Fluid-coupled rotation demonstrates unexpected modes of motion

Two cylinders rotating in a fluid can mimic the behavior of gears and of a belt-and-pulley system.

By Sarah Wells

When a bird flaps its wings, the air pushed away creates a cascade of swirling flow patterns, which in turn assist the flight of fellow birds in its flock. Those types of fluid-mediated interactions are simultaneously well studied and still not fully understood—especially when they involve rotating bodies. To study rotational hydrodynamic interactions in a controlled setting, Leif Ristroph and colleagues at New York University turned to an idealized system consisting of two cylinders rotating in a glycerol–water solution.[1] A better understanding of the dynamics could, for example, improve the development of technologies like wind turbines and enhance physics research on the flow properties of active materials, such as bacteria swarms and microrobots.

In their tabletop experiment, the team members used a pair of six-inch-long acrylic cylinders suspended vertically in a fluid solution to see how the motorized rotation of one cylinder could drive the rotation of the other, which was able to rotate freely. The researchers varied parameters like speed and cylinder separation and recorded the rotation behavior from the passive cylinder. To visualize how the rotating cylinders affected the flow of fluid around them, the team members densely seeded the fluid with bubbles (as seen in figure 1), illuminated the fluid with a

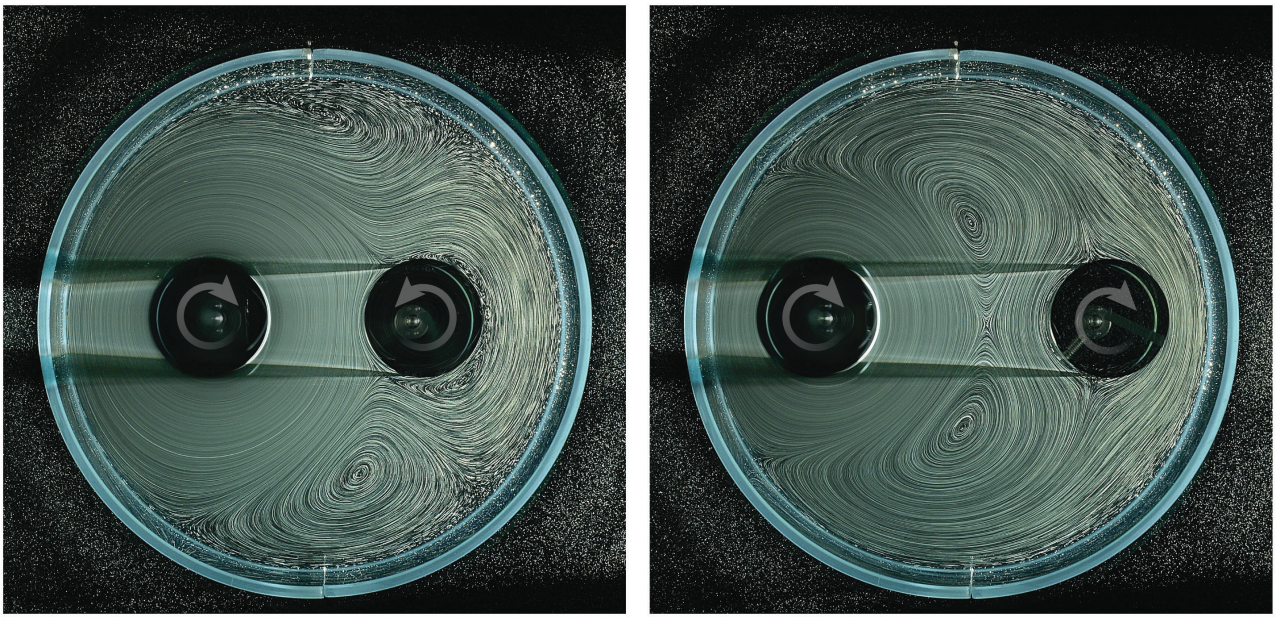

Figure 1. Researchers submerged two cylinders in a tank filled with a glycerol–water solution to observe how one cylinder would respond when the other was rotated. The image on the left demonstrates counterrotation; the one on the right demonstrates corotation. Bubbles seeded in the solution highlight the different fluid flow patterns. (Photos courtesy of NYU's Applied Math Lab.)

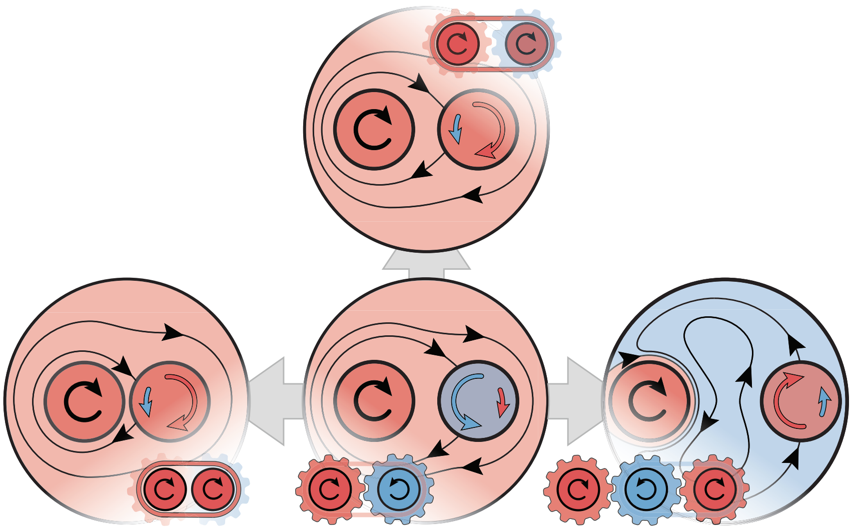

Figure 2. By making small changes to the experimental setup, such as placing the cylinders farther apart in the tank, the New York University researchers observed unexpected changes in the rotational coupling between the cylinders. In this cross-sectional schematic, the color of the cylinders, shear forces (arrows), and the surrounding fluid indicate the sense of rotation. Blue denotes counterrotation, reminiscent of interlocking gears, and red denotes corotation, which resembles belt-coupled pulleys. (Image adapted from ref. 1.)

horizontal plane of light at the cylinders' midplane, and then captured the bubble motion from below with a camera.

Based on similar interactions seen in biological contexts, the researchers expected to see counterrotation, in which the passive cylinder rotates in the opposite direction of the driven cylinder, like two adjacent, interlocking gears. Although they observed counterrotation for some drive parameters, they also observed three modes of corotation—rotation in the same direction—that were totally unexpected, says Ristroph. "What combinations of parameters led to the different outcomes turned up surprises at every corner."

Each of the four rotation modes was accompanied by distinct patterns of fluid flow around the cylinders, as sketched in figure 2. The researchers observed a transition from counterrotation to corotation when the cylinders were in close proximity or when the surrounding flow was strong; in both cases, the surrounding fluid acted like a belt that rotated the passive cylinder in the same direction as the drive cylinder. Corotation also appeared when the cylinders were sufficiently far apart to support a region of counterrotating fluid that acted like a third interlocked gear.

The team members are working on 2D simulations to better understand the underlying fluid dynamics that create the distinct modes. They are also exploring whether changing other aspects of the experimental setup, such as the fluid's viscosity or the driving torque on the active cylinder, will affect fluid flow and rotational coupling. **PT**

Reference

1. J. E. Smith, L. Ristroph, J. Zhang, "Hydrodynamic spin-coupling of rotors," *Phys. Rev. Lett.* **136**, 024001 (2026).