This thesis brings together the fields of fluid mechanics, as the study of fluids and flows, isogeometric analysis, as a numerical method to solve engineering problems using computers, and shape optimization, as the art of finding "best" shapes of objects based on some notion of goodness. The flow problems considered in the thesis are governed by the 2-dimensional, steady-state, incompressible Navier-Stokes equations at low to moderate Reynolds numbers. We use isogeometric analysis both to solve the governing equations, and as framework for the shape optimization procedure. Isogeometric analysis unites the power to solve complex engineering problems from finite element analysis (FEA) with the ability to effectively represent complex shapes from computer aided design (CAD). The methodology is appealing for flow modeling purposes also due to the inherent high regularity of velocity and pressure approximations, and for shape optimization purposes also due to its tight connection between the analysis and geometry models. The thesis is initiated by short introductions to fluid mechanics, and to the building blocks of isogeometric analysis. As the first contribution of the thesis, a detailed description is given of how isogeometric analysis is applied to flow problems. We present several new discretizations of the velocity and pressure spaces, we investigate these in terms of stability and error convergence properties, and a benchmark flow problem is analyzed. As the second contribution, we show how isogeometric analysis may serve as a natural framework for shape optimization within fluid mechanics. We construct an efficient regularization measure for avoiding inappropriate parametrizations during optimization, and various numerical examples of shape optimization for fluids are considered, serving to demonstrate the robustness of the method. As the third contribution, the methodology is extended to acoustics. We establish a coupled flow-acoustic model of sound propagation through flow in ducts based on isogeometric analysis. Validations using known acoustic duct modes demonstrate the powers of the methodology. Based on the model, we identify distinct geometric effects that enhance the sensitivity of the acoustic signal to the background flow. The thesis is concluded by suggestions for future studies within the field.

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