10th OpenFOAM Conference

Implementation of a surrogate-based shape optimization workflow for bionically modified tidal turbine blades using OpenFOAM

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Renewable energy is seeing a continued rise in politic, economic, and scientific interest. Tidal stream energy, while still being a relatively new and underutilized form of renewable energy, has potential to become a valuable addition to a sustainable future energy supply, due to high predictability and reliability. Aiming to advance its technical maturity, this study builds upon findings, showing how biomimetic adaptations, such as a sinusoidal leading edge inspired by the humpback whale's pectoral flippers can significantly affect hydrodynamic performance [1]. However, because positive effects are often only observed in selected configurations while others prove detrimental, an optimization of the geometric parameters is considered vital [2].
Consequently, the objective was to implement a shape optimization workflow for tidal turbine blades with biomimetic modifications, to advance the existing research from structural analysis to structural synthesis. First, a parameterized blade model was created to allow easy adaption and automatic adjustability. Subsequently, an OpenFOAM simulation setup was used to conduct CFD simulations to assess the performance parameters for each tested blade configuration. Aiming for a full automatization, automatic meshing was achieved using *cfMesh* and *snappyHexMesh*.
To minimize computational costs, the simulation was implemented using a frozen rotor approach, keeping the mesh fixed while using source terms for Coriolis and centrifugal forces to account for the blade rotation (*SRF/MRF* approach). Steady state and transient simulations, especially for the off-design operation were conducted.
To evaluate the design space efficiently, a *Surrogate Based Optimization* approach was combined with the simulation environment, which performs the actual optimization on a Gaussian process meta model, thereby reducing the number of expensive simulation runs needed. A genetic algorithm was paired with a local search algorithm to reliably find the optimal available configuration of parameters.
The results illustrate the setup of a case-specific optimization for bionic structural modifications, which relies solely on open-source software and could easily be expanded to different types of modifications, constraints, or related applications, such as wind turbines.

References
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[2] M.W. Lohry, D. Clifton, L. Martinelli. *Characterization and Design of Tubercle Leading-Edge Wings*. 7th International Conference on Computational Fluid Dynamics, 2012.