BETTER WAY TO FLY

Airspeed or Angle of Attack?

BY JAMES B. FRANTZ

What makes an aircraft fly is not airspeed, but angle of attack. I know, that's not what your flight instructor said! Unfortunately, we have all been conditioned to trust the airspeed indicator keeping us flying and avoiding stalls. In short, it was the only instrument we had at the time. Our instructors gave us the best training given the limited instrumentation available. Today's popular sport aircraft fly faster, higher, further and with larger payloads as a percentage of their gross weight. As a result, the stall speed, the approach speed and other performance speeds can no longer be assumed to be a constant IAS. They never were.

NTSB reports indicating that the pilot "failed to maintain flying speed" are misleading because a safe flying speed at 1 G may be below the stalling speed at 2 Gs. In actuality, the pilot allowed the AOA to exceed the critical AOA and stall. Remember the colored white and green arcs on your airspeed indicator? If you were trained like I was, the bottom of the green radial is about where the airplane will stall in the clean configuration. In a 60° bank and at the maximum gross weight we all know that the aircraft stalls at a speed much faster than the bottom of the green arc, but how much faster? Until we look at an instrument that tells us the truth, stall related accidents will continue.

The Navy got it right since their carrier pilots are trained to make carrier approaches using angle of attack instrumentation exclusively, ignoring the airspeed indicator altogether. Spin recoveries in the military are again made using angle of attack instrumentation as are tight high performance maneuvers. At slow speeds, the airspeed indicator is just not accurate and has too much lag. AOA instruments on the other hand become more accurate as the speed decreases and the angle of attack increases. Angle of attack instruments are also common on transport category and corporate jets. Until recently, installation of these AOA systems were very expensive and beyond the pocketbook for general aviation aircraft owners. Not any more!

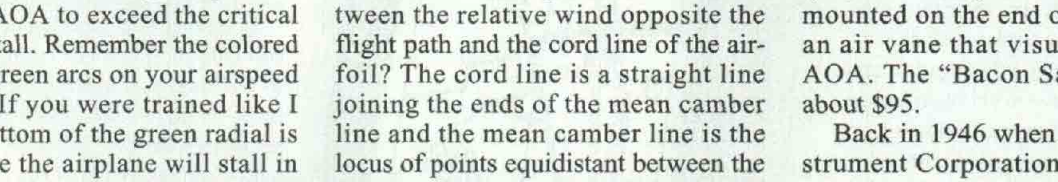
All pilots know that East is least, and West is best, maneuvering speed increases with gross weight, and a bird in hand is worth . . . But did you know that AOA is the angle as measured between the relative wind opposite the flight path and the cord line of the airfoil? The cord line is a straight line joining the ends of the mean camber line and the mean camber line is the locus of points equidistant between the upper and lower surfaces of an airfoil as shown in Figure 1. AOA is short for angle of attack and some aero guys even shorten it more calling it alpha ∝. It is important to remember that AOA is not the aircraft's attitude, body angle, or flight path angle. Gluing a bubble level to your longeron will not give you AOA information in flight or on the ground. In fact, it would be possible to be going straight up and still have an AOA of less than a few degrees.

And did you remember from your early flight training that as a general rule the stalling AOA is the same regardless of weight, bank angle, CG and fuel load? Conversely, the indicated airspeed at stall depends upon load and distribution of load. It makes no difference if that load is fuel, maneuvering loads or gust loads. Unfortunately, the airspeed instrument is notoriously ineffective at predicting the difference between flying and falling. The most accurate method of maintaining a proper margin above stall is to gauge AOA!

The Wright brothers were the first to understand AOA and discussed the concept in their letters. Probably the simplest of AOA instruments is a device marketed as the "Bacon Saver" by O'Neill Airplane Company in Carlyle, IL. It is a protractor type device mounted on the end of a boom with an air vane that visually indicates AOA. The "Bacon Saver" sells for about $95.

Back in 1946 when Safe Flight Instrument Corporation invented stall warning it began marketing stall warning instruments which use a vane that protrudes into the airstream and may have been the first financially successful general aviation AOA based instrument. These prestall warning and speed control instruments measured the deviation from an airspeed represented by a reference angle of attack using a wing mounted vane. Safe Flight's stall warning switch, horn and light is

FIGURE 1

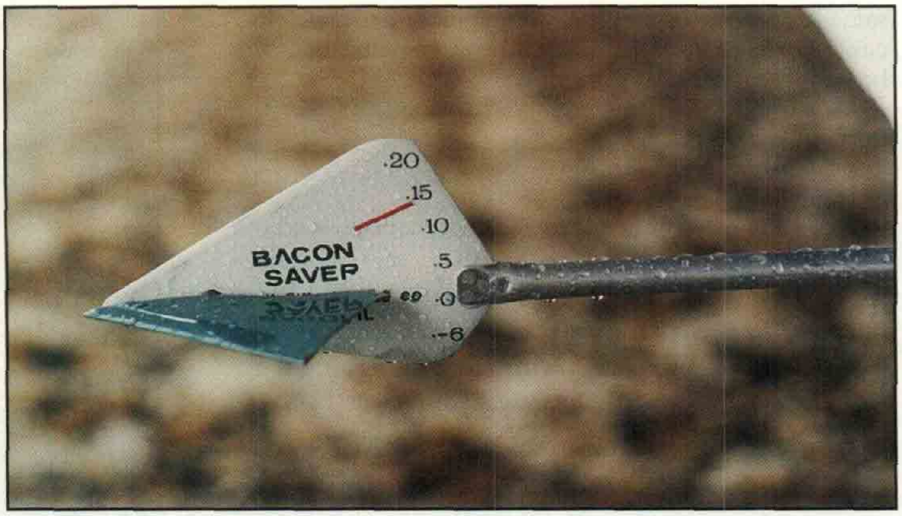


available through Aircraft Spruce for about $1,295 and their speed control system, which is based on an AOA transducer, is listed for $1,995.

Other entrants in the AOA market included Controlled Flight Mechanisms who market the Hunnington Lift Reserve Indicator. They use probes mounted on the wing which is rotated until the flared touch down indication matches a mark on the display.

The latest entrant with the most advanced general aviation instrument yet is Proprietary Software Systems, Inc. They designed and manufactured a patented AOA instrument with no moving parts or probes. It is all solid state, has a sunlight readable four-color liquid crystal AOA display, sounds aural warning and cautions, and is microprocessor controlled. The display has a green donut shaped target for the optimum approach AOA familiar to all Navy carrier pilots and red chevrons indicating when the AOA is dangerously high. A green split bar is called the performance bar which may be programmed by the installer and pilot to the best engine out glide or maximum endurance or best lift to drag AOA. The AOA instrument also has a self-testing feature that checks its accuracy and verbalizes "AOA PASS" when completed successfully. The quality and design is compatible with instrumentation found on the most expensive business jets. Even more amazing is the total lack of any protruding probe, strip or vane installation on the exterior of the aircraft. The instrument is not yet TSO or PMA approved. Because the AOA instrument is microprocessor controlled, it is programmed to talk to you, announcing warnings of high angles of attack, instrument problems and installation errors. It can also be used to drive stick shakers and buzzers. A warning "Landing Gear" will help prevent inadvertent gear up landings when the airspeed is slow and the gear is not down.

This quantum leap in affordable AOA and gear warning instrumentation is due in part to a relatively new device called the piezoresistive pressure sensor which is formed into a solid state chip. A typical pressure sensor chip measures only slightly larger than a grain of wheat. Sensors can be purchased for under $50 with additional circuitry for temperature compensation making this pressure measuring device affordable. Hurrah for technology!



The "Bacon Saver," first developed in 1963.

Proprietary Software Systems, Inc. combined the pressure sensing technology with another long known aerodynamic fact. When the difference between the pressures on the top and the bottom of the wing is known and divided by the measured airspeed pressures, the result is a coefficient of pressure. There is a unique variation of this coefficient of pressure (CP) with angle of attack. So, by using these new pressure sensors to measure the wing differential pressure and the pitot/static differential pressure, the AOA could be calculated. The requirement to perform a mathematical divide requires the power of a microprocessor which is another affordable solid state device.

Flying AOA is educational and great fun. Since we have never had anything to compare the IAS, we just didn't realize how misleading the IAS really is. A Lake Buccaneer was used as the test bed over the past three years while the AOA instrument was in development. The Lake factory briefing guide recommends that normal approaches should be flown at 75 mph. This allowed quite a large buffer for IAS errors and lag since the airplane stalls at 45 mph. We felt more than comfortable with this speed in all conditions, including steep turns to final. On the other hand the guide recommends only a 10 mph stall margin for a final approach speed of 55 mph IAS and a 150 fpm rate of descent for glassy water landings. The guide explains that this speed will put the Lake in the proper attitude for a glassy water splash down. The glassy water approach takes your full and undivided attention with one eye glued on the IAS and the other on the ROC. With the AOA instrument and flying a constant alpha, the glassy water approach is a snap. The AOA immediately indicated which way the IAS was trending well in advance of any detectable movement of the IAS indicator's needle. AOA tells you where the airspeed is going to be while the airspeed indicator tells you where it was.

It became very easy to use the elevator to hold the proper AOA and throttle to control the descent rate. In fact, this is exactly what the Navy requires and teaches aircraft carrier pilots.

A Lancair with a fairly high wing loading was also used as a test bed for the AOA instrument. Lancair approach speeds are fast, landing rollouts are long and stalls at pattern attitude are deadly. Lancair approaches are akin to a glassy water approach in that precision is a must, especially when landing on strips of less than about 2,600 feet. Again, the AOA greatly reduces the work load and allows a slower speed on final. The AOA and IAS instruments also act as a nice confirmation that each is working as expected. I once shot an approach with an inoperative airspeed indicator in a Lancair to a 2,600 foot strip. It sure would have been nice to have had an AOA instrument in the cockpit that day!

In the event of an engine stoppage it is imperative to immediately establish the best glide to the closest strip. Ignoring propeller effects, the best glide (best lift over drag) also occurs at the same AOA regardless of fuel weight, bank angle, etc. The precisely flown glide to the closest suitable could be the difference between a good hangar story and hospitalization.

Measuring AOA using pressure sensors is based on the following.

Definitions:

Ps	static pressure (ambient atmospheric pressure)
Pt	total pressure = $Ps + 1/2\ \rho V^2$
ρ	ambient air density
q	Pt-Ps used to drive the IAS instrument
P_1, P_2	local static pressures measured on the airfoil
CP_1, CP_2	pressure coefficient measured at points 1 and 2
α	angle of attack

There is a unique variation of CP with angle of attack α where the CP at the point of measurement is:

$CP_1 = (P_1 - Ps)/q$ and $CP_2 = (P_2 - Ps)/q$

With two wing pressure port sources to increase the instrument's fidelity located on both the top and bottom of the wing, the combined CP is:

$CP = CP_1 - CP_2 = (P_1 - P_2)/q = (P1 - P2)/(Pt-Ps)$.

It is then apparent that a pressure port located on the top of the wing and a pressure port located on the bottom of the wing with the local pressures ported to a differential pressure transducer divided by the airspeed's pitot/static differential pressure will result in a coefficient of pressure. It has been established that the coefficient of pressure varies linearly with AOA over most of the airfoil's AOA. Of course, the local wing pressures in the vicinity of the pressure ports must also vary linearly with AOA too in order to get precise results. This takes some airfoil analysis or experimentation.

The coefficient of lift vs. angle of attack relationship shown in Figure 2 illustrates the effect that flaps create on the relationship when retracted or extended. Since most aircraft have flaps or other high lift devices, the AOA instrument must take this into account as well. In effect, there are several airfoils the AOA processor must consider depending upon the number of flap settings available to the pilot. Each discrete flap setting has a distinct variation of CP with alpha including a unique critical AOA.

The wing pressure ports on the Lake were at 10% MAC and located about 16 inches inboard from the wing tip. The ports are simply an .040" (#60 drill bit) diameter hole drilled through the skin of the wing and connected to 1/8" OD tubing inside the wing. It is recommended that an air water separator be installed under the upper wing port. The pitot/static pressures were measured by teeing into the pressure tubes just behind the airspeed indicator.

Proprietary Software System's AOA central processing unit is equipped with a digital communications plug that can be cabled to a personal computer's RS-232 port. Software is available so the personal computer can collect and store wing pressure data during flight, along with IAS, AOA, coefficient of pressures and is a great source for later analysis back at the shop.

Angle of attack systems present visual indications of optimum aircraft performance and are primarily used during the approach and landing phases. AOA is also useful in high performance maneuvers. Aerodynamically in 1 G flight, angle of attack is airspeed. Or to put it another way, in 1 G flight by controlling the angle of attack, you are actually controlling

Proprietary Software System's angle of attack liquid crystal display.

Proprietary Software System's display during an optimum approach with the gear down and an AOA of 7.9 units.

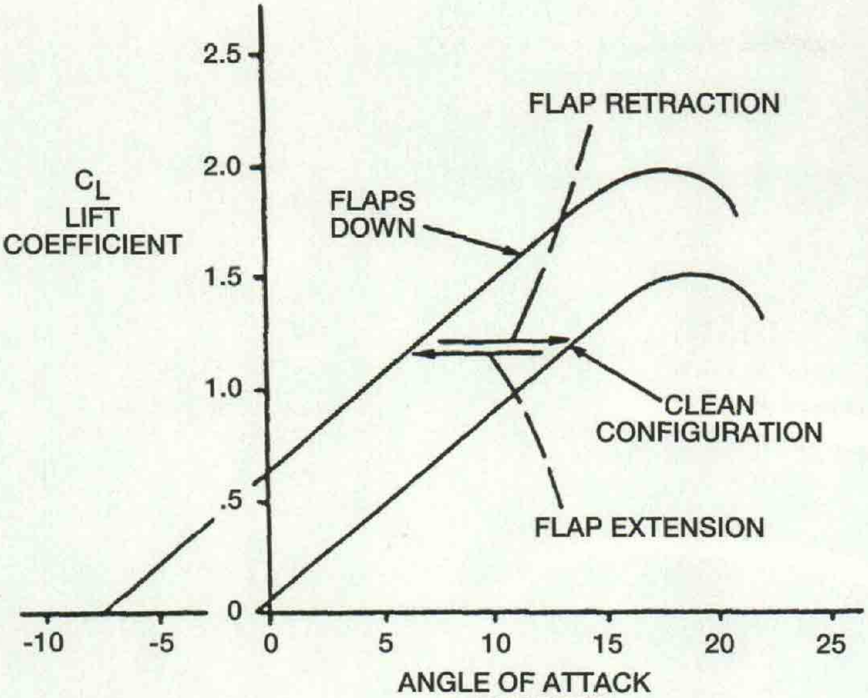


FIGURE 2

airspeed. When an aircraft is flown in a steady flight path at the best prescribed angle of attack, the resulting airspeed will be correct. When the pilot computes an airspeed for a specific phase of flight, he is actually computing the best angle of attack. Angle of attack is not directly affected by gross weight, angle of bank, fuel load, G loading or density altitude. Proper use of the angle of attack indicator will aid the pilot in obtaining optimum performance from his aircraft and can relieve him of many airspeed calculations.

The need for high tech angle of attack systems became apparent with the increasing numbers of high wing loaded fast experimental aircraft. The unacceptable fatality rate as a result of loss of aircraft control and contact with the ground has taken far too many of our friends and acquaintances.

AOA forever!

◆

ABOUT THE AUTHOR

My background is bush flying, software design and electrical engineering. My vocation is airline captain with over 18,000 flying hours. My company, Proprietary Software Systems, also publishes the Lancair Network News (a bimonthly newsletter), develops aviation related software and markets a full featured annunciator panel.

The Lancair I built won an Oshkosh Bronze Lindy in 1995. The Lancair did not have a stall warning device at show time because I thought they were unsightly and too expensive. I went to considerable pain to hide the antennas, so why ruin the sleek lines of the Lancair with the installation of a vein, probe or strip. In walking the flight lines at Oshkosh, I noticed that almost none of the other homebuilts had stall warning devices either. Someday other pilots will fly my Lancair. Why not provide them with the best tools to fly safely? That way, I don't have to worry.

My next flight will be to Oshkosh '98 with the revolutionary device that's more than a stall warning, an AOA instrument, the all around performance instrument that looks sexy too, just like my Lancair.

(For more information, contact James Frantz at 950 Iris Cir., Excelsior, MN 55331, 612/474-4154.)