Data driven CFD-based ship design using Polynomial Chaos Expansions

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ABSTRACT

Maritime transport is responsible for an annual emission of around 1000 million tonnes of CO2 annually, which is around 2.5% of the global greenhouse gas emissions. Nowadays, ships are designed using Computational Fluid Dynamics (CFD) on a few important operational conditions that represent the expected operational profile. Often, these simplified design profiles are based on limited information of comparable ships. As a consequence, a discrepancy exists between design profiles and the profiles of the actual operational conditions a ship encounters during its lifetime. This discrepancy leads to inefficient hydrodynamic ship design resulting in a waste of fuel and an increase of greenhouse gas emissions.

The amount of available data on actual operational conditions of ships is rapidly increasing. The Automatic Identification System (AIS) [1] and onboard monitoring systems [2] produce a huge amount of historical data on ship operations. These developments call for efficient data-driven design methods that enable to include realistic operational profiles derived from data.

Knowledge of operational conditions can be used for probabilistic uncertainty quantification leading to robust design: A hull shape that is optimal with respect to uncertain operational conditions whose probability density function is learned from operational data. Robust design is a promising approach since it makes ships energy efficient for the real usage situation.

This contribution will focus on Uncertainty Quantification (UQ) using Polynomial Chaos Expansions (PCE), see [3]. To this end, we use the open-source DAKOTA software package from Sandia National Laboratories. UQ is applied to a 22000 TEU container vessel operating in uncertain conditions. The PCE results are consistent with the results from perturbation methods and the statistical moments converge with the number of PCE evaluations. This makes the PCE method a viable candidate for robust design.

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