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Coupled modelling of flow and biofilm in a laminar flow regime through a high-resolution fluid-structure interaction (FSI) solver

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Biofilms are ubiquitously present in fluvial systems, growing on almost all wetted surface and has a significant impact on both water quantity, in terms of ambient flow condition, as well as water quality, biofilms growing in water distribution system leads to unwanted contamination. The local hydraulic conditions have a significant impact on the biofilm lifecycle as in order to sustain their growth biofilms draw essential nutrients either from the flow or from the surface on which they grow. This implies that in convection dominated flow, nutrient transfer from water, would nurture the growth of biofilms. However, at higher flow rates biofilms are subjected to higher stresses which may lead to their detachment. Furthermore, biofilms in ambient flow conditions oscillate and therefore alter the local flow conditions. There is, therefore, a complex feedback between biofilms and flow which have has implications for flow dynamics and water quality issues in riverine ecosystems.

The research presented here describes a fluid-structure interaction solver to examine the coupled nature of biofilm oscillations due to the ambient flow and its feedback on the local flow structures. The fluid flow is modelled by the incompressible Navier-Stokes equations and structural deformation of the biofilm is modeled by applying a linear elastic model. The governing equations are numerically solved through Finite Volume methodology based on cell-centered scheme. Simulations are conducted in a laminar regime for a biofilm streamer modelled as moving slender plate. The temporal evolution of the pressure, flow structures are examined in the vicinity of the biofilm. Further investigations examine the impact of changing Reynolds number on the oscillation frequency as well as drag and lift forces experienced by the biofilm. The changing frequency of biofilm oscillation with varying Reynolds number is characterized by the Strouhal number (St). Our investigation reveals that as the flow separates around the biofilm attachment point, vortices are formed both above and beneath the biofilm which propagate downstream. As the vortex rolls off from the end of the biofilm, the interaction between the vortex from above and beneath the biofilm leads to the generation of instability which appears to be the main driving force behind the biofilm oscillation.