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Optimising the Design and Operation of Ultrasound-based Flow Meters using Computational Fluid Dynamics

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Small-diameter ultrasonic flow meters present an interesting industrial internal-flow problem due to their unique geometry and complex interaction with fluid flow. In order to efficiently evaluate and optimise these flow meters, their flow physics must be accurately understood and predicted. In this study, computational fluid dynamics is used to predict the turbulent flow and to perform robust shape optimisation of an ultrasonic flow meter with an intrusive two-stand configuration. Reynolds-averaged Navier-Stokes (RANS), with $k-\varepsilon$ and $k-\omega$ SST turbulence models are evaluated in a wall-modelled and a wall-resolved grid. The simulation results are compared against laser Doppler velocimetry, pressure drop, and vortices visualisation experiments in both qualitative and quantitative manners. Numerical results qualitatively agree with experimental data although some discrepancies are predicted by the $k-\varepsilon$ model. Overall, the results that best predict the flow structures, axial velocity, and pressure drop are achieved by wall-resolved RANS $k-\omega$ SST model. While minor differences are predicted by the wall-modelled $k-\omega$ SST, it is concluded that this approach is a good candidate to perform optimisation studies due to the reduced computational cost.

Global shape parametric optimisation is performed by Design and Analysis of Computer Experiments (DACE), a Multi-Objective Evolutionary Algorithm (MOEA), Kriging surrogate-based methods, and Latin Hypercube Sampling (LHS). Minimisation of pressure drop and maximisation of flow-meter accuracy are taken as fitness functions. Optimisation results are shown and compared against the baseline geometry, displaying performance gains and topological changes in the 3D space. The applied methodology provides a robust and time-efficient framework to analyse and optimise internal-flow problems with similar features.

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