitative results are reached so far. This can be related to choosing not the most suitable surge force mean value function.

Further development of the work could include more focused tests, in order to identify better relations and parameters of the entire system. Then, more extensive modelling and comparison with test data could be conducted.

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