Hydro-visco-elastic analysis of floating membranes using a monolithic finite-element model

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ABSTRACT

Membranes made of materials such as reinforced rubber, geotextile fibres and plastics are conventionally used as temporary breakwaters. These membranes are lightweight, easily deployable, reusable and have minimum impact on key coastal processes. Recent advances in wave-energy converters (WEC) explore the use of piezoelectric material in floating membranes to extract wave energy from wide-range of frequencies. Similar innovations in floating photovoltaics (FPV) include thin-film amorphous panels which can potentially survive in harsh wave-conditions and have improved efficiency due to convective cooling by the surrounding water and undisturbed access to solar irradiance. Therefore, there is a need to develop methods and tools for design and analysis of structures analogous to floating membranes for diverse applications in the offshore environment.

This manuscript presents a fully monolithic finite-element model, coupling the 1D visco-elastic membrane equation with 2D potential-flow equation, resulting in a mixed dimension PDE in frequency domain, based on the framework in [1]. This hydro-visco-elastic approach can capture both the elastic deformation (storage modulus) and the viscous dissipation (loss modulus). The manuscript reports the partial reflection, absorption and transmission of irregular waves (JONSWAP spectrum) by the finite floating membrane, as shown in Figure 1. The manuscript also studies the variation of these coefficients with material properties, such as membrane length, density, and design properties such as tension, mooring conditions and number of joints.

The analysis highlights that the absorption coefficient is maximum near the natural frequency of undamped membrane. This natural frequency can be controlled using material and design properties for achieving the desired objective in the local wave-environment. For example, the natural frequency is directly and inversely proportional to tension and density, respectively. Crucially, membrane with free-ends can absorb a wider range of frequencies, with higher overall absorption, compared to fixed-ends. However, the free-end membrane has higher transmission coefficient for long waves. The shorter wavelengths are largely absorbed or reflected by viscous membranes.

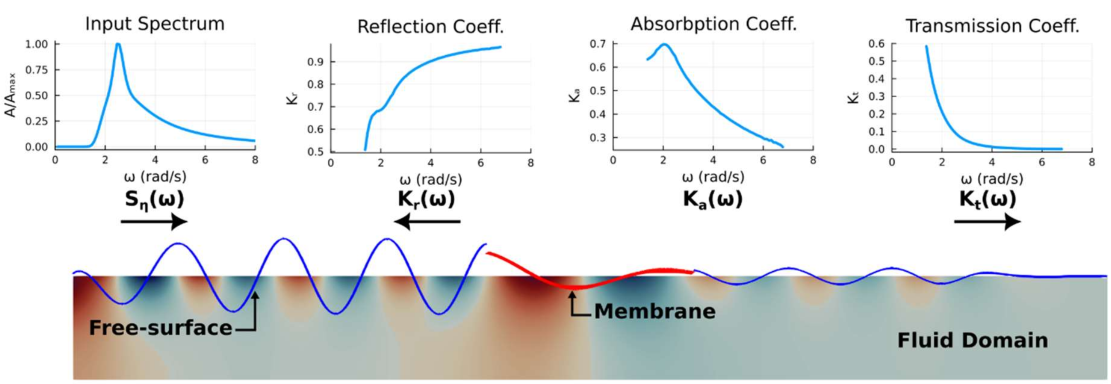

Figure 1: Schematic showing partial reflection, absorption and transmission of incoming wave-spectrum by visco-elastic floating membrane with free-ends.

REFERENCES

[1] Colomés O, Verdugo F, Akkerman I. A monolithic finite element formulation for the hydroelastic analysis of very large floating structures. Int J Numer Methods Eng 2022:nme.7140. https://doi.org/10.1002/nme.7140.