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Fluid-Structure Interactions response of a composite hydrofoil modelled with 1D beam finite elements

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ABSTRACT

In high performances racing yacht design, hydrofoils are becoming more and more common. To study their performances, Fluid-structure interactions (FSI) are realized. Theses simulations are mandatory to study high performances hydrofoils because their significant deformations have an impact on the hydrodynamic flow around the foil that can't be neglected. To realize FSI simulations, a method has to be defined to solve the flow around the foil and its mechanical response. To compute the flow around the foil, an inviscid flow solver based on the boundary element method (BEM) is considered, this solver takes into account the nonlinear free-surface effect on the hydrodynamic forces acting on the foil. The structural part of the simulations is solved with the finite element method, as implemented in Abaqus 2022. Two type of modelisation are considered in Abaqus, a first one where the foil is descrided with 2D shell and 3D solid finite elements and a second one where the foil is modeled with 1D beam elements equivalent to the 2D/3D model. To give realistic results, the 1D finite element model must be able to take into account the anisotropic properties of the 3D hydrofoil. To do so, the structural problem is decomposed into a set of 2D problems where the sections of the foils are characterized (Han et al. 2014) along its span and then, from these analysis, beam elements are constructed and a 1D finite element analysis is performed (Hodges 2006) to compute the deformation of the foil. The choice for the finite element modelization results in different fidelities for the fluid-structure interaction simulations. The different simulations could be used in a multifidelity optimization tool (Sacher et al. 2021) but this requires a preliminary estimation of the fidelity of the different structural solvers.

In the present study, the hydrodynamic performance of a NACA0015 hydrofoil is studied numerically and experimentally. The foil is made with composite materials and its fibers are not aligned with the its span. This results into the apparition of a Bend-Twist Coupling (Temtching Temou et al. 2021) which increases the angle of attack of the foil when it is deformed by the hydrdodynamic loads.

The experiments are conducted at the Ifremer of Boulogne-sur-Mer where there is a open circulation water channel. For a given incidence and speed, these experiments measures the forces applied on the foil and the displacements they induce. In the present work, the method used to model a foil with equivalent beam elements is presented. Then, for a simple load case, the results given by the equivalent beam model are compared with the one given by a classical finite element model (with 2D

shell and 3D solid finite elements). Then, the coupling strategy for the fluid-structure simulations is presented and then, FSI simulations are realized and compared with the experiments realized at the Ifremer. The main goal of this work is to validate that the behavior of a composite hydrofoil in a flow can be studied with 1D beam finite elements.

Keywords: Hydrofoil; Equivalent beam; Fluid-Structure Interactions; Composite; Bend-twist coupling.

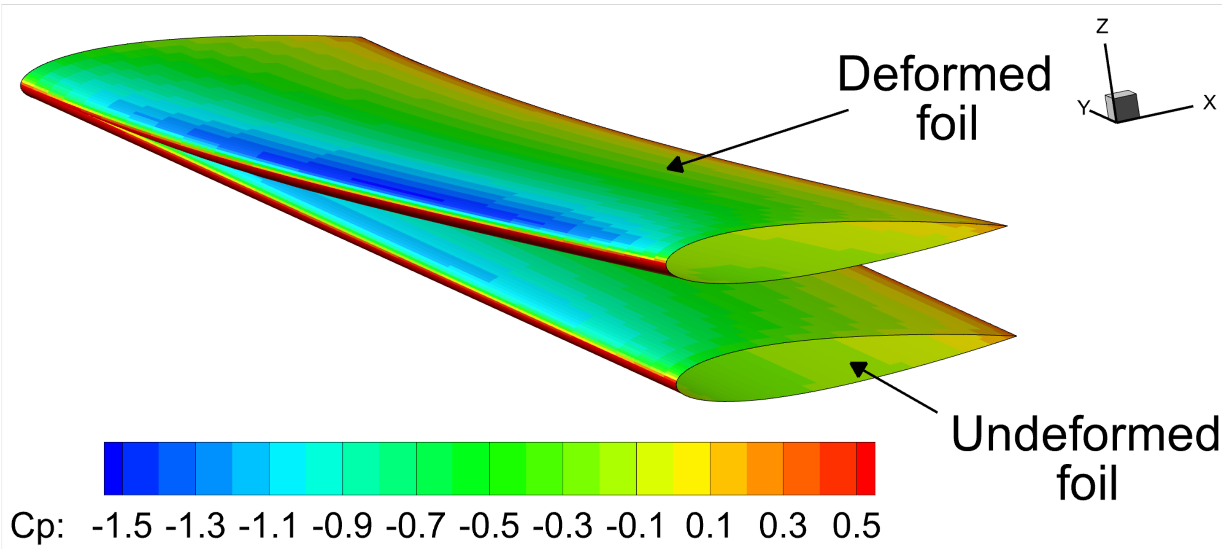

Figure 1: Example of result given by a Fluid-Structure Interactions computation on the considered foil.

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