Surface Pressure Integration of Point Absorber

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WAVESTAR

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Introduction

The scope for this research is the floating point absorbers used in the Wavestar wave energy project. The floats on the current prototype have a diameter of 5 m and therefore cannot be assumed to be slender i.e. D/L not small. This extends the problem outside the boundaries of undisturbed wave pressures since the wave-structure interaction will affect the pressure field.

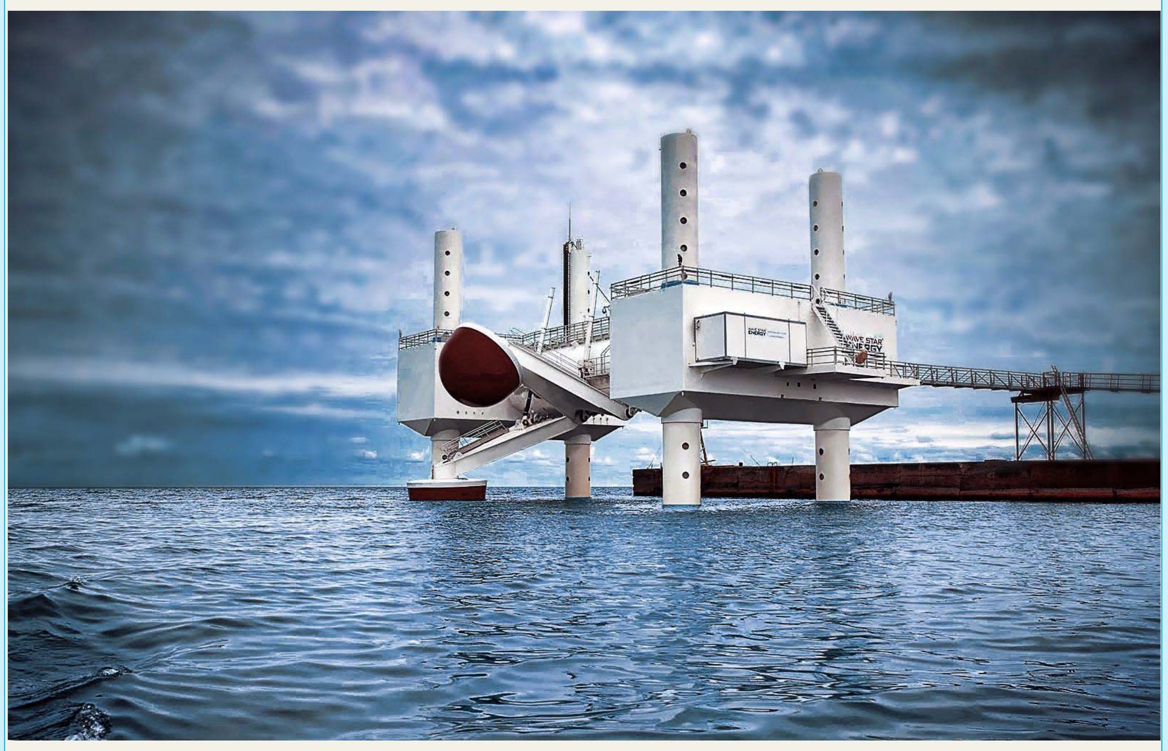

Figure 1: Wavestar prototype in calm water conditions outside Hanstholm, Denmark. One float raised to safety position.

Pressures on float shell point absorber is investigated to obtain knowledge about pressure distribution and peak pressures and forces. The problem is investigated from an experimental and numerical approach whilst using an analytical approach on less complex geometries to verify model validities.

Pressures

When examining the pressures excited on the structure, there are two different views on the results – obviously the pressures are used to obtain the forces for the wave energy device, but also a better understanding of the distribution of, and peaks in, pressure is needed to design and preserve the structural integrity of the exposed structure i.e. the float in this case, see Figure 2.

Figure 2: Fractured glass fiber prototype float.

The pressures for the structural design will not be commented further in this study, but will be extracted as an additional result when the pressure field is described.

Scaling

To be able to compare the results from the different approaches both the numerical and experimental investigations will be carried out on a 1:20 scale model of the prototype i.e. Ø 250 mm.

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Undisturbed Pressure Field

As mentioned the pressure field cannot be expected to behave as undisturbed, but this is still a relevant case to study since this can be used as a baseline to describe the difference between the disturbed and undisturbed case. In Figure 3 an undisturbed wave is seen passing "through" a float.

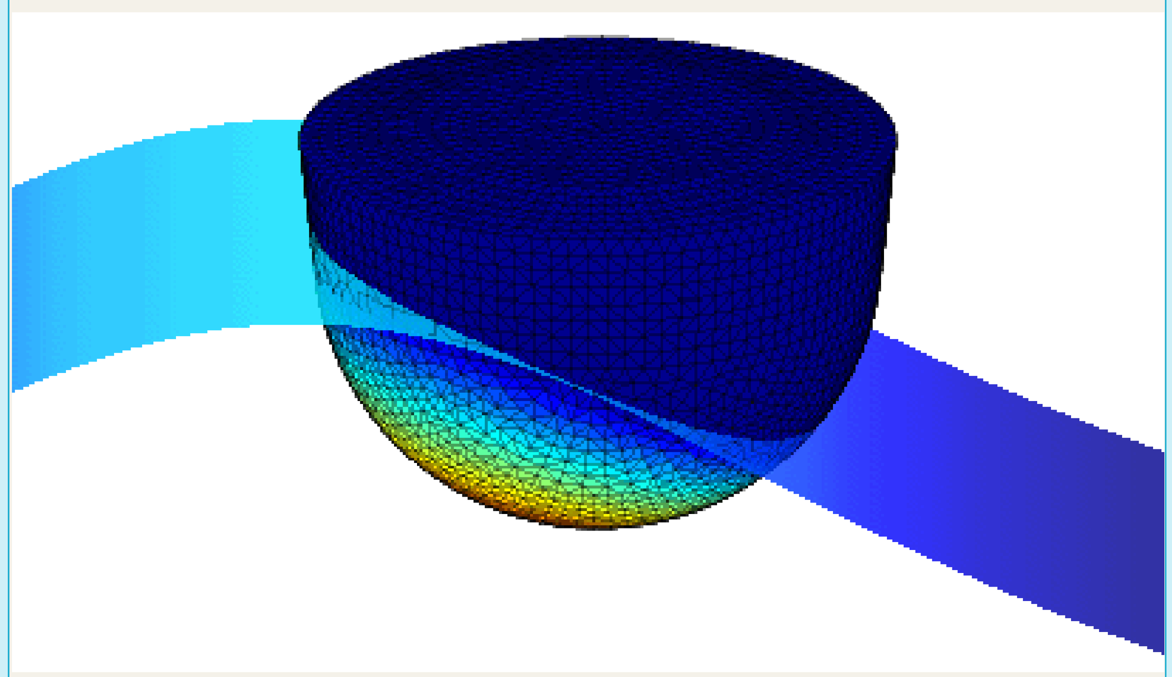

Figure 3: Undisturbed wave pressures on float.

The undisturbed pressure field have been described with Stokes 1st order, Stokes 5th order and Deans stream theory for regular waves. For irregular waves Stokes 1st order theory with superposition is used.

Element Model

To evaluate the pressures and forces on the float an element model is constructed from a CAD data and loaded into MATLAB where centroid, area and normal is calculated for each panel.

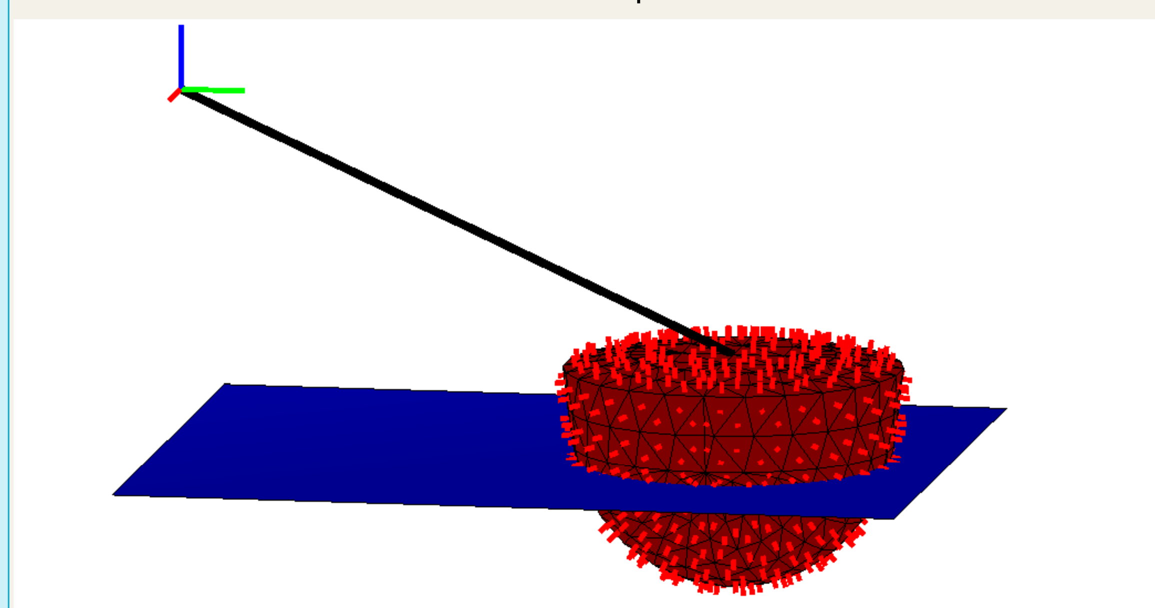

Figure 4: Element model used in MATLAB with normals and mean water level for illustrative purposes.

Forces and Moments

The force on the structure can be solved through the Froude-Krylov theorem. When the pressure field and element model is established, the Froude-Krylov force can be numerically solved as follows:

$$\vec{F}_{FK} = -\iint_{S_w} p\,\vec{n}\,ds$$

$$\vec{F} = -\sum_{i=1}^{n} p_i\,A_i\,\vec{n}_i$$

$$\vec{M} = -\sum_{i=1}^{n} \vec{a}_i \times (p_i\,A_i\,\vec{n}_i)$$

$\vec{F}_{FK}$	Froude-Krylov force
S_w	Wetted surface
p	Undisturbed pressure
$\vec{n}$	Normal vector

$\vec{F}$	Force vector
$\vec{M}$	Moment vector
p_i	Pressure at element centroid
A_i	Area of element
$\vec{n}_i$	Normal vector of element
$\vec{a}_i$	Arm vector of element

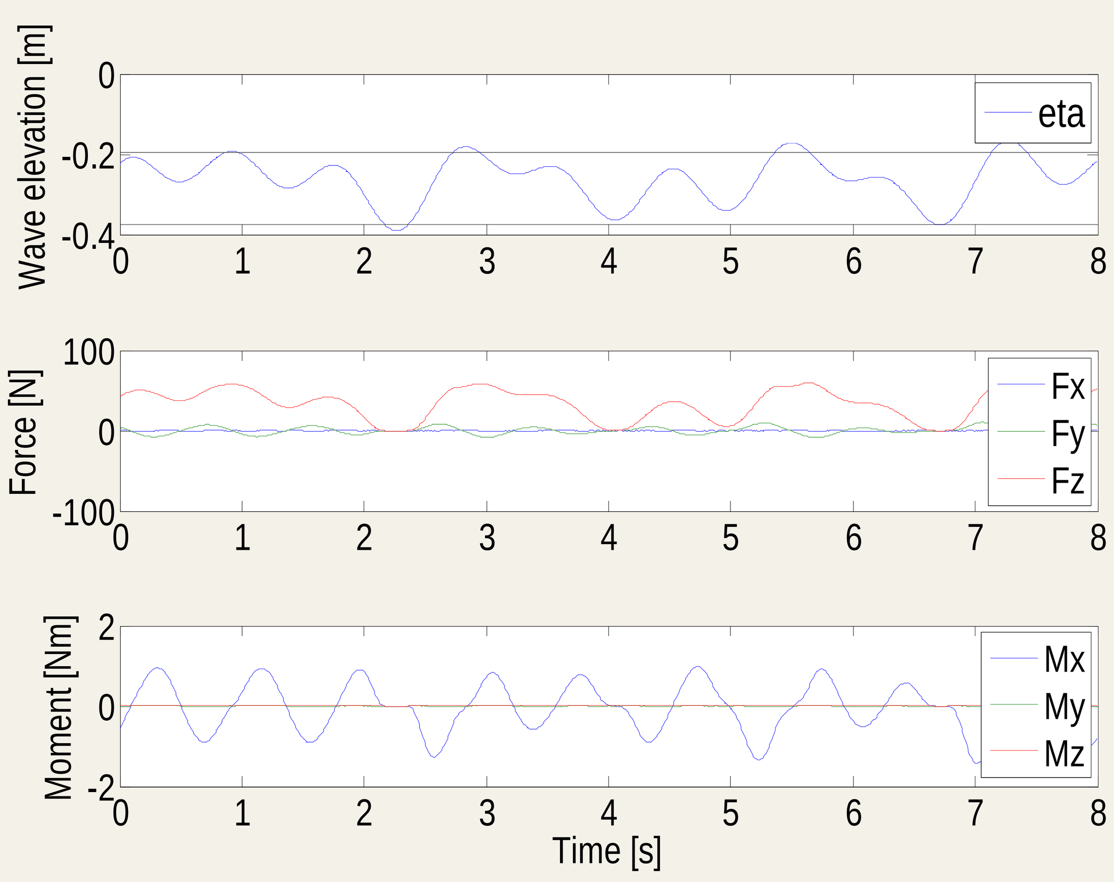

Figure 5: Water elevation, forces and moments exciting the float when pressure field is considered undisturbed.

Disturbed Pressure Field - Numerical

Evidently the wave will not pass the structure undisturbed. To solve the pressures and forces on the float, in a pressure field affected by wave-structure interaction, the numerical tool WAMIT is used. WAMIT is a linear radiation/diffraction panel program which solves the interaction by using sources/sinks at each panel in order to solve the Laplace equation to get the velocity potentials.

Disturbed Pressure Field - Experimental

Experiments are carried out in the deep water wave basin at Aalborg University. A Ø 250 mm glass fiber float is mounted on a 6-axis F/T-transducer, and in the shell of the float 13 pneumatic pressure sensors are installed. The float is kept stationary in the waves around the natural buoyancy level to exclude influences from the dynamic motion. In other experiments the floats motion is governed by a causal control strategy.

Figure 6: Model used in experiments equipped with pressure sensors and a 6-axis F/T-transducer.

Comparison of Results

The final result of this research is to determine coefficients linking the undisturbed and disturbed pressures. The idea is to be able to describe design pressures and forces on the float while only knowing the wave conditions on the desired site i.e. the undisturbed pressure field.

From the numerical analysis both pressures and forces are obtained and are to be compared to the undisturbed results. For the experimental analysis only forces and moments are obtained, but is still a valid result to compare the magnitude in relation to the undisturbed.

Further Studies

For the disturbed numerical solution some more parameters could be taken into account to obtain better results:

- Introduce the correct motion of float instead of a fixed body
- Apply higher order waves to investigate more complex waves

For the experimental part it could be interesting to expand the investigation to also include:

- Motion of float as it would be though correct control strategy
- Interaction between more floats placed in a parallel system

Figure 7: Glass fiber float on pivot arm in wave basin.

References

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