OFFSHORE FLOATING PLATFORMS
EXPERIMENTAL ANALYSIS OF A SOLUTION FOR MOTION MITIGATION: THE HEAVE PLATES IN SATH

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 IH Cantabria, in Santander (Spain).

These 1:33-scale tests (modeled following Froude’s similitude) simulated a 2-MW-turbine prototype, under sets of linear monochromatic waves aligned with the platform’s bow-to-stern axes, 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 to 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.

SATH

The experimental data was gathered from tank tests on a scale model of SATH (Swaying Around Test 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.

Method and data acquisition

The experimental data included 25 series of monochromatic waves of different 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 range 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 began). 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.

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—):

\[ a = a_h + a_p + a_s \]

Where:

- \( a_h \) is the plate acceleration, and is computed from the linear acceleration in heave \( a_{h,0} \) and surge \( a_{s,0} \).
- \( a_p \) also causes an acceleration on the plate proportional to the lever arm \( r \).

\[ a_p = \frac{ F}{m} - \frac{v}{r} \]

In the following equation, \( a_{h,0} \) is the plate acceleration, and is computed from the linear acceleration in heave \( a_{h,0} \) and surge \( a_{s,0} \). The angular acceleration in pitch \( a_{p,0} \) also causes an acceleration on the plate proportional to the lever arm \( r \).

\[ a_{p,0} = \frac{v}{r} \]

\[ a_{h,0} = \frac{v}{r} \]

\[ a_{s,0} = \frac{v}{r} \]

Results

The pressure field was recorded in the transducers 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).

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.

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 natural 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—Seasim)—are being carried out in order to compare these experimental results with those obtained 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.

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References

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