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The C-130 Fin Stall Phenomenon

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THE C-130 FIN STALL PHENOMENON

The Gooney Bird of the future . . . that's what many people call the durable C-130 Hercules. It has been around the Air Force for almost twenty years and will be around a lot longer. By any measure it is a classic airplane. It has been used as both an inter and intra theater airlifter, a bomber, a refueler, a ground attacker, a command post, a rescuer, an ambulance, and probably half a dozen other roles. About the only role it hasn't played is that of an air-to-air interceptor (and we're not too sure about that).

It's a good airplane, and like the Gooney Bird, a forgiving airplane. Neither, however, is without its idiosyncrasies and one common to both is the phenomenon known as FIN STALL.

WHAT IS IT ?

You who push 130s around are probably familiar with terms such as "rudder lock" or "rudder force reversal," both of which carry ominous overtones, and both terms actually concern the phenomenon of fin stall.

To explain fin stall, let's drop back and review some basic concepts of directional stability. First some ground rules: let's remember that left yaw produces right sideslip and that the relative wind is coming from the sideslip side. Okay here we go . . .

Sideslip produces forces on areas of the airplane forward of the center of gravity (CG), which tend to increase the yaw angle. In order for an airplane to possess the desired tendency to return to a zero sideslip angle or not increase the sideslip angle, the forces on the areas aft of the CG must be in a direction to return the airplane to straight flight or prevent the sideslip angle from increasing.

As seen in Figure 1, an initial application of left rudd[er]

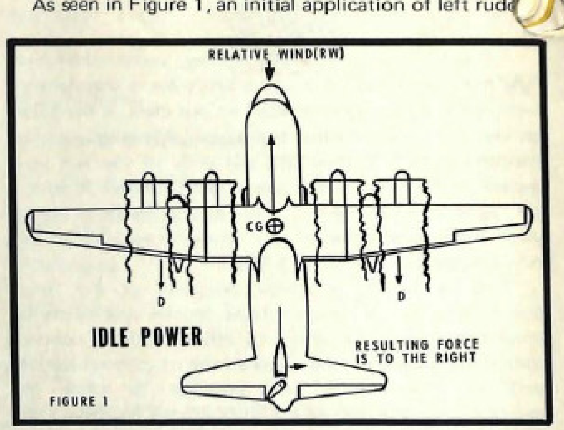

FIGURE 1

will cause a resulting force to the right which, in turn, will cause the airplane to start yawing to the left. If the force vector remains to the right, the desired stability is not achieved and the sideslip angle may increase. However[,] the airplane continues to yaw to the left and the sides[lip] angle stabilizes (Figure 2), the forces on the vertical fin are to the left (left rudder applied). These forces will keep the sideslip angle from increasing and will thus provide the necessary stability.

Whoops! How did we abruptly switch force vectors?

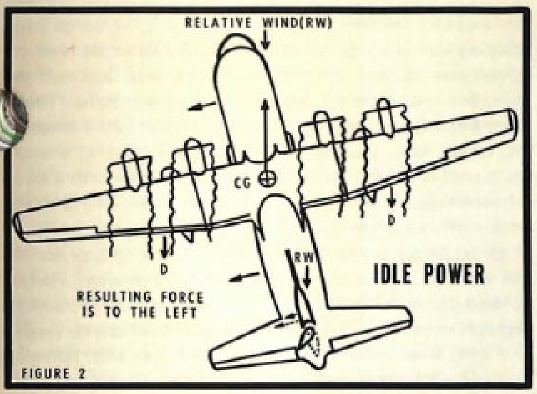

FIGURE 2

When the rudder is neutral, the airfoil formed by the vertical fin and rudder is symmetrical. If the relative wind is down the centerline of the airfoil, there will be no unbalanced lift. If, however, the rudder is deflected, it causes the airfoil to become unsymmetrical. A new line down which the relative wind must flow is formed and called the camber symmetry line. On initial application of rudder, the relative wind flowing over the newly formed airfoil produces negative pressure on the "long side" and positive pressure on the "short side" of the airfoil, resulting in a force vector: right force for left rudder and vice versa (Figure 3).

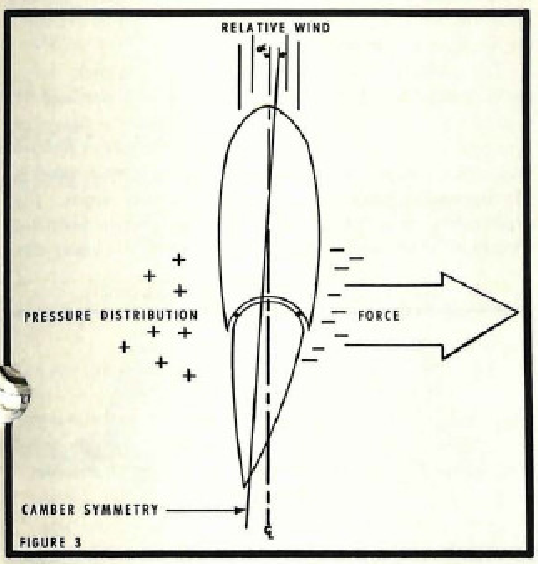

FIGURE 3

The airplane will continue to yaw to the left (left rudder applied) until the sideslip angle is greater than the camber symmetry angle. When this occurs, the resultant pressure distributions and force vectors will have swapped sides (Figure 4). If the rudder is released, the forces will cause it to float back toward neutral which will increase the restoring force causing the airplane to yaw toward zero sideslip. This is the desired stability feature.

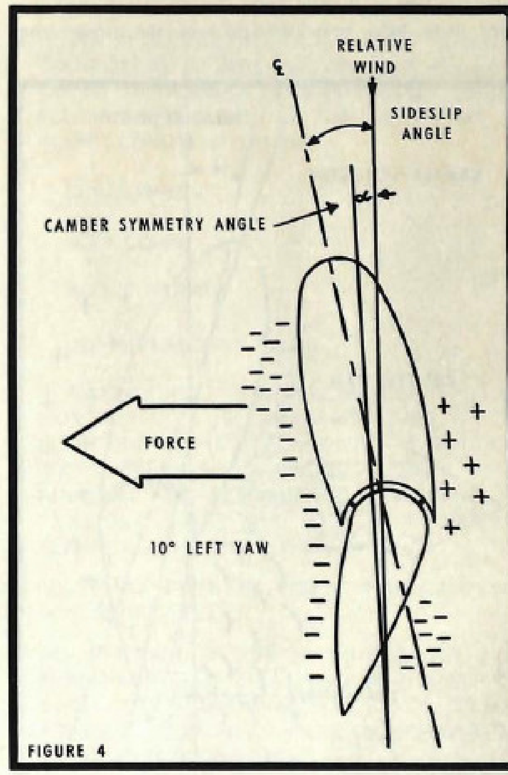

FIGURE 4

In some airplanes (C-130, C-47) a sufficient sideslip angle can be induced which will cause airflow separation. When the rudder is deflected and a sideslip is produced, the relative wind is acting on an upside-down airfoil, which, basically, is not very efficient. At certain sideslip angles the interaction of fuselage interference, vortex from the wing to fuselage juncture, and engine slip stream, combined with the magnitude of the angle of attack, can cause a disturbed airflow, separation and fin stall. This air flow separation can produce forces that will cause the

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rudder to float to a larger angle (Figure 5). When the rudder begins to float, a force reversal occurs; that is, a right pedal force is required to keep the rudder from

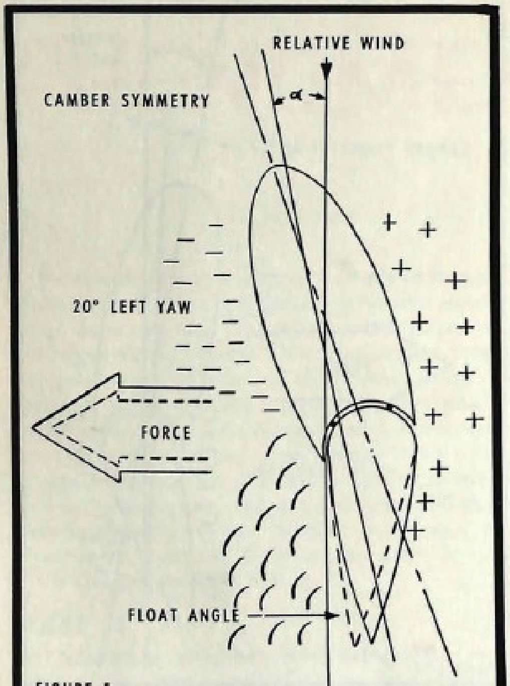

FIGURE 5

floating to a larger left angle. The stabilizing force is diminished and the airplane yaws further left and produces a greater right sideslip. The rudder is "locked" aerodynamically and will not return to a lesser sideslip angle of its own accord.

FIN STALL C-130 STYLE

As shown, fin stall is a product of large sideslip angles. In the C-130 (as well as other airplanes) there are basically two ways to perform sideslips. The first is the wings level skidding turn used by some pilots to make small heading corrections during instrument approaches, as well as formation maneuvering, and very low level turns. These turns are accomplished by feeding in rudder while keeping the wings level. During the wings level heading change maneuver, it is impossible to produce fin stall with a slow deliberate application of full rudder at speeds of 1.2 times power off stall or greater.

Sideslips are also induced during crosswind approaches and landings where no heading change is desired. You're all familiar with the wing low method for crosswind landings in the C-130 (the only method that can be used). The wing is lowered into the wind and opposite rudder is applied to maintain a straight flight path. Greater sideslip angles can be produced by the wing down method; therefore, this is more likely to produce fin stall. But sideslip angles required for all normal operations are not of the magnitude that will produce fin stall.

After the fin has stalled on the C-130, and if the rudder is allowed to float, the airplane will yaw out to about a 40 to 45 degree sideslip angle. It stabilizes at this point due to the barn door effect of vertical fin. Under these conditions the rudder will maintain about a 24 degree deflection. If the rudder is forced back to neutral, which requires a maximum of 50 to 100 pounds of rudder pedal force, the airplane will return to zero sideslip.

Fin stall in the C-130 has never been experienced in the power off configuration or in a slow deliberate application of right rudder. This implies that the airplane is less stable with power on and that left rudder is more powerful than right rudder. Both are true and to explain a bit, we have to talk about torque effect.

The major contributor to torque effect in a multi-engine propeller driven airplane is the spanwise lift distribution on the wing. Figure 6 portrays the power on spanwise lift distribution on the wing of a C-130. The flow from the props produces more lift on the wing on the upcoming blade side of the propeller wash. This produces a peak lift on the left side of the propeller slipstream sloping to a lower lift value on the right side,

LIFT(OR DRAG) SPANWISE DISTRIBUTION

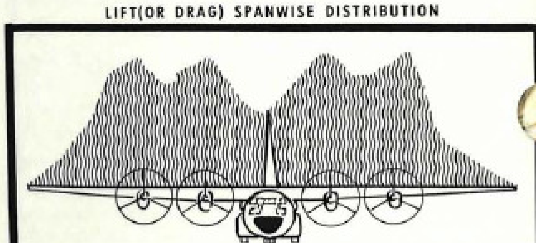
FIGURE 6

and shifts the total lift on each wing to the left. To keep the airplane from rolling, aileron is applied and one would think that this would make the lift symmetrical again; however, because the ailerons are located far out on the wing they balance the rolling moments, but the peak lift areas remain to the left of each wing.

Lift on the wing also produces induced drag with spanwise distribution very similar to the lift distribution. Consequently, the total drag on the left wing is further outboard than on the right wing which causes the airplane to turn to the left. The pilot must apply right rudder to prevent this turn to the left. In straight flight, right rudder trim is required; therefore, more rudder is available for left yaw-right sideslip than there is for right yaw-left sideslip. For this reason it is possible to stall the fin because of left rudder application but it is not possible to do so by applying right rudder.

It's important to emphasize at this point that fin stall will not occur due to turbulence, crosswind corrections, or engine out control maneuvers.

REQUIRED CONDITIONS TO PRODUCE FIN STALL

- POWER ON (USUALLY POWER FOR LEVEL FLIGHT OR GREATER)
- LEFT RUDDER (LEFT YAW-RIGHT SIDESLIP)
- WING DOWN TO MAINTAIN STRAIGHT FLIGHT PATH (ZERO TURN RATE)
- SPEED FROM MINIMUM TO 170 KIAS
- FLAP AND GEAR EITHER UP OR DOWN

FLIGHT CHARACTERISTICS ASSOCIATED WITH FIN STALL

- ONSET OF UNMISTAKABLE FIN BUFFET BETWEEN 15 AND 24 DEGREES SIDESLIP
- REDUCTION IN RUDDER PEDAL FORCES AT 18 TO 30 DEGREES SIDESLIP
- NOSE UP PITCHING TENDENCY
- ZERO RUDDER PEDAL FORCE AT SOME POINT ABOVE 20 DEGREES SIDESLIP
- AN INCREASED TURNING RATE TO THE LEFT WHICH CANNOT BE CONTROLLED BY BANK ANGLE

PILOT ACTIONS

- NORMAL MANEUVERING OF THE AIRPLANE, INCLUDING NORMAL SKIDDING TURNS AND SIDESLIPS, WILL NOT RESULT IN FIN STALL
- AVOID LARGE SUSTAINED, ABRUPT RUDDER INPUTS AT SLOW SPEED ESPECIALLY POWER ON UNLESS NEEDED FOR ENGINE OUT CONTROL
- IF FIN STALL OCCURS, RETURN THE RUDDER TO NEUTRAL BY APPLYING OPPOSITE RUDDER (50 TO 100 POUNDS RUDDER PEDAL FORCE) PLUS A COMBINATION OF THE FOLLOWING, IF FLIGHT CONDITIONS PERMIT:

  LEVEL WINGS

  NOSE DOWN

  REDUCE POWER

  USE ASYMMETRIC POWER

- IF AN UNDESIRED RUDDER CONTROL INPUT IS EXPERIENCED, SUCH AS A HARD OVER, WHICH RESULTS IN A FIN STALL, TURN THE RUDDER BOOST PRESSURE OFF AND CONTROL THE AIRPLANE WITH ASYMMETRIC POWER AND, IF FEASIBLE, USE THE OTHER RECOVERY TECHNIQUES MENTIONED PREVIOUSLY
- NEVER ATTEMPT TO FORCE THE AIRPLANE INTO A FIN STALL
- AS STATED IN THE DASH ONE, DO NOT PERFORM POWER ON STALLS; IF A POWER ON STALL IS ENTERED INADVERTENTLY, DO NOT ATTEMPT TO MAINTAIN LATERAL CONTROL BY LARGE RUDDER INPUTS.

SUMMARY

Fin stall is a phenomenon that all C-130 pilots should be aware of and know how to counteract, should it occur. It is a maneuver that the pilot has to almost force the airplane into but the possibility still remains that the pilot may inadvertently encounter the phenomenon. One point must be emphasized again. Never attempt to force the airplane into a fin stall for any reason. ➤

Adapted from a briefing given by Walter E. Hensleigh, Chief Engineering Test Pilot, Lockheed-Georgia Company.