Microswimmer propels itself with near-zero friction

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Scientists have found that a very slender micro-sized swimmer can propel itself without friction by surface treadmilling. The microswimmer moves by generating backward surface motion at the front end of itself, which is then consumed at the rear end. Because the surrounding fluid remains nearly motionless, the only possible friction stems from the motion of the front and rear ends.

The researchers, Alexander Leshansky, Oded Kenneth and Joseph Avron from Technion-Israel Institute of Technology, and Omri Gat from the Hebrew University of Jerusalem, say that this swimming technique is more efficient than any other self-propulsion technique proposed so far. Besides being an interesting concept, surface treadmilling may have applications in nanomedicine, where micro-organisms and micro-robots will travel through fluid environments.

As the scientists explain in their paper published in the *New Journal of Physics*, moving objects on the micro-scale are dominated by friction. On this scale, objects quickly come to rest without an external energy supply because of the low Reynolds number (the ratio of inertial forces to viscous forces in a fluid environment).

The authors investigated a scenario where motion is only apparent, in a sense: the swimmer moves forward without actually moving itself or changing its shape. Instead, the microswimmer uses unidirectional tangential surface motion, where the swimmer barely exchanges momentum with the surrounding fluid—the prime cause of high friction.

"The best analogy that explains the underlying physics would be the motion of tank tracks," Leshansky explained to *PhysOrg.com*. "While the portion of the tracks in contact with the ground is not moving relative to the ground, the tank is propelled forward. The same idea is employed here where the swimmer surface is pushing against viscous liquid. Thus, in the frame fixed with the swimmer propelled forward with velocity U, the surface is moving backward with the velocity -U, i.e. the surface material remains stationary in the laboratory frame almost everywhere except the ends that move."

The scientists explain that the treadmilling strategy can not be made completely frictionless because the front and rear ends must move slightly and cause energy to dissipate. These ends are the only cause of dissipation, and the swimmer experiences no drag along the rest of its body. In their paper, the scientists present a quantitative estimate of this remnant friction, showing that, as slenderness increases, viscous dissipation tends to zero.

Compared with other swimming techniques, treadmilling appears to be the most efficient method so far discovered. Other methods, including spherical squirming cyanobacteria, rotating helical flagellum, and even dragging by an external force, exhibit lower motion efficiency and more drag than the treadmilling technique.

"A low energy requirement is an important factor in a potential design of autonomous nanorobots swimming through the human body," said Leshansky. "For instance, such a nanorobot may swim through the arteries, digestive system, spinal canal, etc., transmit images and deliver microscopic payloads to parts of the body, and perform some kind of therapeutic action outside the reach of existing technology."

Leshansky explained that the recently reported designs of such nanorobots use flagellum-like tails for propulsion—swimming techniques with quite low hydrodynamic efficiency.

“A swimming technique based on treadmilling can offer a better solution for fighting viscous dissipation,” he said.

Citation: Leshansky, A. M., Kenneth, O., Gat, O., and Avron, J. E. “A frictionless microswimmer.” *New Journal of Physics* 9 (2007) 145.