OFFSHORE FLOATING PLATFORMS

EXPERIMENTAL ANALYSIS OF A SOLUTION FOR MOTION MITIGATION: THE HEAVE PLATES IN **SATH**

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1 Abstract

This study covers an experimental analysis of the pressure levels recorded on the heave plates of a new concept of floating platform —SATH, developed by Saitec Offshore Technologies— during some wave tank tests performed in the facilities of IHCantabria, in Santander (Spain).

These 1:35-scale tests (modelled following Froude's similitude) simulated a 2-MW-turbine prototype, under sets of linear monochromatic waves aligned with the platform's bow-to-stern axis, as in a pure heading sea, in deep water.

The motion of floating platforms, in contrast to that of a fixed structure, tends to have an important contribution in the accelerations of the fluid around it, causing instantaneous pressure increments in the structure. With this study, the author wanted to investigate whether the magnitude of the pressure is related with simple motion indicators, such as the acceleration vector normal to the heave plates in the steady-state oscillation, for structures in which the motion of the heave plates is not negligible compared to the wave amplitude.

2 SATH

The experimental data was gathered from tank tests on a scale model of SATH (Swinging Around Twin Hull), which is a new concept of floating platform for wind turbines developed and owned by Saitec Offshore Technologies.

SATH technology incorporates several characteristic features worth pointing out. First, the whole structure is made of prestressed concrete, improving fatigue life and minimizing corrosion, usual in offshore steel structures. As for the geometry, the two identical hulls provide the needed buoyancy and stability, while the heave plates around the structure improve damping and hydrodynamic performance in general.

The heave plates are the core of the study presented here. Since they are rigidly attached to the main body of the platform, they accelerate the fluid when the platform oscillates in pitch, roll or heave.

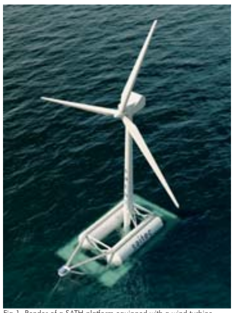

Fig 1. Render of a SATH platform equipped with a wind turbine.

3 Objectives

Time series of tank tests were used to identify the averaged peak pressure level, both in every face of the plate and as a net pressure defined as the absolute difference between the two.

The main objectives of this study were:

- Identify the magnitude of the pressure and how it changes with the characteristics of the incident wave: wave height H and period T, helping in a subsequent structural analysis of the structure.
- Compare the variation in the magnitude of the net pressure with simpler general motion indicators, such as the normal acceleration to the face of the plate, defined in terms of the measured pitch, heave and surge motions.

4 Method and data acquisition

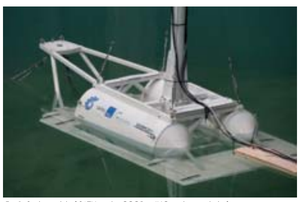

Fig 2. Scale model of SATH, in the CCOB in IHCantabria, right before a wave test.

The experimental tests included 25 series of monochromatic waves of diferent wave heights and amplitudes, in a deep water environment, which were used in the data collection for this study.

Data acquisition: two custom-made submersible pressure transducers —Honeywell 40PC series—, with a pressure rZange of 0-15 psi were used to measure the dynamic pressure (meaning all pressure components not included in the static pressure as measured before the test begins). Sampling frequency on these transducers was 50 Hz.

For motion tracking, a Qualisys system was used, with a set of 4 infrared cameras and a sampling frequency of 100 Hz.

In every time series, the transient part was disregarded and the peaks identified in the stationary signal.

Fig 3. Qualisys Oqus 3+ (L) and Honeywell 40PC (R), from catalogue

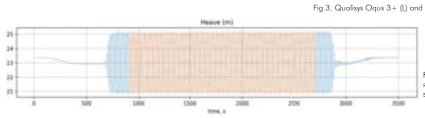

Fig 4. Heave motion time series. Sample of signal taken from Qualisys, with the selected stationary part to be used in the analysis.

The time series of the acceleration at the center of the bow heave plate was computed by combining those in heave, pitch and surge (as in the equation that follows —rigid body mechanics—). The peaks identified in these series were then compared to the magnitude of the pressure for the corresponding regular wave (H, T) that caused them.

In the following equation, a_{pl} is the plate acceleration, and is computed from the linear acceleration in surge ($\ddot{\eta}_1$) and heave ($\ddot{\eta}_3$). The angular acceleration in pitch ($\ddot{\eta}_5$) also causes an acceleration on the plate proportional to the lever arm r.

$$a_{pl} = \ddot{\eta}_1\, sin(\eta_5) + \ddot{\eta}_3\, cos(\eta_5) - \ddot{\eta}_5 r$$

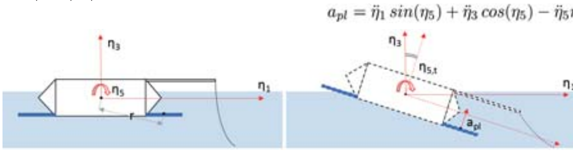

Fig 5. Coordinate system for the rigid body motion in pitch.

5 Results

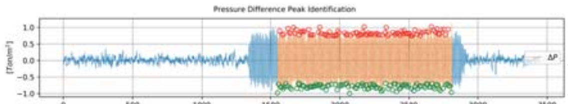

Fig 6. Identification of significant peaks in the pressure difference time series.

The pressure field was recorded in the transistors on the center of the top and bottom faces of the bow heave plate. The data analyzed was the *significant pressure difference*, which will cause a net force on the structural components (see pressure peaks identification, Fig 6).

When the pressure magnitudes (and the difference —or net— pressure) on the faces of the plates were graphed against the ratio of incident wave period T_w to the natural period in heave T_n, some clear trends could be identified (see images in Fig 7).

In general terms, hydrodynamic pressures (especially the pressure difference that causes a net force on the plate) and normal plate accelerations were greater in magnitude waves close to the natural period in heave, which is coherent since global motions are amplified at these resonant periods.

In addition to that, although larger waves obviously cause higher pressure variations, the net pressure acting on the plate was not that much affected by it (Fig 7, bottom-right corner).

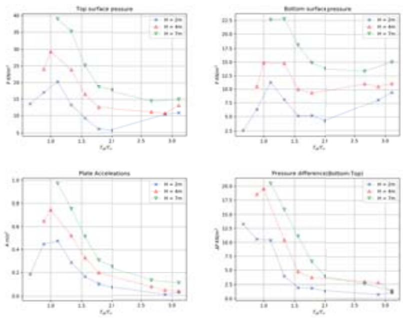

Fig 7. Pressure magnitude and plate accelerations for 3 different wave heights and by incident wave to natural heave period.

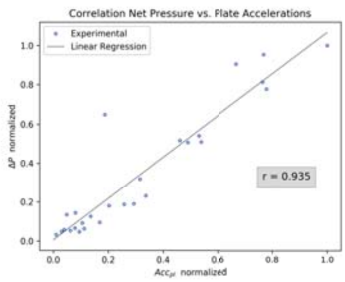

Fig 8. Correlation graph for the normalized pressure and plate's normal acceleration.

It was noticed that the evolution of the plate pressures had a similar shape to that of the normal accelerations. This can be graphically shown, too, with the correlation between the average peak magnitudes of these two variables, as in Fig 8.

The *Pearson's r coefficient* for the normalized pressure difference and the plate's normal acceleration turned out to be **r > 0.93**, indicating an important correlation between these two magnitudes.

This is coherent with the idea that a normal acceleration in the heave plate will tend to drag (accelerate) fluid with it (added mass phenomenon), causing a net force on it.

6 Conclusions

- Regular wave tests were performed on a scale model of the SATH platform, recording the values of the pressures on the heave plates at the top and bottom, in order to compute the net force acting on them.
- Pressure on the top and bottom surfaces of the plate increases at periods closer to the heave resonant period, where motions are slightly amplified too.
- The pressure difference shows a strong correlation with the normal acceleration of the heave plates, which is coherent with the fluid added mass being accelerated to move with them.
- Currently, some numerical analyses (including the use of potential theory software -Sesam-) is being carried out in order to compare these experimental results with those obtainable numerically.
- Some future work on this matter might include analysis on irregular wave trains as well as variation in the pressure distribution in addition to the magnitude.

7 Acknowledgments

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8 References

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