Abstract

To the thesis titled

Hydrodynamics of active swimmers: Modelling and Analysis

By

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Research on the hydrodynamics of natural and artificial self-propelling systems offers exciting opportunities for engineering and biomedical applications. The studies involve an extensive range of theoretical, numerical, and experimental approaches. The primary objective of the thesis is to deal with the problems arising in these microsystems through a simplistic analytical treatment. The mathematical model, developed in the realm of low Reynolds number hydrodynamics, aims to unify various internal and external propulsive mechanisms as simple physical models which are sufficient to gain fundamental insights into the mechanism of locomotion. With an emphasis on the kinematic properties, we have quantified relevant fluid mechanical properties of self-propulsion throughout the thesis.

The first part of the thesis focuses on using different idealized hydrodynamic models to study the independent active swimmers. Under this theme, we extend the classical "squirmer model" to analyze the migration of microorganisms with a distribution of propulsive appendages. We also present hydrodynamic investigations of self-propulsion in presence of two competing driving fields and in the low but finite inertial effect of the external medium. A comparative study with the existing literature and the feasible microfluidic visualizations are stated such that the results are physically meaningful.

We next turn our attention to pairwise and collective swimming in a viscous medium in the second phase of the thesis. We have illustrated qualitative predictions on the swimming state of single and a pair of swimmers in a confined tapered channel utilizing the hydrodynamic interactions. Different swimming states are classified in the effective phase diagrams depending on the morphological parameters of the channel. On the other hand, for collective migration, we utilize a highly idealized geometric model, the effective medium and cell model approximations, to identify the essential swimming features in a suspension. The model is a significant improvement over the previous analysis on such systems, which did not account for the suspensions flow situation in a realistic manner. Since new experimental methods promise to reveal the mechanisms for biological locomotion with evermore quantitative detail, we believe that the future of the works presented in the thesis is likely to be significant.

Keywords: Low Reynolds number hydrodynamics, swimming, biological organisms, droplets, microfluidic systems.

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