Velocities in Space

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When does a pupil turn into a tutor? Is it like a pupae transforming into a butterfly or a more subtle mental flux? An instrument rated pilot transitioning to a flight instructor carries a heavy burden. Gone is his reliance on the person in the right seat since he is now the one in the right seat. So when does this transmogrification occur? The answer to these questions lies within the pilot/pupil/instructor.

The art of instructing does not come from impressing an examiner, nor from acing the written test, both are comprehensive and allow for reasoning and deduction. But neither can assess the degree of understanding required to explicate the laws of aerodynamics that apply to a body hurtling through a 3-dimensional space. There in lies the crux of instructing. It is the comprehension of the complex aspects of human behavior and the ability to tune them to the variegated fundamentals of aerodynamics – a circular peg in a round hole – that can create a perfect fit.

And so, the other day, I was asked the question what does 1.3 Vso mean? The answer seemed so simple that it flew out of my mouth, like a gasp, involuntary and utterly without thought. 1.3 Vso is 1.3 times the stalling speed, or the minimum steady flight speed, in the landing configuration with flaps down, engine at low or idle power as it would be just prior to touchdown. And then, with further reflection, I questioned myself. So what is 1.3 Vso? Now, you cannot describe the ethereal beauty of a rose in bloom by looking at a petal, so let's look at the whole picture.

AERODYNAMIC FORCES

We will start by looking at the magical asymmetry of the wing. What makes this piece of hardware fly? Remember the four forces exerted on the airfoil that are etched in every pilot's mind?

Let's take them in concert: The thrust compensates for the drag and the lift counters the weight. Given the relative constancy of the airfoil, it is the thrust that ultimately decides flight. Without thrust the airplane would stay put. So, knowing the variability of the thrust, various modes of flight can then be contemplated (high power for take-off, cruise power followed by specified lower power for landing). Now look at the relationship between, thrust, time, weight and drag. An airplane will progressively become lighter as it consumes fuel and with the change in the weight of the fuel, the angle of attack would change ever so slightly to maintain the same lift that will ultimately affect the airspeed. This change in the angle of attack will help increase the relative thrust to drag ratio. Atmospheric conditions will vary the thrust produced by the engine especially high density altitude which will reduce the power-plant efficiency but, on the flip side, it will also reduce the atmospheric friction and hence the drag. That is why turbo-charged aircraft can maintain their thrust at higher altitudes and fly faster. This preamble explains the varying conditions in-flight and now we will consider how they impact 1.3 Vso.

STALL SPEED

The 1.3 Vso is the calculated stall speed times 1.3. Why is this important? Because it gives you, the pilot, a cushion of a few knots of lift before stall occurs. The problem we run into is the absolute belief that what the airspeed indicator is showing is the gospel. It isn't. For one thing the indicated airspeed varies from the calibrated airspeed (called instrument error). Therefore what you are seeing is not essentially what the real airspeed is. The margin of error is capped by 14CFR part 23, paragraph 23.1323 at 3 percent or 5 knots whichever is greater. So, the instrument certification is based on this known instrument error. But do we keep that in mind in our day-to-day flying? Probably not. Knowing this can alter the "flight by the numbers" thinking. The errors between book values and real values must be determined and the real values flown (a mix of flight-by-the-seat-of-your-pants and by-the-numbers). A power off stall (Vs) may not occur at the designated indicated airspeed or the converse, it could happen before that specified airspeed. An aircraft will fly or, put it another way, the wing will continue to produce lift as long as the airspeed is above the stall speed or Vs. To keep that comfort zone, therefore, an approach to landing is done best at 1.3 times Vso. This gives the pilot the few extra knots till the aircraft is close to the ground and ready to touch-down. As you can now begin to understand, if this indicated airspeed is not telling the real tale then the stall speed times 1.3 will also be inaccurate and the margin of comfort could be less or more.

Also critical to this understanding is that we are talking about the stall speed (Vs) in a straight and level mode. It is here where the maximum coefficient of lift and lift itself equals to weight. But it's important for pilots to remember that the wing can stall at any speed. A stall is the result of the loss of lift when the angle of attack exceeds the critical angle.

FORMULA

The stall speed (Vs) is then determined by Weight, Maximum coefficient of lift, Wing area and Air density. The formula would be:

> Stall Speed (Vs) = Air density times maximum coefficient of lift times wing area divided by Weight.

Based on this equation, it is obvious that increasing the maximum coefficient of lift, increasing the air density (flying from higher to lower altitude) and the total wing area (Deploying the flaps will increase the wing area) will decrease the stall speed of the aircraft while increasing the denominator (weight) will increase the stall speed.

In demonstrating the Vs, a pilot manipulates the control column aft to the stops. This increases the AOA (angle of attack) and thus increases the drag and decreases the airspeed (with no or low power). The stall occurs when the airflow over the wing separates and lift no longer overcomes weight. This leads to an increased "sinking" feeling, something akin to when your heart gets tangled up into your throat as you flare a little higher over the runway then you wanted. The next event leads to a chill down your spine and an extra bit of dental work to protect your smile. Not all aircraft mush down – some will have a sudden pitch down effect as the lift is lost. If you keep the pitch attitude stable and the rudder and the ailerons neutral the aircraft will demonstrate the "falling leaf" maneuver. Please don't try this without an experienced instructor, and never at low altitude. A much maligned secondary stall is essentially a stall followed by a temporary lift followed by another stall. A normal stall occurs when the wing loading is at or near 1G.

It is important to remember that the aircraft attitude may not always be nose high (pitch-up). The loss of lift can occur at any attitude and at any altitude and at any airspeed. The airflow that matters is the relative wind. So, sudden changes in wind velocity or shift in direction can create the same scenario as sometimes occurs in strong wind shears.

ANGLE OF ATTACK

While we are at it, another caveat to remember is that different parts of the wing stall at different times. For example, the wing root in a single engine propeller aircraft will have a lower AOA than the wing tips due to the slipstream tube from the propeller wash. All aircraft stall at a specified AOA **and not a specific airspeed**. Military jets with thin airfoil have a higher AOA (20-21 degrees) while the thicker wings will have the critical AOA at 15-18 degrees.

WING LOADING AND ACCELERATED STALL

Now consider the accelerated stall when the aircraft is no longer in a 1G state, as in a 60 degree bank (a 2G mode). The wing-loading increases by 1.41 times normal, increasing the stall speed (stall speed equals the square root of the load × normal 1G stall speed, e.g. square root of 2 = 1.41 × Vs1). Most stall spin accidents occur during a landing approach when a turn from base to final goes wide and is "ruddered" around. A stall in a cross-controlled condition can result in a spin close to the ground. The pilot at a slow airspeed might compensate by excessively pushing the rudder and banking in the opposite direction. If the nose is allowed to drift upward, increasing the AOA, that increases the stall speed, which decreases the vertical component of lift and an accident becomes imminent. Circling-to-Land in IFR conditions can create similar problems at low altitudes making recovery difficult if not impossible. Of course if the wing remains unloaded and the aircraft is in a pitch-down attitude and allowed to "sink" (if you have lots of altitude to spare) the margins are not reduced and the stall speed is not increased, therefore an accelerated stall is prevented. Based on the formula above the stall speed to bank angle is 7% at 30 degrees, 19% at 45 degrees and 41% at 60 degrees (A 175% increase in stall speed between 30 to 45 degrees and a 120% between 45 and 60 degrees).

This is why 'certificated aircraft in normal category' are limited to a 60-degree bank angle. It is important to maintain gentle bank angles and safe airspeeds at low altitudes.

STALL/SPIN

One universal truth to consider for stall/spin occurrences is that for a stall to progress into a spin two things must be operating. 1.) The wing has to be stalled, and 2.) The airplane has be yawing. One without the other will not yield a spin. Therefore it is important to keep the rudder centered when demonstrating a stall, and in-flight never compound an excess bank or pitch angle with excess yaw! It is important for all pilots that they observe complete and total awareness of the pitch attitude during any phase of flight to prevent stalls and keep a 'centered ball' to prevent a stall progressing into a spin. A stall is easy to recover from: Change the pitch (reduce the back pressure) to down and increase thrust (add power) then level off. A spin recovery requires specific training, altitude, alertness and a calm mind – a whole different ballgame.

1.3 Vso

Now that we have figured some of the nuances of stalling the aircraft, let's bring it down near the runway. Here the aircraft, if properly flown at a 'real' Vso1.3, when flared near the runway will increase drag, increase the AOA and with minimal/no power lose lift and touchdown will occur in a complete 1G stall mode. The problem occurs when new or fearful pilots will approach the runway with excess speed of Vso1.6-1.8 and find the rubber is not meeting the road and half the runway is behind. This can lead to excess floating, porpoising (the pilot forces the aircraft to the runway and bounces off with transient lift only to try again), and even ground-looping if the aircraft is hit with cross winds or cross-controls. That is why it is important to determine the true Vso1.3 for your aircraft and fly it to the ground on final.

Near the runway a short discussion of Ground-Effect is prudent. An aircraft near the runway will lose some of its induced drag and it will tend to float. Excess airspeed can exacerbate the float. Given the detriment of crosswinds and gusts, this floating can try the patience of the even the most experienced pilots. Therefore, exorcise the demons of excess and exercise the understanding gained from experience, knowledge and practice.

It all boils down to this: Know the airspeeds on your aircraft. They all have a purpose – to keep you safe!

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