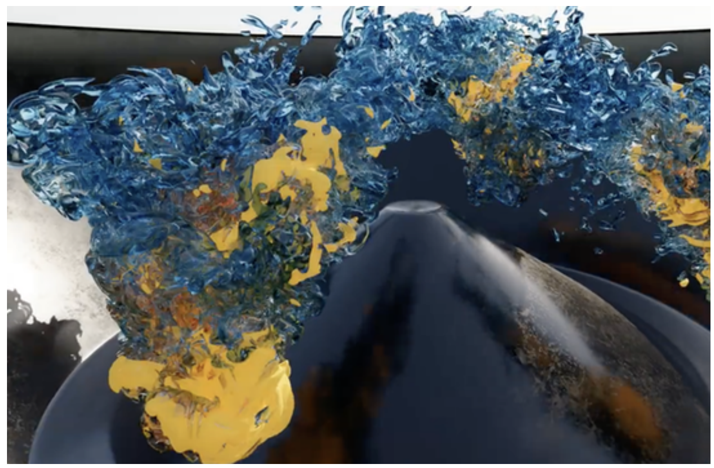
Fuel Ignition and Bottle Bubbles Snag Video Prize

An annual APS video prize went to supercomputer simulations, control of chaotic Faraday waves, and studies of a large bubble in a bottle.

By **David Ehrenstein**

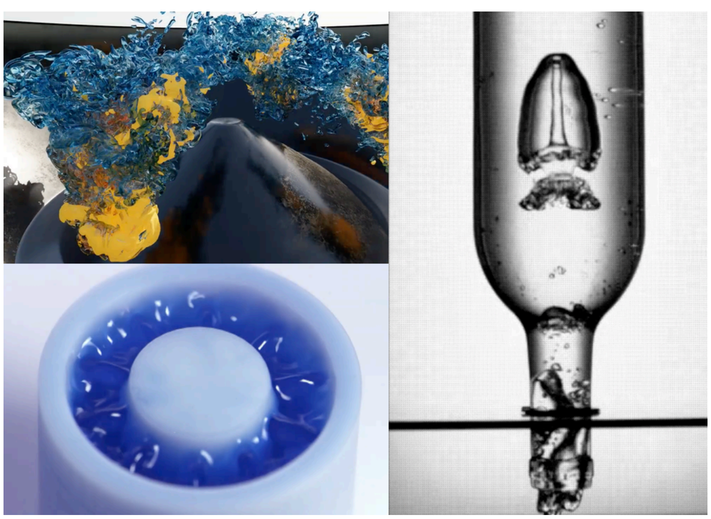
The APS Division of Fluid Dynamics has announced the 2022 winners of its annual **Gallery of Fluid Motion** video and poster contest. Below are the video recipients of the Milton van Dyke Award, which recognizes both videos and posters.



A supercomputer simulation captures details of fluid flow and chemical reactions in the moments before and after ignition in an RCCI engine cylinder, where both a methane-air mixture (not visible) and jets of diesel fuel (blue) are ignited. The locations where the fuels ignite appear in yellow.
Credit: N. Wimer and colleagues/NREL/Sandia National Laboratory

Supercomputer Simulates a Diesel Engine

Researchers have been redesigning diesel engines to increase efficiency and reduce emissions. This work relies on supercomputers for modeling the turbulent flow of the fuel-air mixture and the thousands of different chemical reactions within an engine's combustion chambers. Things get even more complicated when there are two fuels, as in the new reactivity-controlled compression ignition (RCCI) engine, which uses methane for its efficient burning and diesel for its ability to spark at low temperatures. “To move to that next realm of multifuel modeling, [it] really does require a new generation of computational tools,” says fluid dynamicist Nick Wimer of the National Renewable Energy Laboratory in Colorado.



Credit: N. Wimer/NREL; J. H. Guan/UNC; H. Mayer/Cal Poly, San Luis Obispo

Wimer and his colleagues have created two new codes that will run on Frontier, the world's fastest supercomputer, which recently began operating at the Oak Ridge National Laboratory (ORNL) in Tennessee. To demonstrate the codes' power, the team tested them on two slightly slower supercomputers at

ORNL with a problem of current interest to engineers: the earliest moments of ignition within an RCCI engine cylinder.

In the video taken from one simulation, the 3-cm-wide chamber is initially filled with an air-methane mixture. Then four jets of diesel fuel appear, and the simulation captures the complexity of the turbulent mixing of the diesel with the gas. A short time later, the ignition “kernels”—the spots where the fuel begins to burn—appear at the diesel-gas interface. The code divides the space into over two billion cells for the simulation and reaches grid sizes smaller than 7 μm. Wimer says the codes will also be useful for improving power-generation turbines fueled by hydrogen and heavy-duty, off-road vehicles that run on multifuel mixtures.

The usually stationary or chaotic Faraday waves that result from vibrating a liquid can be made to move in an orderly way through channels of various shapes.
Credit: J. H. Guan and colleagues/UNC, Chapel Hill/University of Glasgow

Faraday Waves Get Moving

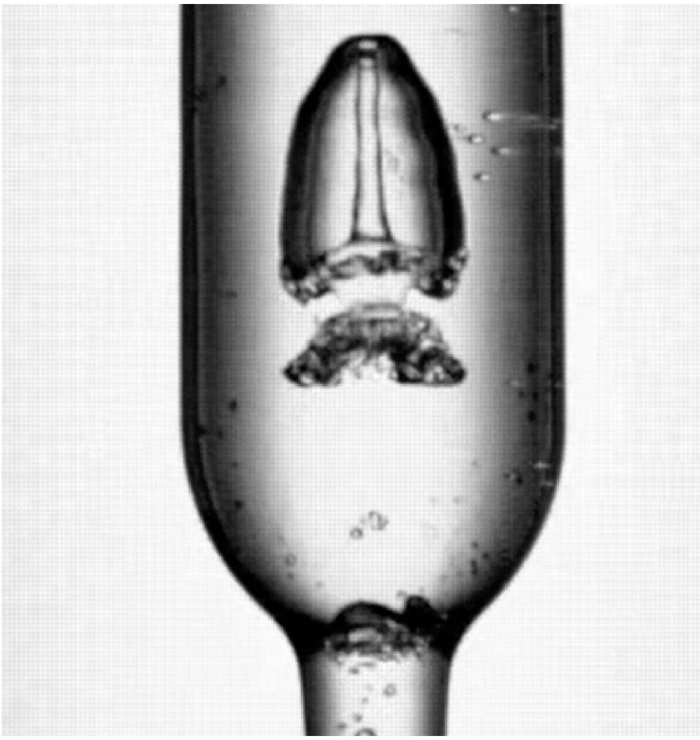
It’s one of those classic physics classroom demonstrations: water in a shallow vessel placed on top of a speaker producing a loud tone generates ripples on the liquid surface. These “Faraday waves” can form a range of patterns that are normally stationary, but the ripples will move around chaotically when the sound amplitude is large. Pedro Sáenz of the University of North Carolina, Chapel Hill, and postdoctoral researcher Jian Hui Guan wondered if this chaotic motion could be converted to coherent motion by restricting the space where the waves move. The researchers set up the liquid in a circular channel and were thrilled to see that the waves moved around the loop in an orderly way. The desired behavior appeared on the first try. “This is something that will happen once in my life,” Sáenz jokes.

The video from Sáenz, Guan, and their colleagues, shows that this coherent motion can proceed either clockwise or counterclockwise by random chance, but it can also be forced in one direction by adding a sort of staircase pattern (“ratchet”) to the walls of the channel. The researchers show that this steady motion of surface waves can also be guided through a more complicated channel network and can potentially be arranged to power a pump that could move another fluid through a separate channel. They titled the video *Run, Faraday, Run* to playfully refer to a famous line, “Run, Forrest, run,” from the movie *Forrest Gump*.

What Goes “Glug” When Pouring Wine

Wine normally leaves the bottle with a pleasing “glug-glug” sound as air forces its way through the narrow opening. In 2019, Hans Mayer of the California Polytechnic State University, San Luis Obispo, recorded a video of water falling out of an inverted wine bottle to show his mechanical engineering students the contrast with a simple draining tank. Watching the action in slow motion, “I was stunned to see what looked like an absolutely beautiful event,” he says, where a rising air bubble changed shape in a way he had not previously noticed.

Mayer has now teamed up with two undergraduate students to document the evolution of this bubble behavior. They took an empty bottle of the famously cheap “Two-Buck Chuck” wine, filled it with water, and then turned it upside down. Using a high-speed camera, the team observed several repeatable stages of the process wherein a large bubble pinches off, rises, produces an upward “jet” of liquid at its bottom edge, and then forms a toroidal structure before disintegrating. They then recorded this evolution for a range of water-glycerin mixtures, showing that the velocity and shapes vary with viscosity. Mayer says that the work is meant to grab the interest of students and the public. “I hope that we can inspire others to see the beauty in fluid dynamics, especially when it is something that is in a seemingly mundane and everyday event,” he says.



When liquid drains out of an inverted wine bottle, the first rising bubble goes through a series of shape transformations that depend on viscosity.
Credit: H. Mayer and colleagues/Cal Poly, San Luis Obispo

David Ehrenstein is a Senior Editor for ***Physics Magazine***.