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MODELING BREAKING WAKE OF A SUBMERGED HYDROFOIL WITH FULLY NONLINEAR POTENTIAL FLOW

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Fully nonlinear potential flow (FNPF) has been used extensively as a basis for ocean wave modeling for many years, both in two- and three-dimensions. FNPF solvers can be developed with many numerical methods, including finite-differences, finite-elements, boundary elements (e.g., Grilli et al. [1]), and based on that, coupled models have been developed including viscous effects as needed (e.g., Mivehchi et al. [2]). Essentially all FNPF models are based on the assumption of a well-defined free surface, and therefore cannot easily continue after a wave breaking event without some added energy dissipation terms.

There are multiple ways to deal with this energy dissipation, but a straightforward approach considered by many is through applying a pressure damping to the free-surface (e.g., [3, 4, 5]). Because the wave breaking itself is not explicitly modeled, there are always some limitations, but to a first approximation, the two most important aspects are the breaking criterion, in order to know when a pressure damping should be applied, and the breaking strength, in order to know how much energy should be removed. The exact choice of breaking criterion and strength remains an active area of research, although it is becoming better understood for some situations (e.g., Derakhti et al. [6]).

One of the simpler test cases to benchmark a model is that of a steady breaker. In this way, the free-surface position and energy dissipated can be measured most easily. Traditionally, this has been dealt with using the wake of a submerged hydrofoil, as in Duncan [7]. For small angles of attack, the flow around the foil remains well described with potential flow, if the Kutta condition is correctly applied at the trailing edge. For an example, Duncan [8] initially proposed a breaking drag parameterized only by the phase speed of the wave, gravity, and angle of the front face, or a non-dimensional breaking strength of $b = 0.009/\sin(\beta_b)$ for a free surface angle β_b. Using this parameterization, for foils traveling at the same speed (and thus the same phase speed of the wake), but different depths, we are able to see that in some cases this overpredicts significantly the actual dissipation, and that an FNPF model requires a calibrated value to correctly reproduce the free-surface (Figure 1).

In order to expand upon these validations, additional experiments are ongoing, with better tracking of the free-surface (compared to the earlier results of Duncan [7]) and measurements of the forces on the foil to be presented at the conference, as well as numerical tests with more recent models of breaking strength.

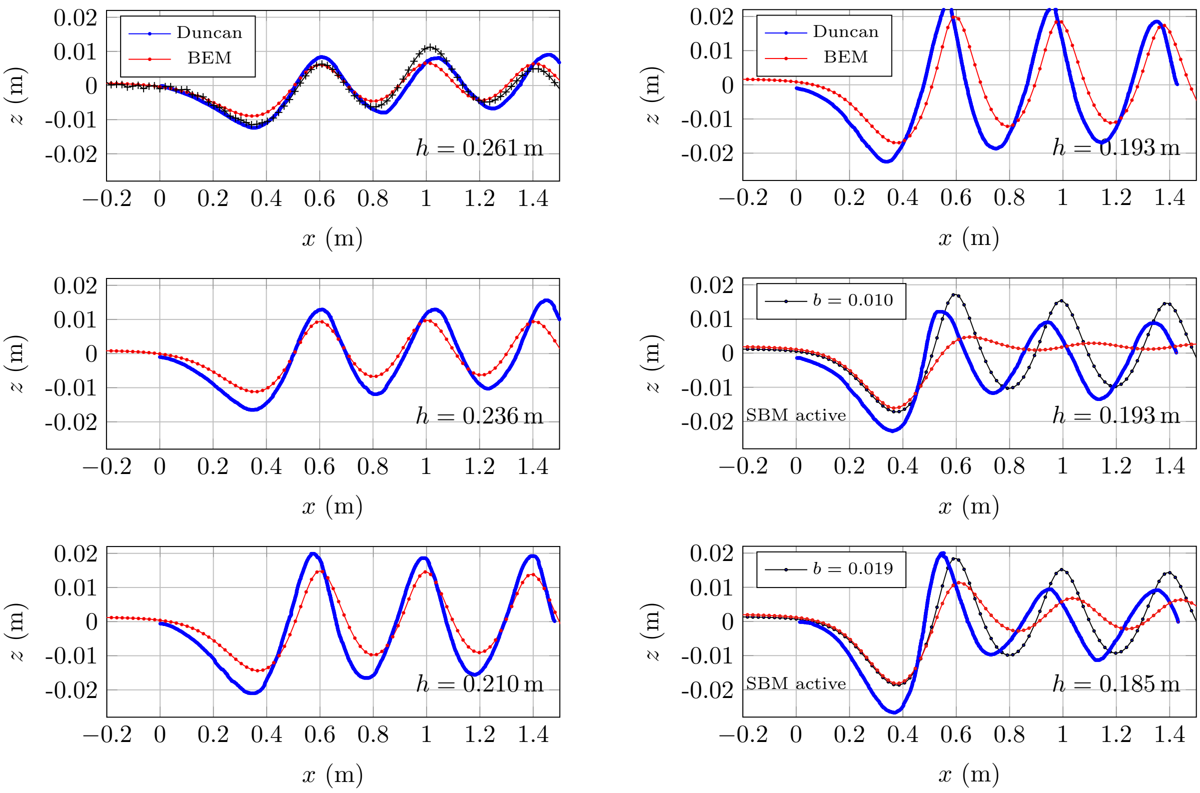

Figure 1. Example of boundary element calculations of non-breaking hydrofoil wake (left) and breaking wake with different breaking strengths (right), for different submergence depths h, compared to the results of [7].

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