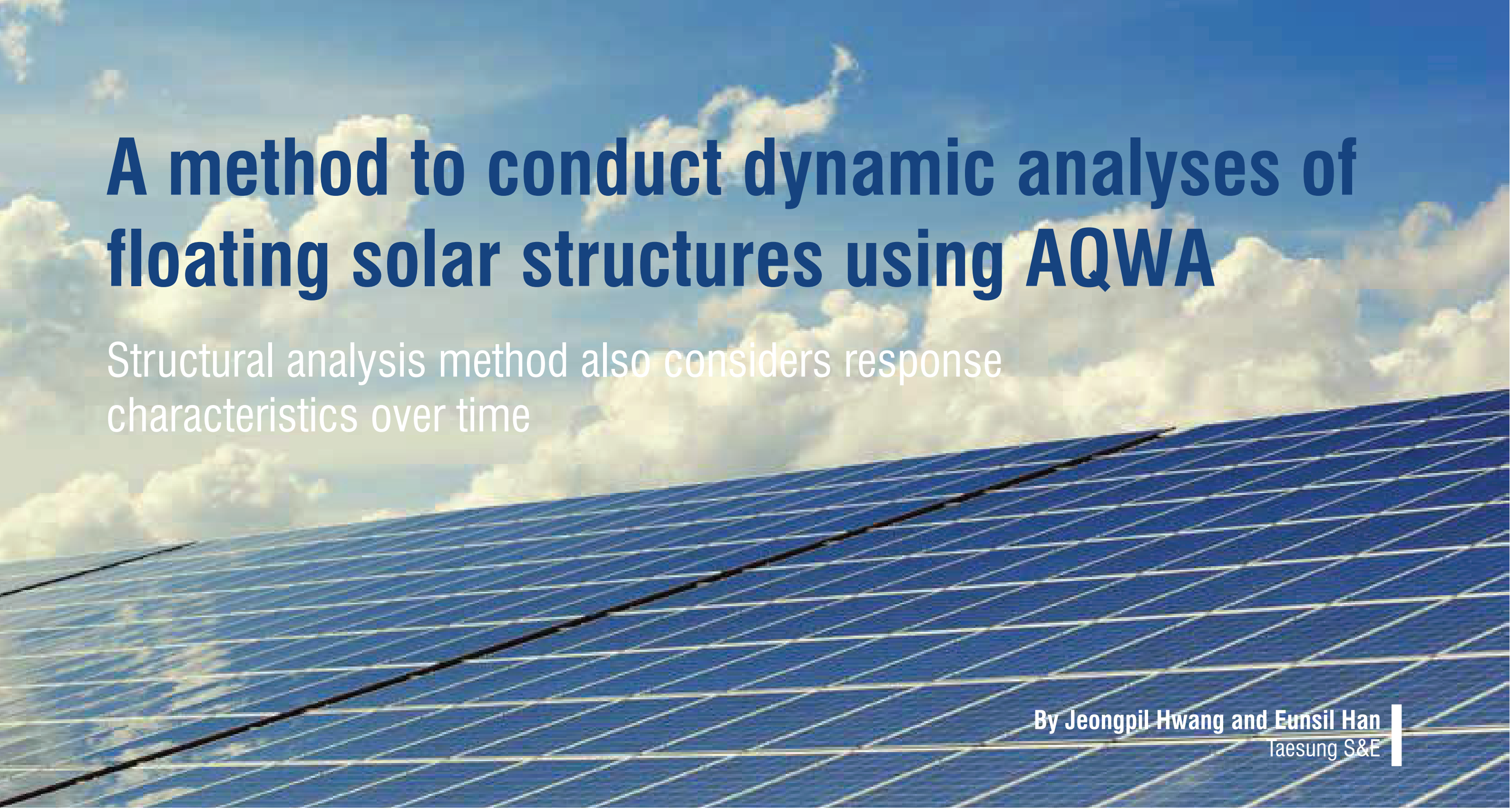

A method to conduct dynamic analyses of floating solar structures using AQWA

Structural analysis method also considers response characteristics over time

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This technical paper presents an analysis process to accurately examine the environmental loads and structural stability of a Floating photovoltaic (PV) power plant. The method includes a hydrodynamic analysis of the Floating PV in its water-based environment as well as a structural analysis of its structural stability based on the characteristics of motion it undergoes. The method proposed used ANSYS AQWA which allows environmental conditions to be included in the analysis such as the fender, the joint, the cable winch, irregular waves, birds, etc.

A new design solution for photovoltaic (PV) power plants is the use of Floating PV systems (FPVS), which are generally installed on bodies of water such as natural lakes, dams, reservoirs, or the ocean. This market is expected to expand because floating PV systems cause less environmental pollution problems than the traditional approach to the development of solar power. This paper introduces a method to conduct the hydrodynamic analysis of floating PV structures using ANSYS AQWA as well as a structural analysis of floating PV structures that considers the response characteristics over time.

The analysis process

The installed floating photovoltaic module structure is exposed to severe environmental loads such as winds and waves. Therefore, the FPVS engineers needed to establish an analytical process for conducting a structural evaluation of the robustness of the solar structure and the solar modules. To this end, our team proposes a four-step process of numerical analysis of the FPVS to understand the hydrodynamics and structural characteristics of floating solar structures, consisting of:

1. CAD modeling using ANSYS SpaceClaim
2. Computational fluid dynamics (CFD) analysis of wind load using ANSYS AIM or ANSYS Fluent
3. Hydrodynamic analysis of wave and wind speed using ANSYS AQWA
4. Time response analysis of the overall structures using ANSYS Mechanical

To summarize, firstly we used ANSYS CFD AIM for fluid dynamics analysis on the extraction of load data. Then, we used ANSYS AQWA for hydrodynamic analysis of the aquatic conditions and environmental loads. Lastly, we used ANSYS Mechanical for the structural analysis of the Floating PV structure, including the frames and solar panels.

Model description (TSNE's Arbitrary Model)

We used three types of models for the different analyses (Fig.1)

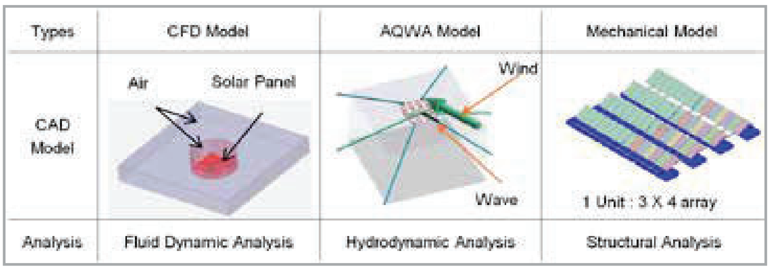

Fig. 1 - Three types of models

Hydrodynamic analysis using ANSYS AQWA

Since the use of AQWA in this analysis process is different from the general analysis method, we have explained it in more detail. The fluid dynamic analysis to derive the loads on the panels of the floating solar structure was conducted with ANSYS CFD AIM, and the hydrodynamic analysis of the water conditions and the environmental loads was conducted with ANSYS AQWA. It is important to emphasize

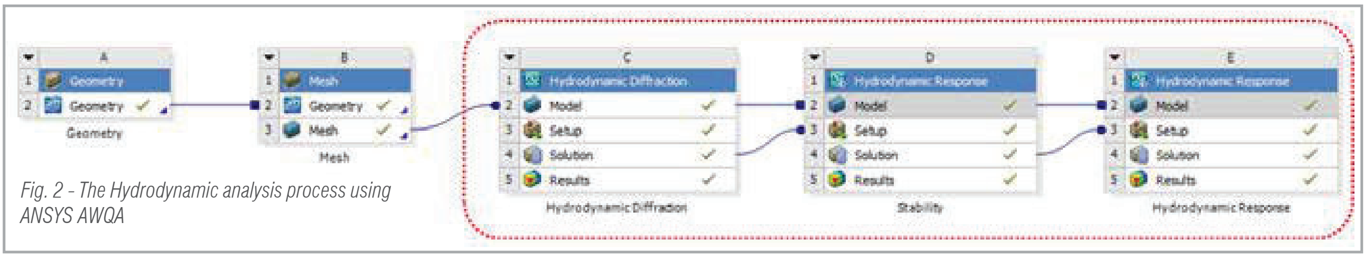

Fig. 2 - The Hydrodynamic analysis process using ANSYS AWQA

the use of ANSYS AQWA in our analysis process. Firstly, we ran a Hydrodynamic Diffraction analysis of the floating body to check its stability. Secondly, we obtained the specific behaviors of the floating body itself using hydrodynamic response analysis. Then, we conducted a simulation that considered the environmental loads created by the wind and waves to obtain the data of the structural position of the floating body. (Please see the red-dotted box in Fig. 2)

Results

Fig. 3 shows the results of the CFD analysis in terms of the total speed and pressure of wind from the direction of 90 degrees and from 180 degrees.

We extracted each X, Y, Z Force component according to the wind direction from -180 degrees to 180 degrees of total wind force with CFD analysis using parametric variables, as shown in Fig. 4.

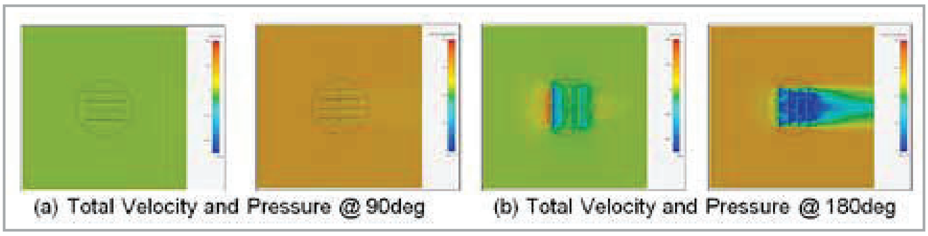

Fig. 3 - Total Velocity and Pressure with wind directions of 90 and 180 degrees

Angle	Force, X(N)	Force, Y(N)	Force, Z(N)
-180	10630.88886	3.783211197	17998.32397
-170	12418.10102	-2160.539692	21313.05518
-160	14790.7097	-5204.486723	26491.81062
-150	14974.60493	-8447.234269	29165.94937
-140	13457.93799	-15005.15894	29756.527

Total Wind Force

Angle	X(N/(m/s)^2)	Y(N/(m/s)^2)	Z(N/(m/s)^2)
-180	11.81209873	0.006425791	19.99813775
-170	13.79789009	-2.400599658	23.68117242
-160	16.43412108	-5.782763025	29.43534513
-150	16.63848326	-9.385815855	32.40661041
-140	14.95326443	-12.22795438	33.06280778

Wind Force Coefficient

Fig. 4 - Wind force and wind coefficient by wind direction

We transferred these wind force data to wind load coefficients by dividing by the square of the velocity. This wind load coefficient condition applies to the hydrodynamic analysis of floating structures.

Fig. 5 shows the wave surface elevation over time using the hydrodynamic diffraction with the above-mentioned wind coefficient results. This result shows the wave properties such as diffraction and radiation around the floating structure according to the wave conditions such as wave direction and wave height. The highest wave height was found to be 0.26m at the 0.2sec period.

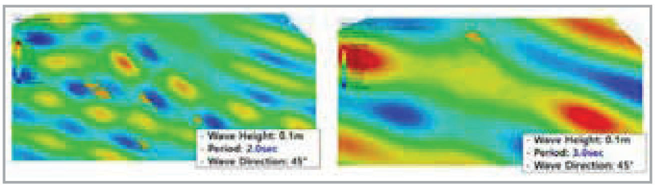

Fig.5 - The wave surface elevation

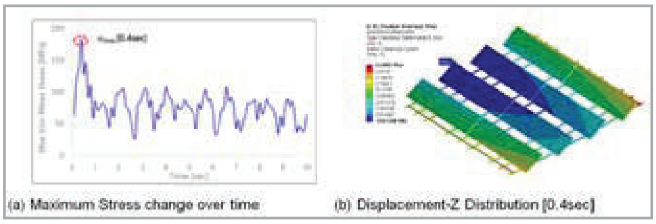

Fig.6 - Transient structural analysis

Finally, Fig. 6 shows the results of the transient structural analysis. These represent the maximum stress on the structure over time with the solar sample model installed in the water-based environment.

The analysis revealed that the sample model experienced its most unstable structural state at 0.4 sec and a maximum stress of 184 MPa.

Conclusions

Since no analysis process exists for the structural evaluation of a Floating PV installation, it was necessary to establish an analysis process to accurately examine the environmental loads and structural stability of a Floating PV. With this purpose in mind, this paper presents a method of conducting a hydrodynamic analysis of a Floating PV in its water-based environment and a structural analysis for examining its structural stability according to the characteristics of motion it undergoes. ANSYS AQWA enables various problems to be included in the analysis such as multiple environmental conditions including the fender, the joint, the cable winch, irregular waves, birds, etc. Furthermore, a fatigue analysis can be conducted to evaluate the fatigue life of the Floating PV.

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