Mechanical Engineering Doctoral Defense

Behavior of Colloids with Anisotropic Diffusivities

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abstract

Locomotion of microorganisms is commonly observed in nature and some aspects of their motion can be replicated by synthetic motors. The motion of any swimmer can be characterized by its translational and rotational velocity and effective diffusivity. In this work, we show that swimming colloids with both translational and rotational velocity can be characterized by a short-time and a long-time effective diffusivities. Both diffusivities depend nonlinearly on the ratio of the translational and rotational velocity and can results in a maximum in the long-time diffusivity. The variation of a colloid's velocity and effective diffusivity to its local environment (e.g. fuel concentration) suggests that the motors can accumulate in a bounded system, analogous to biological chemotaxis. We have observed non-uniform pseudo equilibrium distribution of motors that is the result of a spatially varying random-walk process. The concentration results because at any given time a larger percentage of motors can be found in the regions of low diffusivity than in regions of high diffusivity. Individual motors are not trapped in any given region but at equilibrium the net flux between regions is zero. For microorganisms this response to a chemical gradient is termed chemokinesis and is thought to only occur in microorganisms that are capable of swimming. We show that passive colloids, that migrate only by Brownian thermal motion, are also capable of achieving non-uniform pseudo equilibrium distributions. For Brownian particles the gradient in diffusivity is achieved by creating a viscosity gradient in a microfluidic device. The distribution is described by the Fokker-Planck equation for variable diffusivity. This suggests that any Brownian colloids, natural or synthetic, will concentrate in a bounded system in response to a gradient in diffusivity and that the magnitude of the response is proportional to the magnitude of the gradient in diffusivity divided by the mean diffusivity in the channel .

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