Locomotion of a single-flagellated bacterium

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ABSTRACT

Single-flagellated bacteria propel themselves by rotating a flagellar motor, translating rotation to the filament through a compliant hook, and subsequently driving the rotation of the flagellum. The flagellar motor alternates the direction of rotation between counterclockwise and clockwise, and this leads to the forward and backward directed swimming. Such bacteria can change the course of swimming as the hook experiences its buckling caused by the change of bending rigidity. In this paper, we present a comprehensive model of a monotrichous bacterium as a free swimmer in a viscous fluid. We describe a cell body as a rigid body using the penalty method and a flagellum as an elastic rod using the Kirchhoff rod theory. The hydrodynamic interaction of the bacterium is described by the regularized Stokes formulation. Our model of a single-flagellated micro-organism is able to mimic the swimming pattern that is well matched with the experimental observation. Furthermore, we find the critical thresholds of the rotational frequency of the motor and the bending modulus of the hook for the buckling instability, and investigate the dependence of the buckling angle and the reorientation of the swimming cell after buckling on the physical and geometrical parameters of the model.