Base to Final Stall-Spin

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The base-to-final stall-spin is frequently unrecoverable. It has much to do with angle of attack.

Typically the base-to-final stall spin occurs when a pilot overshoots the runway centerline and attempts to realign the aircraft by increasing bank angle to steepen the turn, adding aft stick and using bottom rudder i.e., in the direction of the turn. Increasing the bank angle and adding aft stick places the aircraft at a near critical/stall angle of attack. Adding bottom rudder results in a yaw rate that increases the angle of attack of the receding wing above the stall angle of attack while decreasing the angle of attack of the advancing wing. The receding wing stalls. The lift on the advancing wing increases resulting in a roll in the direction of the receding wing that results in an incipient inverted or near inverted spin that is unrecoverable and unsurvivable. The anatomy of a base-to-final spin is illustrated in Fig. 1.

Figure 1 also illustrates some second order effects that exacerbate the situation. For example, when the rudder is deflected the resulting rudder force, which typically acts above the vertical center of gravity, results in a rolling moment counter to the bank angle. The pilot may then add opposite aileron to counteract the rudder induced rolling moment. The aircraft is now cross-controlled. The down aileron on the advancing wing results in adverse yaw, causing the pilot to add additional rudder and yawing rate. The deflection of the rudder also results, again acting above the vertical center of gravity, in a nose up pitching moment which increases the angle of attack of the wing. And so it continues.

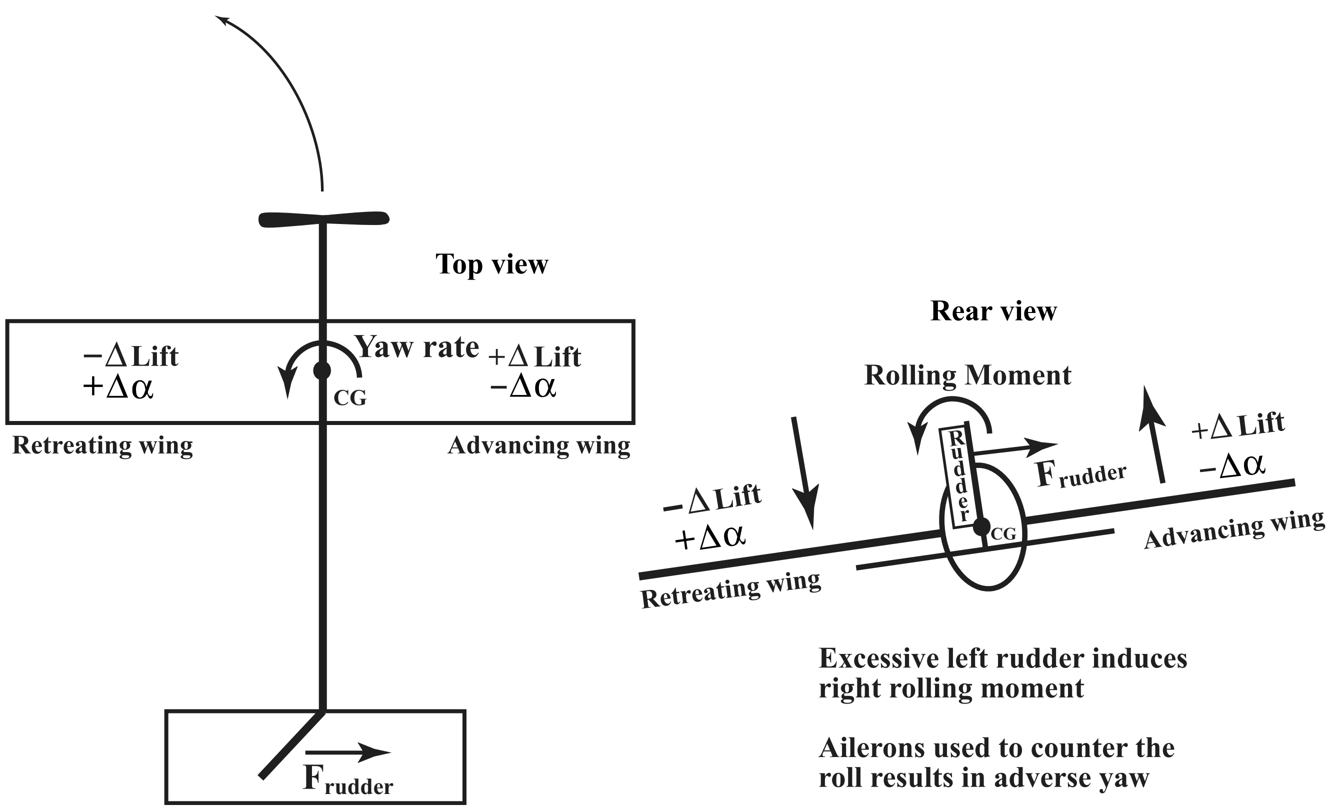

Figure 1. Anatomy of a base-to-final stall-spin.

Yaw Rate Changes Angle of Attack

Velocity is a vector. It has both a direction and a magnitude. For convenience the freestream velocity ahead of the aircraft is represented as a vector opposite to the direction of motion of the aircraft center of gravity.

The velocity vector on the receding wing that results from yaw rate is in a direction that is opposed to the free stream velocity as shown in Fig. 2. In effect, the "wind" direction of the receding wing is trailing edge to leading edge. Given that the aircraft rotates about the center of gravity, the magnitude of the velocity resulting from yaw rate varies with distance from the center of gravity. Hence, the change in effective angle of attack varies with location along the wing.

Vectorally adding the freestream and yaw rate vectors, as shown in Fig. 2, results in an increase in the effective angle of attack on the receding wing compared to the absolute angle of attack when there is no yaw rate, i.e., $\alpha_{\text{eff}} > \alpha$. If the aircraft is close to stall, the increase in effective angle of attack is enough to stall the receding wing.

Similarly, but not shown in Fig. 2, the yaw rate associated with the advancing wing decreases the effective angle of attack and prevents the advancing wing from stalling. The result is an imbalance in lift on the receding and advancing wings which generates a rolling moment in the direction of the receding wing.

It Gets Worse—Roll Rate

Because, near stall, the aircraft is tyically neutrally or slightly unstable in roll as well as a result of the unbalanced wing lift, the aircraft rolls rapidly toward the stalled receding wing. The resulting roll rate further increases the receding wing effective absolute angle of attack as illustrated in Fig. 3.

Again, but not shown in Fig. 3, the roll rate on the advancing wing decreases the absolute angle of attack and prevents the advancing wing from stalling. Roll damping is also somewhat increased.

Base-to-Final Turn Direction

Why is the standard stall warning device typically located on the left wing? Because the standard airport pattern uses a left base to final turn. Hence, the standard stall warning device is located on the left wing to provide advance warning for the typical base-to-final stall-spin situation. But, what about a right-base-to final stall-spin? There is no, or inadequate, warning in this case. Here, excessive rudder induced yaw rate actually decreases the angle of attack on the left wing. The stall warning device does not activate and the pilot has little or no warning prior to the onset of a right-base-to-final stall-spin.

Consequently, if an angle of attack system, or even a second standard stall warning device, is fitted, then it should be fitted on the right wing. Furthermore, it should be fitted as close to the same spanwise location as the standard left wing stall warning device. Finally, it should be calibrated to activate at a similar angle of attack as the standard left wing stall warning device.

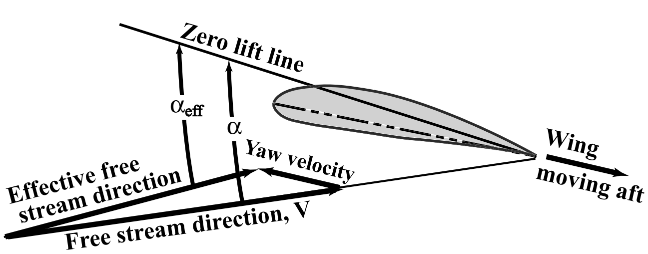

Figure 2. The effect of yaw rate on angle of attack.

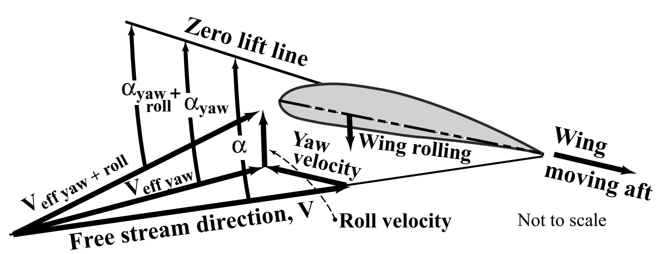

Figure 3. The effect of yaw and roll rate on angle of attack.

With two stall warning devices, one on each wing, the pilot now has warning for either a left or right base-to-final stall-spin.

Summary

Yaw rate caused by excessive bottom rudder input results in an increase in angle of attack, and hence early stall, of the receding wing while decreasing the angle of attack of the advancing wing. A roll toward the receding wing results.

The resulting roll further increases the angle of attack of the receding wing deepening the stall of that wing.

If an angle of attack system is installed, it should be installed on the right wing to provide adequate warning of a base-to-final turn stall-spin.