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PHYSICAL SHAPE OPTIMISATION IN FLUID FLOW USING LATTICE BOLTZMANN METHOD

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Increasing energy efficiency is a task addressed by basic and applied research. In the field of fluid mechanics, this is realised by reducing the friction for high Reynolds number flow. A well-known example is the effort put into minimising the drag coefficient of modern vehicles to increase energy efficiency. In systems engineering, efficiency is pre-dominantly limited by high pressure and energy losses in pipe flow applications. The industry has long understood that the reduction of fluid resistance by changing the relevant pipe system leads to cut costs in the long run.

The computational effort for shape optimisation of fluid flows basically consists of three different simulations: (i) the fluid flow simulation, (ii) the optimisation algorithm and (iii) the redefinition of the geometry and the subsequent remeshing for mesh dependent approaches. Depending on the formulation, the degrees of freedom and the number of iterations, the combination of these three components can be costly regarding time, resources and funds. Therefore, a method of physical shape optimisation is developed which solves the problem of minimising the objective function in a weak manner. The objective function is restricted to the reduction of high wall shear stresses.

Inspired by erosion and sedimentation governing the shaping of river beds, high shear stresses are able to lift-off particles from the wall and sediment them in the wake flow [1, 2]. Thus, the topology of the river bed is reshaped resulting in smaller maximum wall shear stresses. Simulations show that this procedure effectively reduces pressure loss in pipe flows.

The approach is implemented using a highly parallel lattice Boltzmann code combined with a model reduction for the optimisation algorithm. Thus, only a few parameters derived from the physical model for erosion and sedimentation as well as quantities of the fluid flow such as pressure drop and energy loss are related. The shape can be flexibly adapted during runtime by changing the local dynamics without any need for remeshing. Results of the shape optimization for laminar pipe flow are shown.

The big advantage of this approach is the simple implementation within a lattice Boltzmann framework, the big flexibility and efficiency and the prospect of optimising turbulent flows with methods under development based on this work.

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