TURBINES DRIVEN BY TURBULENCE: HOW TO UTILIZE CHAOTIC FLUID MOTION

Significance

Turbulent flow is generally defined as any pattern of fluid motion that is characterized by chaotic changes in pressure and flow velocity. Hydrodynamic turbulence is observed when fluid inertia becomes a dominant factor. It is a common paradigm of unpredictable chaotic flows. In both 2D and 3D turbulence, nonlinear interactions spread the energy of the flow over a broad range of scales, known as the inertial interval. During this process, a substantial amount of energy is accumulated and stored into turbulent fluctuations. An interesting question is whether this energy can be harvested to power turbines or autonomous vehicles?

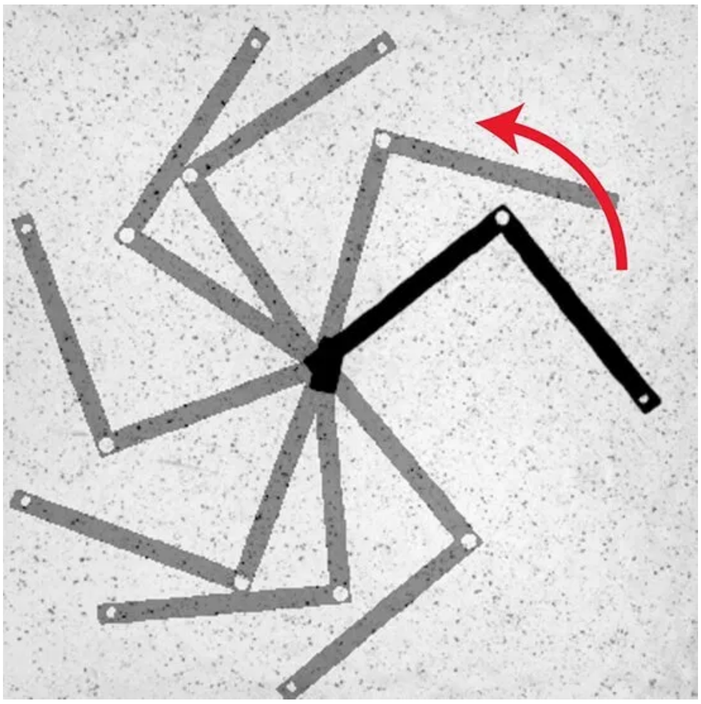
Efficient methods of harnessing the energy stored in turbulent fluctuations cannot be developed without a thorough knowledge of the structure of the turbulent flow. Thanks to advances in technology, it is now possible to describe laboratory turbulent flows from the Lagrangian perspective, i.e. in the reference frame of fluid particles advected by the flow.

Australian National University scientists, Dr. Nicolas Francois, Dr. Hua Xia, Dr. Horst Punzmann and Professor Michael Shats from the Australian National University, conducted a study that showed how to extract energy efficiently from two-dimensional turbulence by taking advantage of its fine Lagrangian structure. They demonstrated that the underlying Lagrangian structure of the wave-driven 2D turbulence could allow for rectification of the turbulent velocity fluctuations to power either a stationary rotor or a floating vehicle capable of propelling along a fluid surface. Their work is recently published in the research journal, *Physical Review Fluids*.

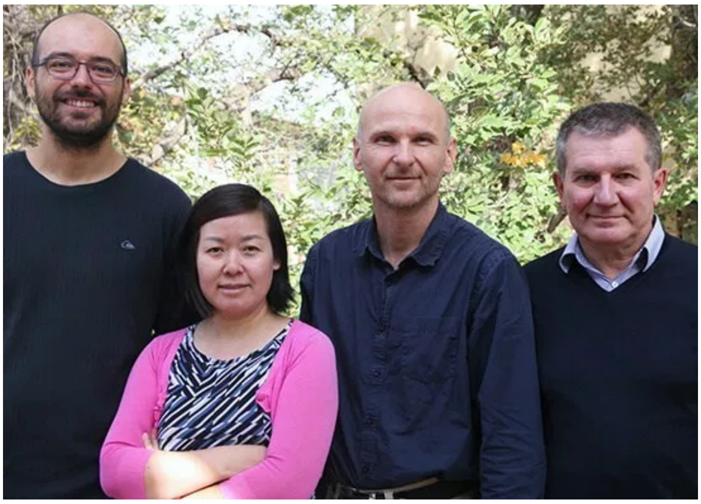
Equipped with modernized experimental approaches, the researchers demonstrated experimentally the operational principle of self-propelled vehicles, or rotors, by studying the coupling of the device geometry with the Lagrangian fabric of turbulence. The authors observed that the floating object in the wave driven turbulence was able to exploit the fluid erratic motion to fuel either directional propulsion or rotation. The shape of the object controls its ability to become a vehicle or a rotor that could tap the energy of turbulent fluid trajectories.

In summary, the results presented by Australian National University researchers allowed to uncover a way of utilizing the energy accumulated in the turbulent flows. More so, the Lagrangian nature of the mechanism allowed them to explain both the locomotion and the rotation at the fluid surface. The significance of this research also lies in the growing realisation that 2D turbulence is far more ubiquitous than originally thought. It is not restricted to the ‘Flatland’ or flows in infinitely thin layers of fluid. 2D turbulence has been observed in thick fluid layers, on the liquid surface perturbed by steep waves, as well as in many rotating flows such as the planetary atmospheres and oceans. It was noted that the key to the extraction of useful work from 2D turbulent flows was the efficient coupling of an object to coherent, yet transient structures present in the flow.

The authors work in the Physics of Biofluids Laboratory of the Research School of Physics and Engineering of the Australian National University in Canberra. The group studies phenomena in non-equilibrium complex systems, such as biological fluids and turbulent flows, as well as self-organisation in such systems. The group's activities cover fundamental problems such as ordering of chaotic and turbulent flows, control of transport and diffusion in fluids, as well as applied topics including self-propelled micro-swimmers for cargo delivery, manipulation of particles and micro-organisms in biological and micro-fluidics systems, and physical factors affecting bacterial biofilms.



Stroboscopic image of the motion of a half-rotor powered by wave-driven turbulence.



From left to right: Nicolas Francois, Hua Xia, Horst Punzmann, Michael Shats

Reference

N. Francois, H. Xia, H. Punzmann, and M. Shats. **Rectification of chaotic fluid motion in two-dimensional turbulence.** Physical Review Fluids 3, 124602 (2018).