Dynamic Response of the Stationmar Heave-Compensated Floating Platform Concept: A Brief Summary

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1.Background

The Stationmar concept consists of a floating platform with an air chamber below its hull, which aims to keep the platform buoyancy constant, thus effectively reducing heave motion and improving its use under harsh environmental conditions such as in the North Sea or Norwegian Sea.

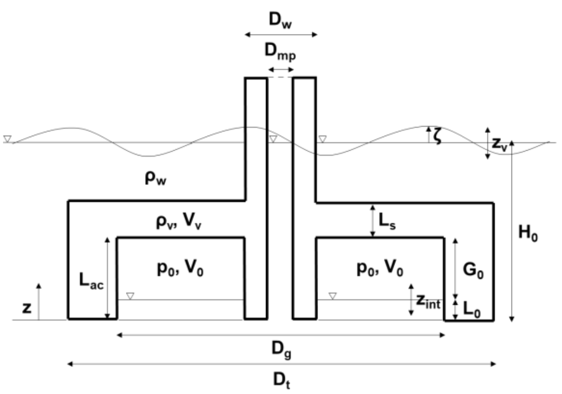
It is informed based on the tests performed at Evje (in 2020), that for this type of concept, the compression of the air chamber due to a hydrodynamic transient pressure pulse leads to a reduction of the buoyancy effect that results in a (close to) net zero vertical force.

In relation to ocean wave dynamics, this effect needs to be investigated in more detail. The reason is that dynamic surface pressure fluctuations attenuate with depth, and the decay is more rapid the higher the wave frequency (i.e. the shorter the wave period) becomes. At a water depth corresponding to e.g half the wave length, the pressure fluctuations are strongly reduced. Accordingly, it is expected that the compression of the air chamber becomes accordingly reduced (somewhat depending on the location of the chamber).

Hence, the variation of the dynamic response of the platform concept as a function of wave frequency has been studied in the attached paper, Ref. [1], based on a “macroscopic” model. (It is noted that more detailed studies also including dynamic pressure propagation paths in the fluid should be performed, as phase lag effects in relation to the dynamic water surface pressure and the pressure at the air-water interface at the chamber have not been included in the model).

2.Platform models and method of analysis.

The equations of motion for a generic platform concept are first established, and subsequently a particular case study is performed. Figure 1 (based on Ref. [1]) gives an illustration of both these two models.



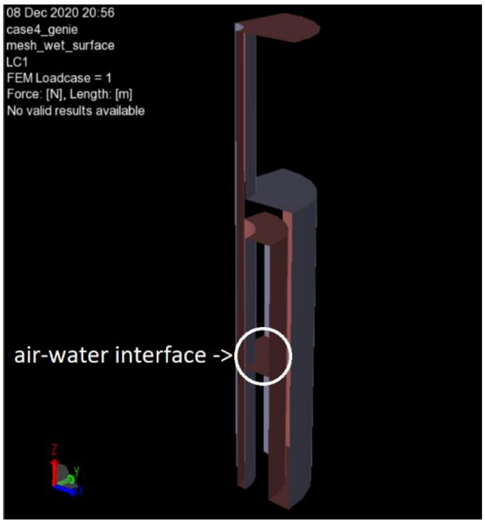


Figure 1. Generic (left) and specific (right) platform concepts

The hydrodynamic coefficients (i.e. force, added mass and damping) are calculated using potential flow theory. The effects of taut mooring lines are represented by means of a linear spring model. In addition to a nonlinear dynamic time domain analysis model, a linearized model is also developed. The latter model allows investigation of the influence of the air chamber and the mooring system on the response amplitude operator (RAO) by means of a closed-form solution.

There are some limitations associated with the present analysis method. This comprises mainly the following: (i) The hydrodynamic coefficients (i.e. force, added mass and damping). This is expected to have some effects on the dynamic response, but not to invalidate the main trends. (ii) Effect of a phase lead of the downwards hydrodynamic pressure over the upwards hydrodynamic pressure at the air chamber-fluid interface is not taken into account (which most likely is a beneficial

3. Dynamic response levels

Calculations in both the frequency and time domain are performed, and results show that the addition of both the air chamber and the mooring lines is the most beneficial scenario, especially in terms of heave reduction at lower frequencies (long periods). This can be summarized by the frequency domain results for the Response Amplitude Operators which are shown in Figure 2 (from Ref.[1]). From the figure, it is also seen that another observed benefit was the change in resonance peak away from the typical observed range of wave frequencies in the sea.

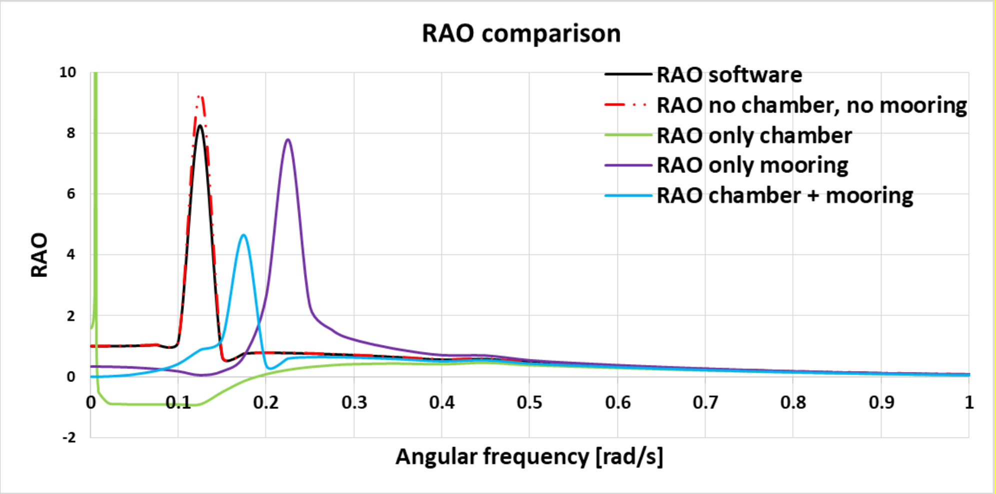


Figure 2. Dynamic floater response amplitude (per meter wave height) as a function of frequency (RAO) based on a linearized analysis for the specific platform concept (with mooring). Cases with/without air chamber and with/without mooring are included.

5.Conclusions

1. The overall conclusion is that the addition of an air chamber to the platform is beneficial in terms of heave reduction for long period waves, and the reduction is even larger if it is combined with addition of mooring lines. For such long period waves, the combination of air chamber and taut mooring implies that zero heave motion can be achieved. This even holds for the case that the beneficial phase effect in connection with the air chamber compression has been taken into account.

2. For short wave periods (high frequencies), the effect of the air chamber (for the presently studied layout of the concept) is found to be reduced. The response for a platform with or without an air chamber tend to coincide in the high frequency region.
3. In the intermediate range of wave periods (and frequencies), there is a heave motion resonance peak for which strong dynamic amplification occurs. The value of the frequency where this peak is located depends on whether the air chamber is present or not, and it also depends on the vertical mooring line stiffness. The magnitude of the peak also depends on the same parameters.
4. The magnitude of the resonance peak is likely to be influenced (most probably reduced) by the phase effects related to compression of the air chamber. These effects are not included in the presently applied response analysis model.
5. The location of the resonance peak can to some extent be influenced by the designer based on choice of relevant design parameters that influence the stiffness and/or the mass properties of the platform.

6.Further work in terms of proposed priorities:

1.Relative phase effect in relation to dynamic pressure variation at the ocean surface and at the chamber-fluid interface as a function of frequency. This is best studied by first performing numerical analysis by means of Computational Fluid Dynamics (CFD), that could be followed by laboratory testing in an ocean basin (at different scales).

2.Application of the Stationmar concept for floating wind turbines. This is presently an on-going study as part of the work by the Brazilian PhD-student Paulo Kiryu, which is based on the same type of macroscopic model as described in Ref.[1]. Also here, there could be potential for additional CFD-studies.

3.Further investigation of pitch motion characteristics must be performed. At the moment, mainly the global stability in terms of metacentric height has been considered, but the corresponding pitch response amplitudes have not yet been analysed. E.g. for the case of floating wind turbines, the magnitudes of the static and dynamic pitch angles are very important design issues.

4.Second-order dynamic load effects that could give rise to low-frequency resonance effects. This can e.g. be based on hydrodynamic load calculations by means of the computer program WAMIT or WADAM (HYDRO-D).

7.Reference:

Jaculli, M. A.; Leira, B. J.; Sangesland, S.; Morooka, C. K.; Kiryu, P. O. (2021): “Dynamic Response of a Novel Heave-Compensated Floating Platform: Design Considerations and the Effects of Mooring”, submitted for Ocean Engineering, January, 2021