Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S14 A10

Adjoint-based shape optimization of an OSV hull using a VAE-assisted propulsion surrogate model

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Abstract

The complex and dynamic character of several propulsion systems often necessitates their partial omission in computational fluid dynamics (CFD)-based shape optimizations of ship hulls, see e.g., [1, 2]. Instead of resolving the propeller in the simulation, the propeller-hull interaction is often considered by body forces using actuator-disk approaches, see e.g. [3]. While this approach can provide significant improvements at a feasible computational cost, it can hardly be generalized to different propeller-hull configurations and is insensitive to the related design details.

To this end, this contribution studies the shape optimization of an offshore support vessel (OSV) hull equipped with a Voith Schneider propeller (VSP) for the minimization of its drag using a variational autoencoder (VAE)-based surrogate model for the prediction of the propeller flow field. The construction of the surrogate model is described in an accompanying contribution by the same group of authors. In this work, we describe the seamless implementation of the model to an adjoint-based CAD-free optimization process. Based on a small set of input flow and geometric parameters ($\mathcal{O}(10)$), which are computed on the fly in each optimization step, the model is able to reconstruct a time-averaged flow field, which is used for the simulation-driven shape optimization.

In particular, we discuss the efficiency of the proposed method as compared to traditional approaches, which model the propeller by means of body forces imposed in an actuator-disk volume. Furthermore, we show the computational implementation aspects for the primal and adjoint problems. Additionally, as regards the latter, we formulate and employ a consistent adjoint system, considering the surrogate model influence on the primal equations and compare it to a “frozen” approach where the surrogate model acts only on the primal.

Keywords: continuous adjoint method, CAD-free shape optimization, ship hull optimization, Voith Schneider propulsion surrogate model

References

[1] Kühl, N., Nguyen, T.T., Palm, M. *et al.* Adjoint node-based shape optimization of free-floating vessels. *Struct Multidisc Optim* **65**, 247 (2022).

[2] Kröger, J., & Rung, T. CAD-free hydrodynamic optimisation using consistent kernel-based sensitivity filtering. *Ship Technology Research*, ***62***(3) (2015).

[3] Kröger, J., Stück, A. & Rung, T. Adjoint aftship re-design for wake optimisation under the influence of active propulsion. *International Conference on Computational Methods in Marine Engineering, MARINE 20111, Lisbon, Portugal* (2011).