Know your AoA

I believe that the aviation industry is starting to have a 'Eureka' moment about solving the problem of Stalls, Spins and Loss of Control. Authorities in the USA and Europe have recently agreed that Angle of Attack devices can be retro-fitted to any certified aircraft with minimal bureaucracy – in the USA simply a logbook entry is all that is required. Why is this such a big deal many will ask? Therein lies the problem. Unless pilots appreciate the importance of AoA and are convinced to think more

‘AoA’ and less ‘speed’, then simply fitting another device to aircraft will not have the desired effect. Here’s what Sully thinks:

“For more than half a century, we've had the capability to display AoA in the cockpits of most jet transports, one of the most critical parameters, yet we choose not to do it.”

Amazingly neither Boeing nor Airbus aircraft display AoA to their pilots, although it is measured and fed to onboard computers. (Both companies are currently giving serious consideration to changing this policy). Sully knows what he is talking about, having learned to fly on a tail-dragger at 16, he flew gliders and on the way to fame on the Hudson spent a lot of time on the McDonnell Douglas F4. Anyone who has flown an aircraft with AoA indication will realise why it is such a wonderful concept, not just for military fast jets and large transport aircraft but for every fixed-wing aircraft, and here’s why....

<u>Stall/Spin/Loss of Control</u>

Every Pilot is taught to avoid stalling. Much time and effort is put into preventing inadvertent loss of control. Yet not a lot has changed in the 100-odd years since the 18-year old 2nd Lieutenant Guy Knocker, a Sopwith Camel fighter pilot with 65 Squadron on the Western front, wrote this in a letter home:

“A fellow called Hancock who was at college with me arrived here two days ago. I went up this afternoon with him to show him the Lines but shortly after he had taken off, he did a right hand turn, stalled & spun. I watched him from above & he didn’t pull out of his spin but spun straight into the ground from 500 ft. He was killed instantly, poor fellow, rotten luck, wasn’t it? Quite his own fault poor chap – pulled the stick back to try & get the nose up & of course the bus spun faster than ever.”

It will come as no surprise to most GA pilots that Stall/Spin and loss of control close to the ground continues to be the single biggest cause of fatalities worldwide. Experience helps, but even experienced pilots are still dying in what appear to be avoidable tragedies. It's not just a GA-thing; the highly regulated environment that is modern commercial aviation has had tragic Stall/Spin LoC accidents in the recent past. Most pilots will have heard about a landmark accident in the USA at Colgan on 12 Feb 2009.

The NTSB determined that the accident was caused by the pilots' inability to respond properly to the stall warnings...... The captain overrode the pusher and continued pulling on the control yoke causing loss of control

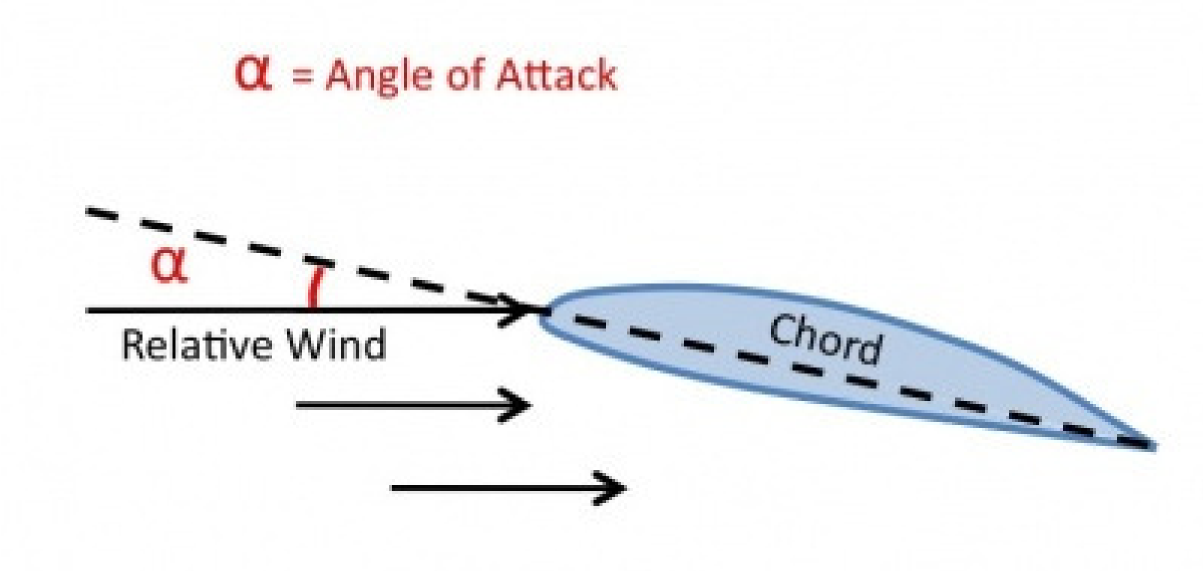
A few months later in June 2009 the aviation world was rocked by the disappearance of Air France 447. Later the incredible news that "**The aircraft remained stalled during its entire 3 minute 30 second descent from 38,000 feet"** led people to question the fundamentals of stall awareness.

<u>Understanding the stall</u>. From our very first flying lesson we are taught to fly airspeeds – rotate speed, climb speed, stall speed, approach speed and so on. However, to quote from one of my favourite 'letters to the editor' of all time (by Brian Lecomber in the Spring 2004 edition of GASCo Flight Safety) '*The ASI is a vague and sometimes actually misleading device*.' In the absence of anything better, we have, however, become obsessed by speed as a measure of how close we are to the stall. Brian goes on to say "*There is no such thing as 'stalling speed'. .... The stall is only and solely related to angle of attack (Alpha)"* This is the key to understanding the stall..

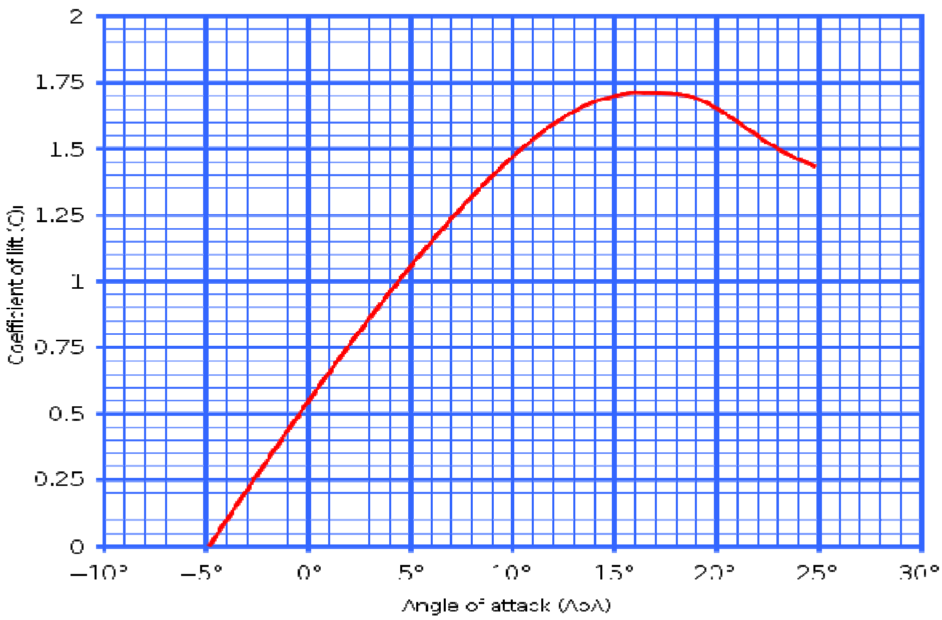
A little theory. I like Wolfgang Langewiesche's approach to Aerodynamic theory in his book *'Stick and Rudder'* first published in 1944. *Forget Bernoulli* he says, *although undoubtedly true, it is a poor concept for pilots in understanding how wings work*. I agree, I like to think of wings displacing air, rather like a plough. Sea-level air weighs well over 1 Kg per cubic Metre. So the more air the wing displaces the more lift is generated due to Newton's law of equal and opposite reaction. The shape of the wing helps the air 'make the turn'. For any given speed, the greater the angle of attack, the greater the amount of air displaced until, instead of displacing air, at a critical angle, the wing simply causes 'commotion'. Stick your hand out the window of a moving car and 'feel' how a wing works.

Wings displace air

Here is the concept of Alpha, or Angle of Attack.



The CL Vs Alpha graph in plain English simply tells us, *"More angle of attack = displace more air (more lift). Too much angle of attack = stall"*



The "*half rho V squared"* lift equation in plain English says that **Lift** is a product of *Angle of Attack* and *Dynamic Pressure* (assuming the wing is below 'stalled' AoA). Dynamic Pressure, from a Pilot's point of view, is equivalent to indicated airspeed, so from our perspective, in even plainer English:

LIFT is a product of **IAS** and **Angle of Attack**… That's it, nothing else!!

Pilots control lift by varying either speed or Alpha. When Alpha gets too much the wing 'stalls' and lift fails. Everything we do when we control an aircraft can be thought of in terms of changing angles of attack. Ailerons change the local angle of attack of a wing, a little more lift on one side, a little less on the other, we roll. Elevators cause the wing's angle of attack to change; if we are flying Level, Lift = weight. Increase the AoA and lift increases, we go up, reduce it and we go down, simple. When we land a Tricycle Undercarriage aircraft at the correct angle of attack (ie low speed), at touchdown the C of G tends to 'pull' the nose down, reducing AoA, dumping lift & causing the aircraft to stay on the ground. Land a tail-wheel aircraft at a low AoA (ie fast) and the C of G will tend to pull the tail down, increasing AoA & lift, leading to a 'bounce' unless the AoA is controlled after touchdown by the pilot pushing forward on the stick.

So what's the big deal with knowing what our AoA is? A practical advantage for GA aircraft is to be able to fly the appropriate AoA for short landings with a safe margin above the stall, irrespective of weight or density altitude.

Glider pilots have for years used tufts of wool to show out-of-balance flight. However, here a Pilot has improvised a wonderfully simple and reliable AoA device – I would imagine quite a useful 'Head up Display' in a Thermal – no doubt the budget would even stretch to having one on both sides ☺

A letter to the Editor in the 2014 Winter edition of the GASCo Flight Safety magazine from Robert Jago described an ingenious device that displayed AoA using a piece of bent wire and a tuft of wool.

Robert puts the case for AoA very succinctly *"In the conventional control of the approach the IAS is always the 'surrogate' for the angle of attack and the relationship may vary (for example when banking or pulling 'G' or with varying AUW). The actual angle of attack is the crucial measurement. The effect of this device is transformative. I cannot overemphasise the reassurance that comes from looking directly at the instantaneous representation of the actual parameter which determines the stall. "* Robert goes on to say that in his opinion if all aircraft had AoA devices, and pilots understood the significance of, and were trained to fly using an AoA indication, then the incidence of Loss of Control would be sharply reduced.

Many great new designs of AoA gadgets are coming on the market, some use vanes and some have pressure tappings to measure a wing's AoA. Displays can be part of an EFIS or stand-alone units. Some showing 'reserve lift' available, others use a linear scale colour coded to represent high and low AoA. Some have an audio function as well. Whatever system becomes popular the basic principle remains the same. *The wing always stalls at the same angle of attack.* Knowing where you are relative to that critical AoA is vital whether you are manoeuvering, approaching to land, coping with an engine failure, towing a banner, dropping parachutists, or in a cloud wondering which way is up.

What can I do if I don't have an AoA device? Most people will be in this situation for many years to come. However, there is a lot we can do to get aboard the AoA revolution. For a start, most aircraft already have a basic AoA device fitted – the stall warner. The very name suggests 'danger' – we tend to avoid them going off and students are (rightly) taught to recover immediately if the stall warner activates on approach. However, for more experienced pilots, it could be regarded as an AoA/airspeed calibration device and, if set correctly, a stall warner going off as a light aircraft touches down might be considered a good thing. I particularly like the Cessna 172/182 pressure measuring-type device that starts with a gentle 'squeek' and with increasing AoA develops into a blaring 'squeal'.

Apart from thinking of the Stall warner as an AoA measuring device, here are a couple of 'mind exercises' to help improve awareness of angle of attack:

Imagine you are Flying Straight and level at a low angle of Attack (ie at high speed). Look out along the wing and imagine where the airflow is coming from. The angle between that and the wing chord line is your angle of attack. Now, staying level, increase the AoA... (ie slow down while maintaining S & L). As the speed decreases the AoA must increase to keep the lift the same (= weight). Increase the AoA all the way to the point when the stall warning goes off. Fly there for a while, think again about where the airflow is coming from; the angle between that and your chord is now close to critical AoA.

Next, try loading the wing. From straight and level in a Low AoA cruise (you got it.. high speed) look out along the wing, pull back gently on the controls and think about what is happening. As you increase the angle of attack you displace more air, lift increases, the aircraft accelerates towards the centre of a huge vertical circle – which you feel as a 'G' force pushing on the seat of your pants – and you go up. The stall warner might sound during the pull up, especially if you pull too hard, not because you are slow, but because you have a high Angle of attack. Now, before you run out of energy, gently relax the pull. As you do so, the angle of attack decreases, less lift is produced, 'G' force reduces and the aircraft stops rising. Now push forward gently as you go over the top of a giant imaginary roller-coaster. The air is now coming from almost directly ahead of the wing, very little air is being displaced, AoA is very low, lift is low, 'G' force is less than 1... The speed right now is very low, in fact it could easily be less than the 'book' stalling speed.. but the stall warner does not go off. As the nose drops, pull out of the dive by increasing AoA then level off.

Both of these exercises are simple from a flying point of view, but the point is to think of **AoA** and not *speed.*

Limitations and food for thought. It is important to understand that any AoA or stall-warning device will have its limitations. Stalling AoA may change if flaps or slats are used. Ice will change the shape of a wing and probably reduce the critical AoA. Wings do not necessarily have constant span-wise AoA. Several factors, including slipstream, asymmetric wing loading (fuel imbalance, use of ailerons, ball not in the middle, a 'twin' engine-out etc) will mean that one part of a wing may in fact be quite close to critical AoA while another is still happily producing lift. Just a small 'overall ' demand for more lift can cause the high-AoA part of the wing to stall, in which case a 'flick' or 'spin' can result. Some aircraft have no washout which makes them prone to 'tip stall' if even a small amount of aileron is present in a high AoA situation – videos of both the 2012 Red bull air-race accidents illustrate this very well.

<u>In Summary</u>, Stalls/Spin accidents have been around since aircraft first flew. Traditional emphasis has been on speed, but ***Angle of Attack ALONE determines when a stall occurs.***   AoA awareness is vital for pilots of all aircraft. AoA measuring devices are becoming readily available. Pilots should be educated in Angle of Attack concepts if the full potential of this new technology is to be realised and the current trend towards more and more Loss of Control fatal accidents is to be reversed.

An F22 at High AoA - shifting lots of air!