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Scientists discover second purpose for vortex generators

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Vortex generators on the wing of an airplane at the Air Force Museum of the German Federal Armed Forces in Berlin. Image credit: Wikimedia Commons

(Phys.org)—An airplane's vortex generators, which look like small fins on its surface, improve the plane's aerodynamics similar to the way in which the dimples on a golf ball improve the ball's aerodynamics: by delaying "boundary layer separation." While this mechanism is widely known, a new study has shown that vortex generators can improve a plane's aerodynamics in a second way, and the researchers demonstrate this way in a wind tunnel for the first time.

When a golf ball, an airplane, or any solid object moves through the air, a small layer of air called a boundary layer surrounds the object. Even the Earth has a planetary boundary layer, which consists of the lower atmosphere that extends a few hundred meters above the surface; we live most of our lives in this boundary layer. Since the boundary layer is somewhat viscous, or sticky, and slow-moving compared to the moving golf ball or flying plane, it falls behind and separates from the object, creating a wake. This wake creates drag on the object and slows it down, resulting in shorter drives for golfers and higher energy requirements, as well as the potential for loss of lift, for airplanes.

To combat this problem, the dimples on the golf ball and the vortex generators on an airplane's wings can delay the separation of the boundary layer by creating minor turbulence, which gives the boundary layer more energy and enables it to move a little faster to keep up with the object. For airplanes, the boundary layer separation is especially problematic when the wing is at a high angle of attack, such as during the take-off or landing. By keeping this air flow "attached" for as long as possible, the dimples and vortex generators make the boundary layer separate later and produce a smaller wake.

Now a team of researchers, Shahab Shahinfar, Sohrab Sattarzadeh, and Jens Fransson from the Linné Flow Centre at KTH Mechanics in Stockholm, Sweden, in cooperation with Alessandro Talamelli at the University of Bologna, Italy, have demonstrated that these simple vortex generators serve remarkably well at minimizing the boundary layer's drag by delaying its transition from a low-friction laminar flow to a high-friction turbulent flow. Their study is published in a recent issue of *Physical Review Letters*.

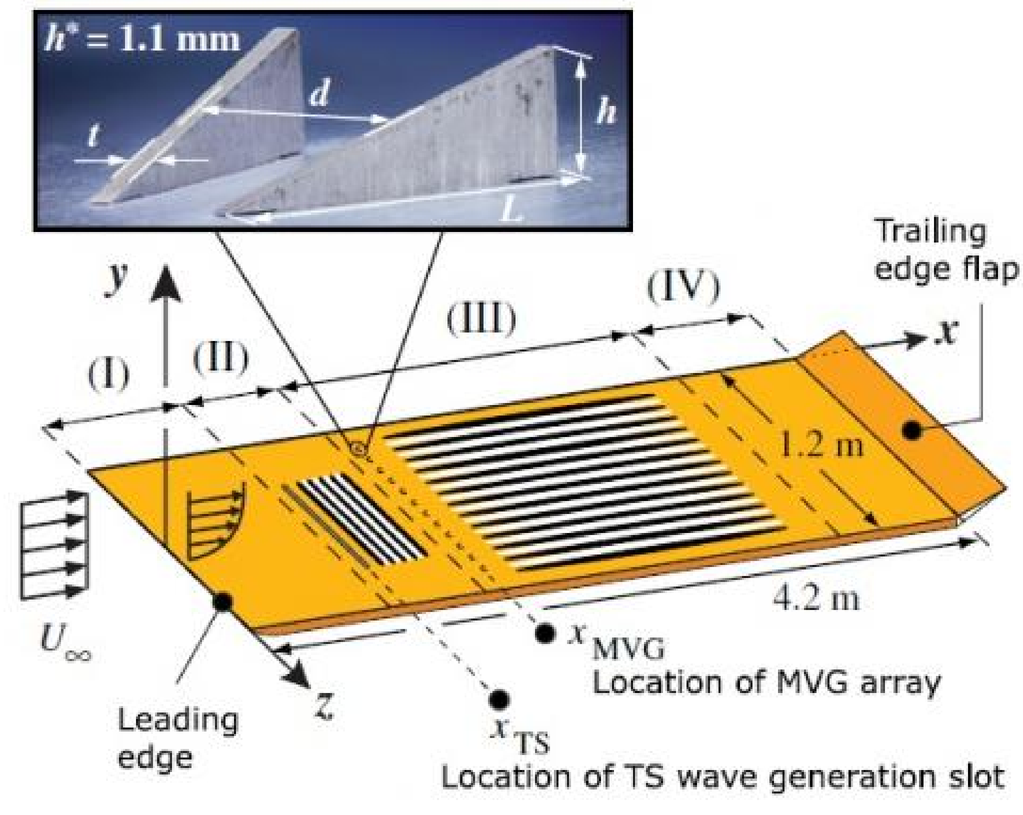

Illustration of the flat plate used in tests, with a photo by John Hallmen of a pair of miniature vortex generators. Image credit: Shahinfar, et al. ©2012 American Physical Society

As the researchers explain, an object's boundary layer starts out as laminar, or smooth and orderly. As the object continues to fly through the air, small disturbances create instabilities and, above a critical value, the laminar flow regime transitions to a turbulent one. The transition can easily result in an order of magnitude increase in skin-friction drag on an aircraft.

To demonstrate the effectiveness of using vortex generators to delay the transition to turbulence, the researchers attached miniature vortex generators (MVGs) to a flat plate and placed the plate in the wind tunnel at the Royal Institute of Technology (KTH) in Stockholm. They found that, under certain flow conditions, the MVGs could significantly delay the transition from laminar to turbulent flow.

"This is the first study ever that convincingly shows transition to turbulence delay in a realistic flow configuration," coauthor Alessandro Talamelli of KTH Mechanics and the University of Bologna told *Phys.org*. "We show that the disturbance energy inside a boundary layer can be reduced by three orders of magnitude by making use of appropriately designed MVGs. This is an important result in the quest to accomplish skin-friction drag reduction."

However, the researchers found that this advantage has an Achilles' heel: if the conditions surpass a certain threshold, the boundary layer will actually transition to turbulence sooner than it would without the MVGs. To avoid this, the so-called "streak amplitude" must stay below a certain threshold.

"The streak amplitude is a measure of how much the flow is modulated in the span-wise direction, i.e., the direction perpendicular to the mean flow (in aeronautical applications it is the one along the wing span)," Talamelli explained. "The key ingredient in ensuring that the amplitude will stay below 25% of the free stream velocity lies in the design criteria of the MVGs."

One advantage of using vortex generators to delay the transition to turbulence is that the mechanism is entirely passive, so it doesn't require the addition of extra energy into the system. Other methods of achieving turbulence delay use sensor-actuated electronics that require energy and are more complicated overall.

Since the flow phenomena studied here exist in a variety of areas, such as lasers, plasma physics, and granular flow dynamics, the researchers hope vortex generators may be useful for a variety of applications that could benefit from turbulence delay.

"The controllable streak amplitude, which is a function of the MVG height among other things, and the fact that the streaks are very robust in terms of stability, gives the method the potential to be used in real applications," Talamelli said. "It can be applied to aerodynamic bodies, which are mainly interested by reducing the skin-friction drag."

More information: Shahab Shahinfar, et al. "Revival of Classical Vortex Generators Now for Transition Delay." *PRL* 109, 074501 (2012). [DOI: 10.1103/PhysRevLett.109.074501](https://doi.org/10.1103/PhysRevLett.109.074501)

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