Researchers explore the unsteady fluid dynamics of sailing

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A typical Olympic sailing race is a lot more energetic than a pleasurable afternoon cruise on the lake. Olympic sailors tip their masts precariously close to the water's surface while turning, right their vessels at what looks like the last possible moment, and bounce up and down over the edge of their boats on the straightaways. These unsteady sailing techniques, called "roll-tacking," "roll-jibing," and "flicking," propel boats faster through the racecourse.

Every aspiring Olympic sailor must master unsteady sail propulsion techniques, but there is no scientific literature that explains exactly how the moves increase a boat's speed. A team of researchers from Cornell University in Ithaca, N.Y. is working to change that.

"We know these techniques are effective, and we're looking into the fluid dynamic reasons why they're effective," said Riley Schutt, a graduate student working in the fluid dynamics research lab of Cornell engineering professor Charles Williamson. "We're studying what's happening in the fluid around the boat, the vortex dynamics that are there, and how they relate to an increased driving force on the boat," he said.

Williamson, Schutt and their colleagues first outfitted an Olympic-class Laser sailboat with an army of sensors. They installed instruments to take wind measurements, an array of cameras to capture sail shapes and angles, and inertial measurement units and a GPS device to record the speed and motion of the boat. They then asked world-class sailors, including Sarah Lihan from the 2012 U.S. Olympic sailing team, to execute roll-tacks, roll-jibes and flicking maneuvers with the boat under a variety of wind and wave conditions.

Williamson, who is the faculty advisor to the Cornell sailing team, even sailed the instrumented boat himself. A number of the sailors from the Cornell team have been involved in the research, including captains Phil Alley, a top-ten collegiate sailor in 2011, and Jenny Borshoff, who finished third in collegiate Women's Nationals.

"We've done a significant amount of on-the-water testing, and we have been able to get characteristic sail motions from the data we collected," said Schutt.

The flicking motion in which the sailor bounces up and down, for example, can make the trailing edge of the sail whip back and forth. The movement has components that are both parallel and perpendicular to the flow of air over the sail, creating what the researchers term an "exotic heave," in contrast to a classic flapping motion that would be purely perpendicular to the sail's motion through the air.

"Our next step is to recreate these motions with a 2-D sail section in a computer-controlled towing tank and measure the lift and drag forces," Schutt said.

The team has so far re-created some of the flicking sail motions. They used particle image velocimetry (PIV), in which the fluid around the sail is seeded with tracer particles, to track the complex vortex dynamics that develop around the sail. The researchers are currently validating these measurements before moving forward with further testing.

Williamson says the team's findings may contribute to flying and maneuvering of other flapping-membrane devices, such as micro-air vehicles.

"What we're doing is all new to the research world, and that's part of the excitement of this work," he said.

"This is like sports-inspired fluid dynamics," Williamson said. "Like bio-inspired fluid dynamics, it looks at the strategies developed by the fittest survivors, but in this case survival doesn't take a million years, survival of the fastest occurs each four years when sailors go to the Olympics."

More information: meetings.aps.org/Meeting/DFD14/Session/M30.3

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