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Numerical Study on the Flow around a Steadily Rotating Spring: Understanding the Propulsion of a Bacterial Flagellum

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Abstract : The propulsion of a bacterial flagellum in a viscous fluid has attracted many interests in the field of biological hydrodynamics, but remains yet fully understood and thus still a challenging problem. In this study, therefore, we have numerically investigated the flow around a steadily rotating micro-sized spring to further understand such bacterial flagellum propulsion. Note that a bacterium gains thrust (propulsive force) by rotating the flagellum connected to the body through a bio motor to move forward. For the investigation, we convert the spring model from the micro scale to the macro scale using a similitude law (scale law) and perform simulations on the converted macro-scale model using a commercial software package, CFX v13 (ANSYS). To scrutinize the propulsion characteristics of the flagellum through the simulations, we make parameter studies by changing some flow parameters, such as the pitch, helical radius and rotational speed of the spring and the Reynolds number (or fluid viscosity), expected to affect the thrust force experienced by the rotating spring. Results show that the propulsion characteristics depend strongly on the parameters mentioned above. It is observed that the forward thrust increases in a linear fashion with either of the rotational speed or the fluid viscosity. In addition, the thrust is directly proportional to square of the helical radius and but the thrust force is increased and then decreased based on the peak value to the pitch. Finally, we also present the appropriate flow and pressure fields visualized to support the observations.

Keywords : fluid viscosity, hydrodynamics, similitude, propulsive force
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