AOA for GA

Angle of attack moves from academic to actual

BY DAVE HIRSCHMAN

For most general aviation pilots, angle of attack (AOA) is an abstract and largely theoretical concept.

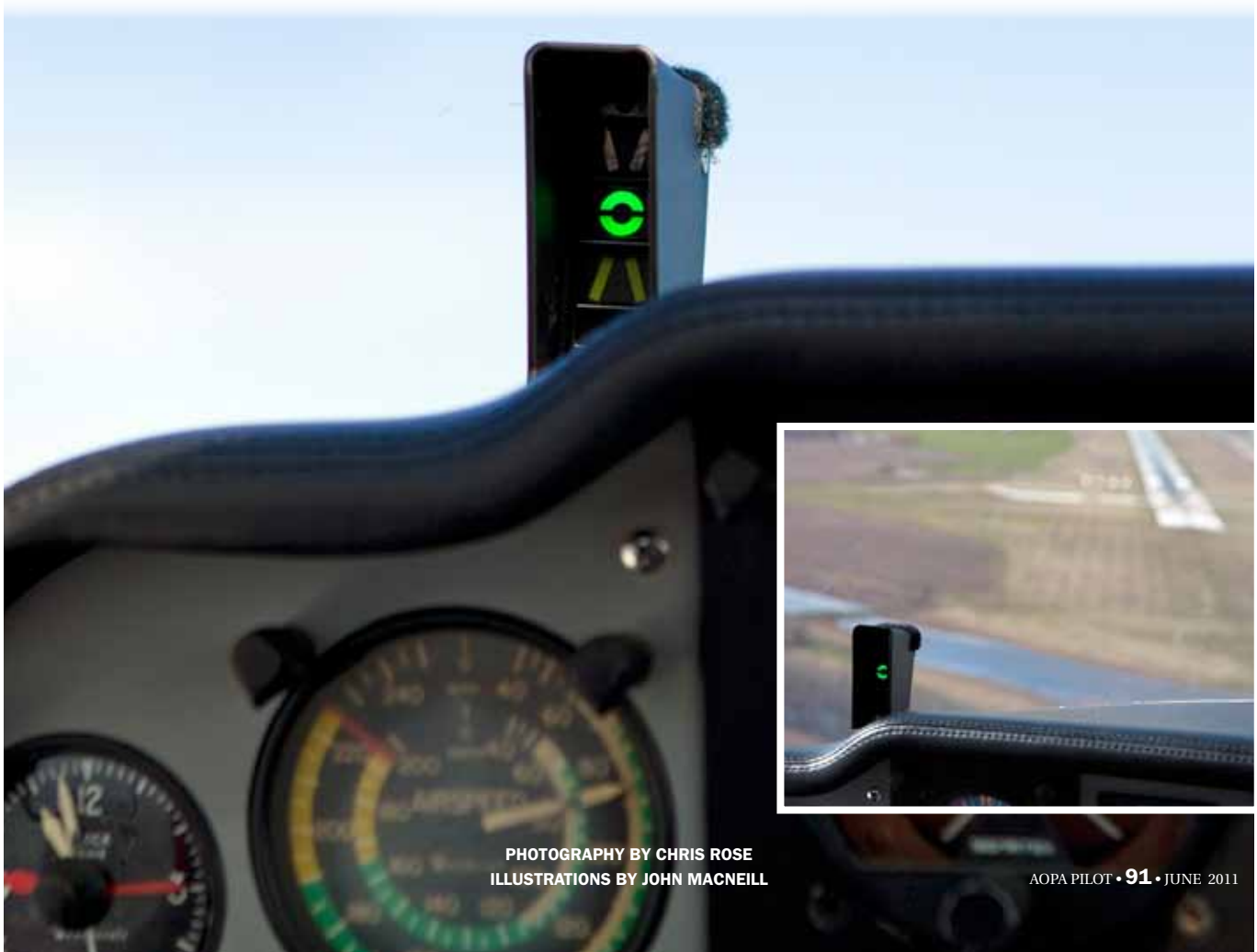
Pilots learn the proper definition—AOA is the angle between the chord line of the wing and the relative wind—and answers to questions we're likely to find on FAA knowledge tests: An airfoil always stalls at the same critical AOA, and an airplane can stall at any airspeed and any attitude. But few light GA aircraft are equipped with instrumentation that can show AOA in real time, so the subject is relegated to academic discussions of aerodynamic theory that seem far removed from the ways we actually fly. Today, however, lightweight, digital, and relatively inexpensive AOA instruments provide pilots of some light piston aircraft the same safety benefits that previously were limited to high-end corporate jets and U.S. Navy and Marine aircraft.

By placing a bright, easy-to-read AOA indicator on the glareshield, and giving a series of aural tones and automated voice callouts when AOA is nearing the critical angle, GA pilots gain a potentially lifesaving tool that can help them avoid inadvertent stalls—such as those leading to deadly base-to-final stall/spins—and other losses of aircraft control during maneuvering flight. (Stall/spins accidents in airport traffic patterns have accounted for about 7 percent of all fatal GA accidents in the past 10 years, and other losses of aircraft control while maneuvering made up 13 percent during the same period, according to the Air Safety Institute.)

AOA indicators also help pilots fly more precise approaches because they automatically compensate for variations in aircraft weight, pitch and bank angles, and density altitude.

"It's like having a trusted, observant, wise, skilled friend in the right seat—even when you're flying solo," said Fred Scott, a Virginia pilot and aircraft owner who set out to improve AOA equipment and education for GA pilots after several close friends were killed in a stall/spin accident five years ago.

Scott and Tom Rosen, an American Bonanza Society director, have funded



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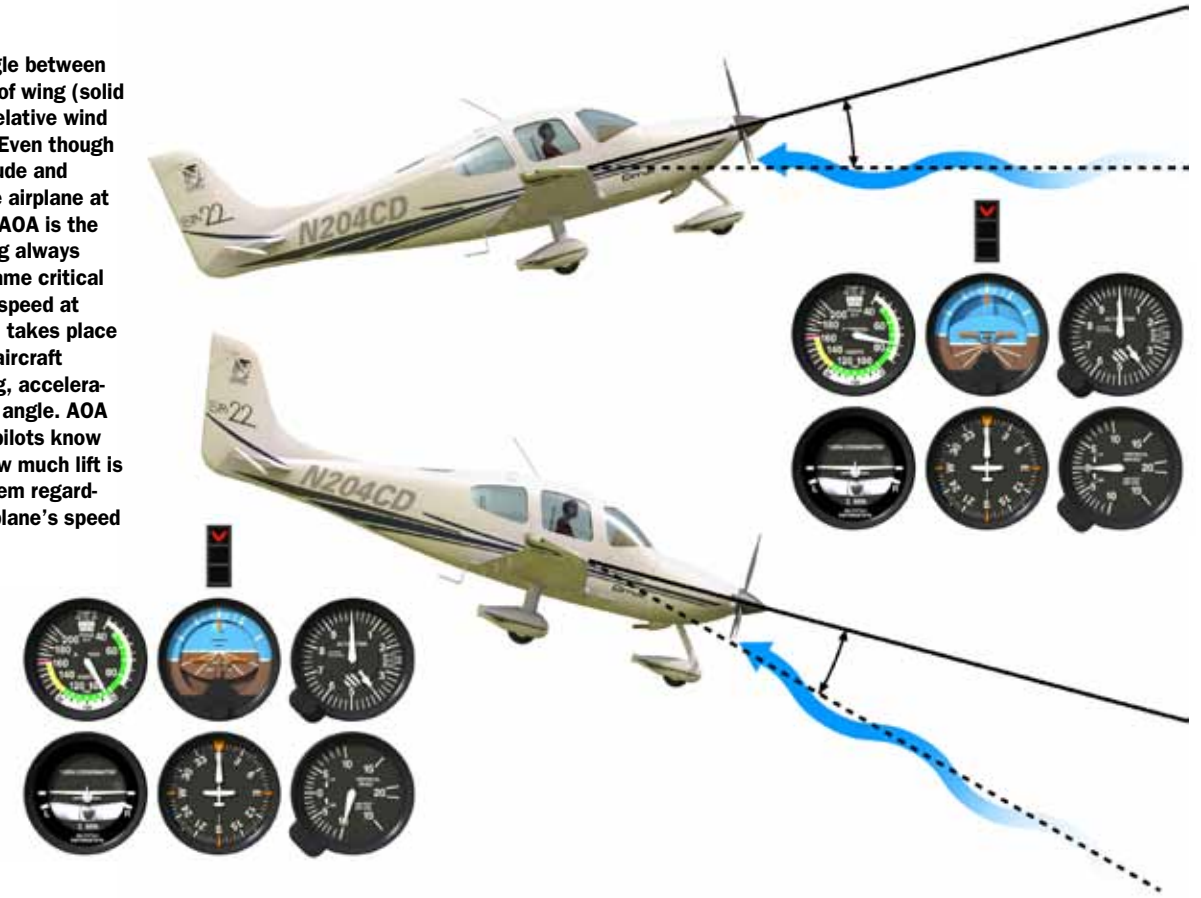

AOA is the angle between the chord line of wing (solid line) and the relative wind (dashed line). Even though the pitch attitude and airspeed of the airplane at right vary, the AOA is the same. The wing always stalls at the same critical AOA—but the speed at which the stall takes place changes with aircraft weight, loading, acceleration, and bank angle. AOA indicators let pilots know at a glance how much lift is available to them regardless of the airplane's speed and attitude.

testing of AOA instrumentation manufactured by Alpha Systems, a Minnesota firm that has developed and sold a variety of AOA equipment for GA aircraft beginning in the 1980s.

"We've tested the equipment, gathered the data, and have conclusively shown that the device is accurate," Scott said. "But whether people buy an AOA indicator from Alpha Systems or someone else, there's no question that this inexpensive AOA technology can save lives, and we in the aviation community need to get it into more cockpits—and do a better job of educating pilots about AOA."

Companies currently manufacturing AOA indicators for light GA aircraft include Advanced Flight Systems, Alpha Systems, Dynon, InAir Instruments, and Safe Flight Instrument Corp. (Only Safe Flight's AOA indicators are FAA approved.)

Mark Korin, owner of Alpha Systems, is an AOA evangelist and spends most of his time and effort at aviation events teaching pilots about AOA. "For me, it's more of a crusade than selling a product," said Korin, a design engineer, GA pilot, and entrepreneur. "Once pilots see how AOA indicators improve safety and reduce their workload, selling products is easy."

Rob Hickman, founder of Advanced Flight Systems, said his Oregon-based company has sold about 3,000 AOA indicators, and the vast majority of them are installed on Experimental aircraft. Some non-TSO instruments can be installed on Standard-category aircraft as "minor alterations," which require a sign-off from an A&P mechanic, and others require going through a more cumbersome field approval process.

"We're looking at certifying our patented AOA system and the FAA has encouraged us to pursue certification," Hickman said. "Giving pilots AOA information is a tremendously effective way to enhance safety, and pilots who fly with our AOA instruments are our biggest supporters."

AOA has long been the main measurement that U.S. Navy pilots use when approaching aircraft carriers for landing. An F/A-18 Hornet, for example, can weigh tens of thousands of pounds more when carrying a full fuel load and external stores than it does when flying with little fuel and nothing attached to the airframe. These wide variations in aircraft weight alter the airplane's stall speed and significantly change its optimum approach speed, but the critical angle at which the wings stall is always the same.

Similarly, a corporate jet landing with full fuel tanks and passengers must approach at a significantly higher airspeed than the same airplane landing with little fuel and just the crew on board. And a Cessna 185 carrying passengers and supplies to a glacier in Alaska's Denali National Park must fly a faster approach than the same aircraft on its empty return to Anchorage.

Pilots have long been taught to calculate the proper approach speeds for these kinds of different scenarios. But the math gets complicated when the airplane is turning, climbing, or descending—and when loads, outside air temperatures, and atmospheric conditions are changing. When in doubt, pilots tend to pad the numbers with higher approach speeds and fly by feel.

AOA indicators avoid such guesswork by continuously displaying the proper angle to fly—and pilots know instantly how much lift is available to them regardless of aircraft weight, air density, attitude, turbulence, ground effect, or flap or landing gear configuration.

"An airspeed indicator is only good for four things," Korin said. "It's a primary instrument, so it satisfies the FAA regulatory requirement that you have one in your airplane. It also lets you know when it's OK to put the landing gear down, when you can put the flaps down, and when you're approaching V_{NE}. But an airspeed indicator can't tell you how much lift is available to you at any given moment. Only an AOA indicator does that."

Traditional AOA indicators get their information from external vanes

mounted on the side of the fuselage that directly measure AOA and display it on a cockpit instrument—usually a series of lights above the glareshield and/or symbols on the PFD. These heated vanes are often certified under the FAA's most stringent Part 25 standards, and they are both precise and expensive.

Non-TSO systems for GA aircraft are usually sold as kits and range in price from about $600 to $1,500. Instead of moveable vanes, Alpha Systems AOA indicators derive their information from a fixed, under-wing mast with a pair of ports that measure differential air pressure. The AOA system is completely separate from the aircraft pitot/static system. Advanced AOA indicators derive their information from static ports on the top and bottom of the wing that measure differential air pressure, so there's no external probe. Dynon gets AOA information from a pitot tube with two ports that measure differential pressure.

Safe Flight makes AOA systems for aircraft ranging from gliders to airliners. The company's product for piston GA aircraft replaces the stall warning tab on the leading edge of the wing with a heated, highly accurate lift transducer that transmits AOA data to a primary flight display and/or AOA instrument. Safe Flight AOA indicators are FAA approved, installations are done through a supplemental type certificate (STC), and its GA products carry suggested retail prices of less than $5,000.

Michael Friedman, a Virginia ATP/CFII who has logged more than 3,500 flight hours in the 1965 Bonanza S35 he's owned for 28 years, said the AOA indicator he installed has changed the way he flies and teaches. It also allows him to confidently lower his approach speed during circling IFR approaches.

"I used to fly no slower than 120 knots during circling approaches because I was concerned about the possibility of an inadvertent stall," he said. "Now, I maneuver at about 85 knots and dramatically shorten my turn radius and stay closer to the airport while circling because the AOA indicator lets me know I've got enough of a margin to fly that way safely. "

Like other Standard-category airplanes, Friedman's Bonanza has a stall warning system that consists of a tab on the leading edge of the left wing and a horn that blares at high angles of attack. But the stall warning system is a simple on/off switch that doesn't show trends. In cases where the angle of attack is rapidly increasing and/or airspeed is quickly

Attitude isn't everything

I was practicing for an aerobatic contest in an underpowered biplane, and my loops were consistently and frustratingly egg-shaped.

To make them round, I'd have to tighten them, and that meant pulling sooner and harder on each maneuver. From level flight I'd pull about four Gs until the nose was vertical, relax the back-pressure as the airplane floated over the top, then pull four Gs again as quickly as possible while the nose fell and airspeed increased.

That's when I got an eye-opening, real-world lesson about angle of attack.

With the nose of the biplane pointed straight down and pulling aggressively on the stick to minimize the radius of the loop, buffeting airflow over the wings made it feel as if I was driving down a bumpy country road. Determined to make the loop round, however, I kept pulling until, finally, the airflow separated, the wings stalled, and the airplane snapped 90 degrees to the right.

The instant I relaxed the back-pressure, the airflow reattached and I emerged from the botched maneuver.

I had heard and read during private pilot training that a wing could stall at "any airspeed and any attitude." But it hadn't occurred to me that an airplane pointed straight down at full power could exceed its critical AOA and stall. Finally, the light came on and I was able to grasp a concept that I had never fully understood or appreciated: An airplane's attitude and its AOA really are completely unrelated.

An F–22 Raptor can climb vertically and accelerate straight up at a very low AOA, while an Extra 300 can snap roll with its nose pointed at the ground and a very high AOA.

Since then, I've provided more than 1,000 hours of dual aerobatic instruction, and observed many fellow pilots deepen their understanding of AOA—usually by way of a seemingly endless variety of hopelessly screwed-up maneuvers. But that's how pilots learn, and for most of us, it takes real-world events for theoretical concepts to jell.

Of course, you don't need unusual-attitude training to understand AOA. Just realize that, in normal flight, pulling on the stick or yoke increases AOA—and when you reach the critical angle, the way to recover is to reduce the AOA regardless of the airplane's attitude.

In most of life, attitude is everything. With AOA, however, attitude means nothing. *—DH*

diminishing, there can be little time from the blare to the aerodynamic stall.

The knowledge that their airplanes are safely above stall allows pilots with AOA indicators to avoid the trap of flying too fast on approach. Pilots are taught to increase approach speeds during gusty winds and while carrying heavy loads—and excessive approach speed can cause pilots to overshoot the base-to-final turn, bank too steeply to correct, and then stall—with catastrophic results.

Flying too fast on final also can lead to excessive speed in the landing flare. Long landings are rarely fatal, but they lead to a great deal of needlessly damaged or destroyed aircraft, along with the anguish and expense that goes with them. "Airplanes are going off the ends of runways because the pilots flying them aren't comfortable in the slow-speed regime," Friedman said. "They figure if 80 knots is OK on final, then 90 must be better. And if that's so, why not 100?"

AOA indicators provide backup in case of a blocked pitot tube or failed airspeed indicator. If the pitot tube gets clogged by ice or debris, pilots with AOA indicators can use them and fly with much greater precision than the old mantra of "pitch plus power equals performance."

The Air Safety Institute has long taught pilots about AOA (Essential Aerodynamics, www.aopa.org/asf) and evaluated AOA systems for GA aircraft. Now, the displays have evolved after additional testing, experimentation, and real-world experience. And whether AOA information is displayed on dedicated instruments mounted in the pilot's field of view on approach, or incorporated into glass-panel PFDs, they hold great promise for improving pilot understanding of AOA and becoming key safety tools in GA cockpits—just as they have long been regarded as essential equipment in corporate jets and naval aircraft.

Scott installed an Alpha Systems AOA indicator in his King Air 90, and an extensive series of tests shows that it's accurate at his home airport near sea level all the way to the flight levels where the airplane cruises. Scott and Rosen paid for testing the AOA system in several piston and turbine aircraft and say they will share their data without charge.

"We know AOA education and accurate, low-cost AOA indicators will save lives," Scott said. "We want to share the benefits as broadly as possible." AOPA

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