CIRCLING THE HOLIGHAUS WAY - OR DO YOU REALLY WANT TO KEEP THE YAW STRING CENTERED?

BY RICHARD H. JOHNSON

ANSWERS:

1. During Straight Flight - YES, that minimizes drag and maximizes the sailplane's performance.

2. During Turns - NO, not really, because then the sailplane is actually in a slight skid, and more-than-necessary cross aileron is required to prevent over-banking. That will be explained below.

3. During Circling Flight - NO, that does not minimize drag, and the possibility of an inadvertent spin entry can be reduced significantly if one maintains a true mild sideslip while circling.

INTRODUCTION

The well-known German sailplane engineer, designer, Schempp-Hirth factory owner, and sailplane pilot Klaus Holighaus generously brought the benefits of maintaining a mild sideslip while circling to my attention some 30 years ago while we were both competing at the World Gliding Championships in Yugoslavia. He was flying his beautiful new Nimbus 2 sailplane for the German Team, and I was flying an equally fine ASW-17 for the U.S. Team. I was and always have been impressed with his knowledge, generosity and sportsmanship. He died in an unfortunate mountain soaring accident some 9 years ago, but his legend will always live on.

WHY MAINTAIN A MILD SIDESLIP WHILE CIRCLING?

Essentially all sailplanes are designed with positive wing dihedral. During a sideslip, that causes the windward wing to achieve a slightly higher angle-of-attack relative to the airstream than the leeward wing. That creates a rolling moment toward the leeward wing.

That is easy to prove. During straight and level flight while holding the control stick fixed, push on one of the rudder pedals and note your sailplane's roll response. It should definitely roll toward whichever rudder pedal that was depressed. That is known as positive roll stability.

The beneficial effect of positive roll stability is not so obvious during circling flight, but it is still there. The lowered inside wing panel has less airspeed, and hence less lift than the raised outside wing panel. To compensate for that, while keeping the sailplanes' skid ball centered, one must deflect the lower wing's aileron downward to increase its lift so that the lower wings lift equals that of the upper wing. If that is not done, the sailplane would keep increasing its bank angle, and a steep spiral dive would result.

When the lowered wing's aileron is deflected downward, not only is its lift increased, but also its drag is increased, and a skidding turn will be induced. The skid can easily be corrected for by adding some top rudder to keep the skid ball centered. The danger here is that when the aileron is deflected downward, it is more prone to stalling. When that happens, an out-of-control spin will likely result unless corrective action is promptly taken.

Figure 1 shows a cross section of a typical sailplane wing airfoil and its airflow streamlines. The upper airfoil represents a relatively high angle-of-attack thermaling condition with the

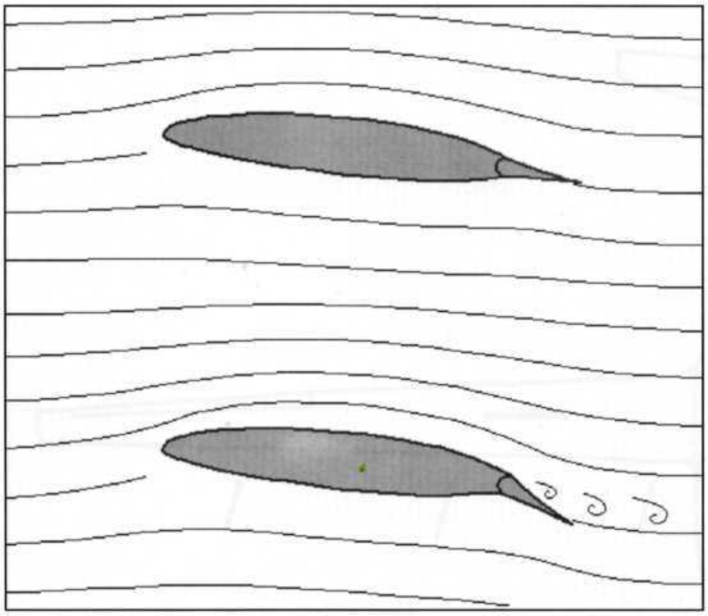

FIGURE 1

aileron un-deflected. There both the upper and lower surface airflows stay attached to the wing surfaces, and near maximum wing lift is achieved. The lower airfoil shows the same airfoil, but with the aileron deflected downward. If the aileron is deflected downward far enough, the airflow will separate from the upper portion of the aileron surface, and that will increase the wing drag and decrease its lift. If a pilot then increases the aileron downward deflection angle in an attempt to compensate for its lost lift, it only makes things worse. A spin entry is likely, unless the aileron deflection angle is neutralized, and/or the wing angle-of-attack is promptly reduced.

How does one require less-aileron deflection while circling? That is easily achieved by just maintaining a small angle of sideslip and let the sailplane's dihedral effect provide some additional lift to the lower wing. **Figure 2** depicts how the wing dihedral combined with a sideslip increases the lift on the windward wing, and decreases lift on the leeward wing.

Klaus recommended maintaining a gentle sideslip while circling. The optimum degree of sideslip depends to some degree on both the sailplane's wingspan and dihedral angle. After many hours of flying my 16.6 meter Ventus A and similar sailplanes, I find that my best overall circling performance and handling characteristics occur while the canopy mounted yaw string is deflected about 10 degrees on the high side of the turn (a gentle sideslip actually), because the yaw string forward placement error accounts for about half of the 10 degrees. See section below.

THE SKID-BALL INDICATOR

A skid-ball indicator is a curved glass tube filled with a clear compass-like fluid, and within which a round ball is free to roll from side-to-side. It is mounted laterally on an instrument panel

MORE ON SLIPPING FOR PERFORMANCE

Dick Johnson's article talks about a technique, slipping in thermals, that has been used by some competition pilots (including me) for many years. This sidebar adds some ideas about why and how much.

On my first reading of Dick's article, ten degrees of slip seemed like too much. Four things contribute to how much you should slip in thermals; yaw string position, true airspeed, bank angle and the flow around and along your wings. A yaw string 2 meters ahead of the glider CG, 45 knots, and degrees of bank results in nearly 5 degrees of yaw string error. (Including a factor of 2 for cross flow on the canopy.) You need the yaw string about 5 degrees to the high side of the turn to be perfectly coordinated. The yaw string 1.5 meters ahead of the CG, 30 degrees of bank, and 60 knots (a typical Western thermal in a fully loaded glider) results in only about 1 degree of yaw string error. Canopy cross flow exagerates yaw string angles and how much is difficult to estimate. Comparing the yaw string to a centered skid ball, as Dick recommends, is probably the simplest way to check yaw string error including cross flow.

Why slipping improves the climb in some gliders is not well understood. In generating lift, wings also generate spanwise flow, outward along the bottom and inward along the top of the wings. It is possible that there is flow separation near the tip of some circling sailplanes, and that slipping changes the spanwise flow enough to eliminate or reduce this. Separation can increase the drag significantly long before the tip actually stalls. I flew a Discus for 16 years without winglets and am convinced that it thermaled better in a slip.

As Dick says, and I say more emphatically, it doesn't work with winglets. My experience is with 1 5 and 18 meter spans, it may still work with wingletted open class gliders. Winglets change the flow over a large portion of the wing and reduce spanwise flow. They may correct the same problem that causes some gliders to thermal better in a slip. Properly designed winglets will not stall in a slip, and gliders with winglets that don't stall climb better in coordinated turns. The angle of attack of a winglet depends more on the flow field generated by the wing than it does on the slip or skid angle. If you can stall your winglets in a slip, my advice is to take them off the glider.

How much you should slip, beyond the yaw string error, is a difficult problem. You are looking for a small improvement that is very hard to measure. Seek advice from pilots who are very familiar with your type of sailplane. I added about 5 degrees in my Discus (5 to 7 degrees total flying wet), which is less than Dick uses in his 16.6 meter Ventus (10 to 20 degress total flying dry).

—Chip Garner

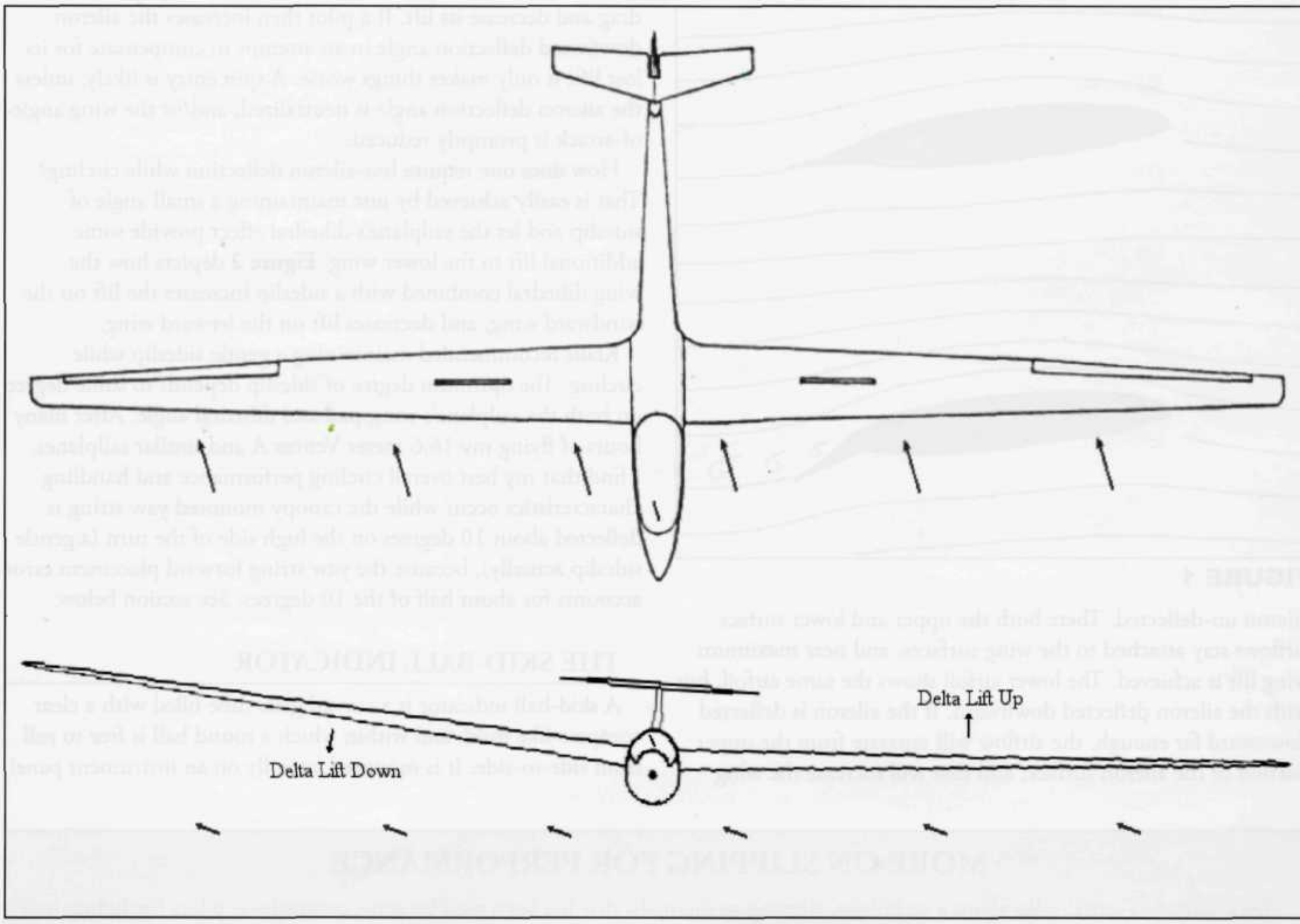

FIGURE 2

and is designed to sense and indicate lateral accelerations of the sailplane. Commonly it is called a ball-bank indicator in the U.S., but it does not actually indicate bank angles, just lateral acceleration.

I observe that under that optimized circling conditions, my Ventus instrument panel mounted skid-ball is not centered, but rests about 1/2 ball diameter on the low side of the turn. **Figure 3** illustrates a hypothetical sailplane cockpit view while thermaling in a slightly slipping circling flight condition. The instrument panel includes a ball skid indicator, and the canopy sports a typical forward mounted yaw string deflected about 10 degrees toward the high side of the turn.

WINGLET PROBLEMS

I did not have winglets installed on my 16.6-meter wings during that flight-testing, and they often are prone to stalling during slipping or skidding flight. Sailplanes equipped with winglets likely need to just keep the skid-ball centered to avoid winglet-stalling problems. Place some wool tufts on the inboard sides of your winglets and see for yourself during a test flight.

YAW STRING LONGIDUDINAL LOCATION PROBLEM

Figure 4 depicts a plan-view of a sailplane while thermaling. Circling with the yaw string centered actually results in a slightly skidding turn because the yaw string is mounted well ahead of the sailplane's CG. That concept is true, and **Figure** 4 illustrates that point. The yaw string is mounted about 2 meters or so ahead of the sailplane's CG; therefore the air approaching the yaw string arrives slightly from the left of the sailplane's nose. Another way to view this turning flight situation is to consider the sailplane to be motionless in space, while the thermal is rotating at say 45 kts against the sailplane. That makes it easier to appreciate the effectively curved airflow approaching the nose-mounted yaw string.

Many single-seated sailplanes do not carry ball skid indicators today, but fortunately most 2-seated training sailplanes come equipped with them mounted on their instrument panels. The canopy mounted yaw string angle errors can easily be seen during turning flight by referring to the true ball-slip indicator. In a tandem 2-seater with separate yaw strings, one can compare the difference in the angles between the rear and front cockpit yaw strings, and see the differences.

If the yaw string could somehow be mounted at the sailplane's CG, and utilized by the pilot, the yaw string would then show zero yaw deflection when the sailplane was being flown with the skid-ball centered. Because of its normally well-forward mounting location, the yaw string indicates a slight sideslip, even though the sailplane's more accurate skid-ball shows none.

Ventus A instrument panel and canopy view during a gentle right turn at 43 kts, when the yaw string angle is momentarily at almost 20 degrees on the high side of the turn. Author's Ventus thermaling experience showed that the yaw string angles normally varied between about 10 and 20 degrees on the high side when keeping the skid ball at the advocated 1/2 ball width on the low side of center. Unfortunately, I forgot to power the electric turn indicator.

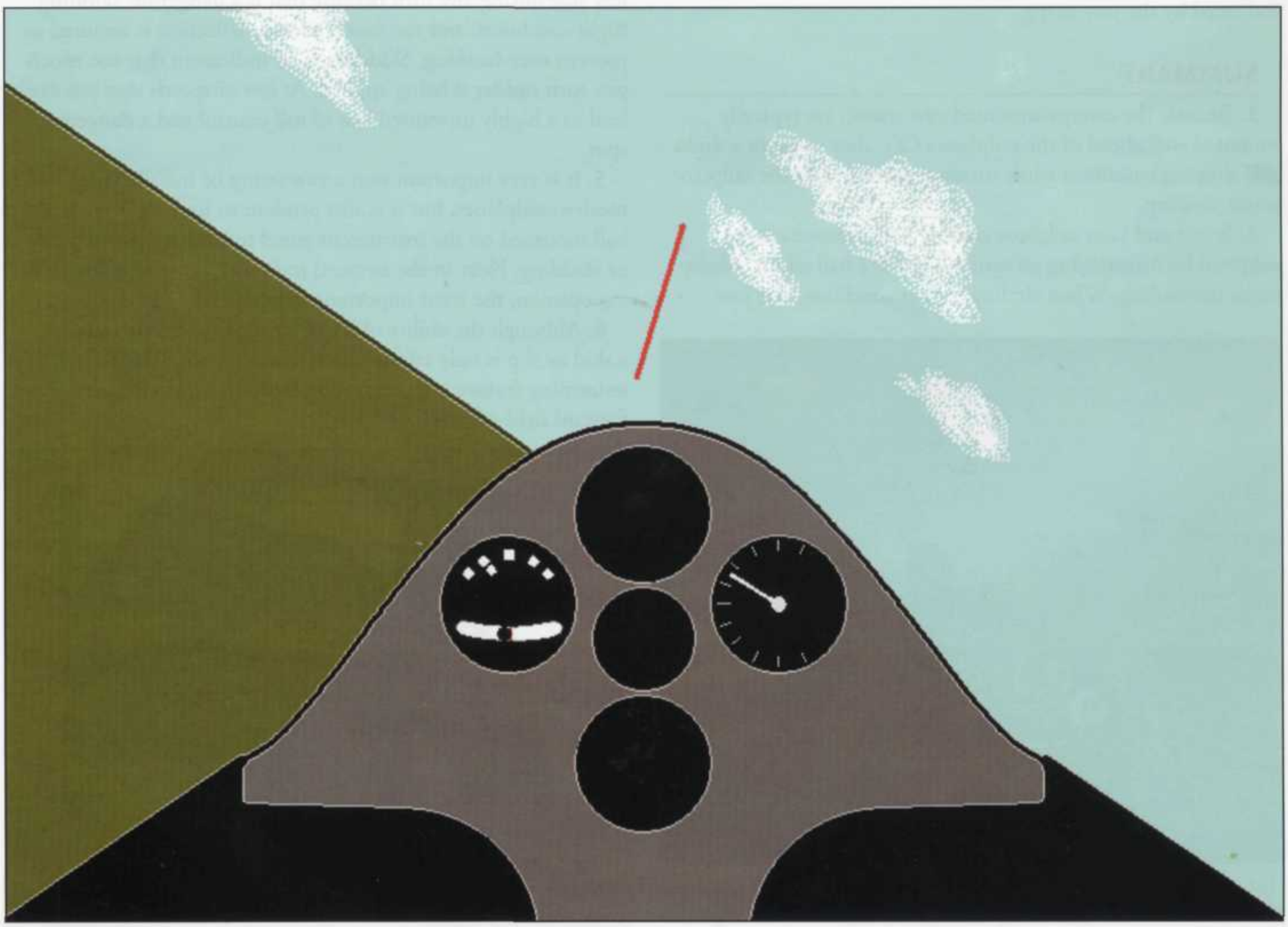

FIGURE 3

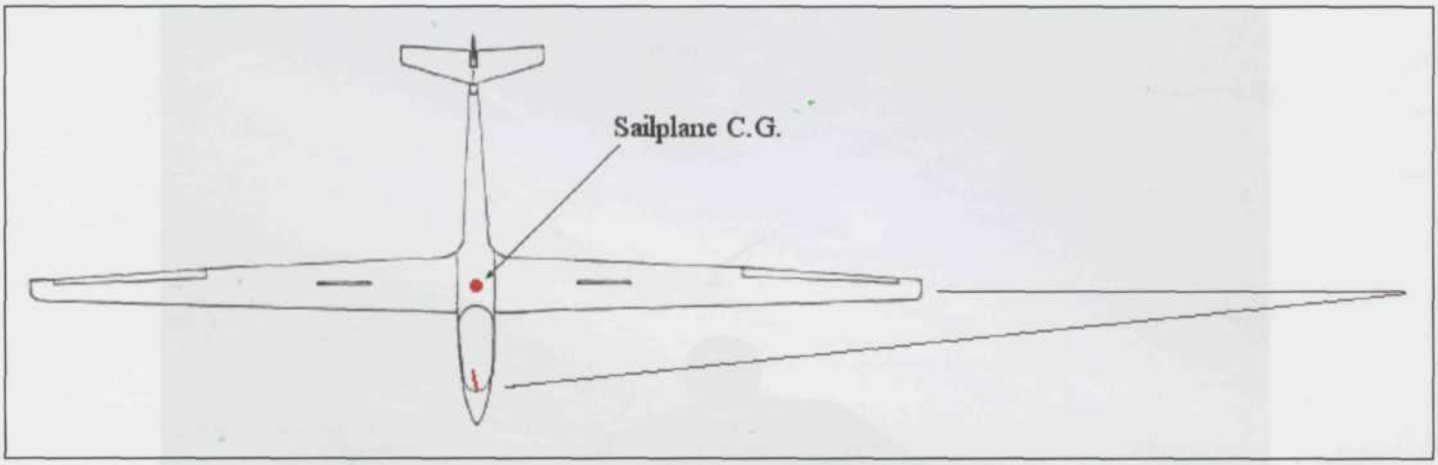

FIGURE 4

Obviously, the skid-ball more accurately portrays the sailplanes' true flight condition.

CANOPY CROSS-AIRFLOW MAGNIFYING EFFECT

During both straight-ahead yawed flight, and also during skidding and slipping circling flight, the canopy air cross-flow has a magnifying effect on the canopy local airflow direction. The actual sailplane slip or skid angles are likely about half that indicated by the yaw string.

SUMMARY

1. Because the canopy-mounted yaw strings are typically mounted well ahead of the sailplane's CG, they indicate a slight side slipping condition while turning, when in fact the sailplane is not slipping.

2. Better and safer sailplane circling performance can be achieved by maintaining an actual slight 112 ball width sideslip while thermaling. When circling in that condition, the yaw string typically needs to ride about 10 degrees on the high side of the turn.

Author's Ventus A cockpit view during a properly coordinated left turn at 43 kts, with yaw string at about 10 degrees on the high side during this relatively gentle turn.

3. Winglet equipped sailplanes may suffer stalling on the inboard winglet during the 1/2 ball sideslip. In that case, keeping the skid-ball centered will most likely optimize climb performance. To achieve that, the yaw string still needs to ride about 5 degrees on the high side of the turn.

4. For safety's sake never skid a turn, unless a spin entry is to be an acceptable condition. Never fly with the yaw string on the low side during any turn because that is a dangerous skidding flight condition, and too much aileron deflection is required to prevent over-banking. Skidding is an indication that too much pro-turn rudder is being applied. At low airspeeds that can easily lead to a highly unwanted loss of roll control and a dangerous spin.

5. It is very important that a yaw string be installed on modern sailplanes, but it is also prudent to have a simple skid-ball mounted on the instrument panel to indicate true slipping or skidding. Next to the airspeed indicator, the yaw string is, in my opinion, the most important sailplane safety instrument.

6. Although the ability of a yaw string to correctly indicate a skid or slip is only fair, it is cheap and simple. Its most redeeming feature is its mounting location, squarely in the pilot's forward field-of-view.

About the author: Dick Johnson is well-known in the soaring community, and has graciously provided the readers of *Soaring* Magazine with flight test evaluations of sailplanes through the years.