PROBABILITY OF CONTACT OF A SELF-PROPELLED MARINE LARVA WITH A PROTRUDING COLLECTOR

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Summary. We considered a problem of hydrodynamic contact of a small marine larva with a large cylinder resting in sea flow. The results of our investigation illustrate that self-propulsion may increase the probability of contact of a larva with a collector by orders of magnitude.

INTRODUCTION

The *probability of settlement* is a number which is frequently used in the biological literature to characterize the proportion of larvae that have settled on a specific substratum to the total number of larvae that could possibly settle on this substratum under the same biological and physical conditions [1]. The probability of larval contact with a substrate is the upper bound of the probability of settlement. Given that the velocity of sea currents is typically much higher than a larva's swimming velocity, the larva's motion towards a collector is highly regarded as transport of a passive particle. However, the concept of passive contact of a small larva with a large protruding collector may greatly underestimate the probability of settlement [2]. We consider a larva that moves as a mechanical self-propelled swimmer which may or may not contact a collector (see e.g. [3]). We illustrate our approach using as a modeling example the bryozoan larva of *Bugula Neritina* with an equivalent diameter $d_p \approx 200\mu\text{m}$ and swimming velocity $V_s \approx 5$ mm/s. Our study includes both an experimental and a theoretical part. In the experimental part we estimate the kinematic parameters of helical motion of *B. neritina*, which are needed for the mathematical modeling of its curvilinear motion in the velocity field of a cylinder. In the theoretical part we calculate the probability of contact of a self-propelled larva with a collector and compare it with the probability of contact of a passive particle with the same collector. The motion of larvae near a cylinder was observed in an experimental flume using 2 synchronized 500 frames/s HD video cameras. In calm water *B. Neritina* moves along a helical path whose parameters were estimated experimentally.

MATHEMATICAL MODELLING OF CONTACT

We consider the motion of a spherical self-propelled particle of diameter d_p in the velocity field $\mathbf{U}$ of a long isolated vertical cylinder of diameter D_c. The cylinder rests in an unbounded current whose velocity $\mathbf{U}_\infty$ is normal to the cylinder's axis. We assume that a small larva does not change the velocity field of the cylinder and that there is no hydrodynamic interaction between individual larvae. *B. Neritina* is too large to be influenced by Brownian diffusion but its Stokes number is small, much less than the threshold number 1/8 below of which the inertial contact does not take place [4]. Thus, we consider a particle as massless, and take into account only the effect of the direct interception. A massless larva-particle translates in the flow with velocity $\mathbf{V} = \mathbf{U} + \mathbf{V}_S + \mathbf{V}_H$ and rotates with an angular velocity $\boldsymbol{\omega} = 2^{-1}\nabla \times \mathbf{U}$, where $\mathbf{V}_H$ is the velocity of the larva in the helical motion. We consider contact of a small larva with the frontal part of a cylinder, where most collisions of passive particles takes place [4]. For calculating the velocity field near the front part of a cylinder we use the theory of laminar boundary layer and the von Karman-Pohlhausen method in particular [5].

We define the probability of contact of particles with a collector placed in a rectilinear flow is defined as the collision efficiency of particles [4]. For calculating the collision efficiency of passive particles we used the method of grazing trajectories. For calculating the collision efficiency of self-propelled particles, we have to take into account the fact that a trajectory of a self-propelled particle depends on the initial random direction of the particle swimming velocity. We assume that these vectors are distributed uniformly within an interval $0 < \phi < 2\pi$. The results of Monte-Carlo simulations are illustrated in Figures 1-2.

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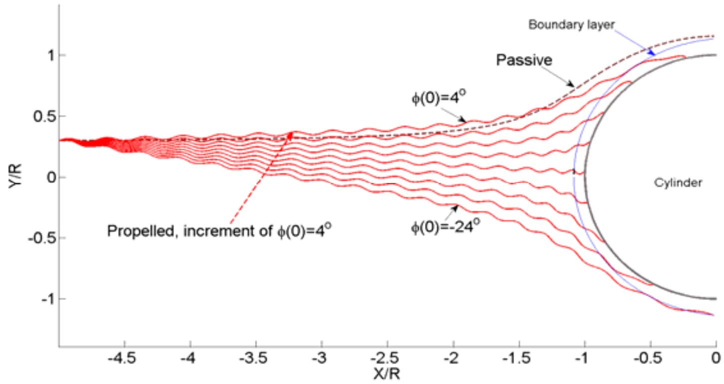

Figure1. Trajectories of passive and a self-propelled particles ($d_p = 250\times10^{-6}\,\mathrm{m}$, $V_S = 0.005\,\mathrm{m}$, $D_c = 0.10\,\mathrm{m}$). Particles start moving at the same point but with different initial track angles $\phi(0) = [-24^{\circ}; 4^{\circ}]$;

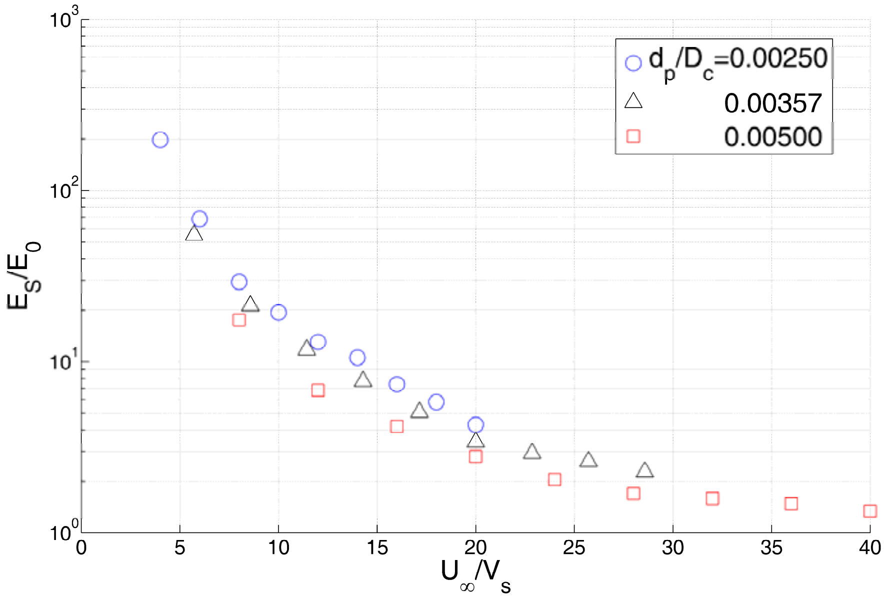

Figure 2. The collision efficiency of a self-propelled particle E_S normalized with the collision efficiency of a passive particle E_0 ($V_S = 0.005$ m/s , $d_p = 250\times10^{-6}\,\mathrm{m}$, $U_\infty = 0.020 - 0.20$ m/s).

CONCLUISIONS

The probability of contact of a self-propelled larva with a cylinder is by 1-2 orders of magnitude higher than the collision efficiency of the same but passive larva, even if the velocity of sea current is much higher than the larva's swimming velocity.

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References

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