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Simulation of swimming strings immersed in a viscous fluid flow

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— In nature, many phenomena involve interactions between flexible bodies and their surrounding viscous fluid, such as a swimming fish or a flapping flag. The intrinsic dynamics is complicate and not well understood. A flexible string can be regarded as a one-dimensional flag model. Many similarities can be found between the flapping string and swimming fish, although different wake speed results in a drag force for the flapping string and a propulsion force for the swimming fish. In the present study, we propose a mathematical formulation for swimming strings immersed in a viscous fluid flow. Fluid motion is governed by the Navier-Stokes equations and a momentum forcing is added in order to bring the fluid to move at the same velocity with the immersed surface. A flexible inextensible string model is described by another set of equations with an additional momentum forcing which is a result of the fluid viscosity and the pressure difference across the string. The momentum forcing is calculated by a feedback loop. Simulations of several numerical examples are carried out, including a hanging string which starts moving under gravity without ambient fluid, a swinging string immersed in a quiescent viscous fluid, a string swimming within a uniform surrounding flow, and flow over two side-by-side strings. The numerical results agree well with the theoretical analysis and previous experimental observations. Further simulation of a swimming fish is under consideration.

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