

Using the Rudder in Thermal Flying by Mark Drela

Purpose of ruddering

Maximizing the performance of your aileron sailplane when thermal flying requires effective use of the rudder. The main objective is to minimize the sideslipping which naturally results from the roll and yaw motions during typical thermalling maneuvers:

- rolling in and out of turns
- maintaining a steady turn
- adjusting the turning radius

Aileron to rudder mixing can somewhat reduce the maximum sideslip angles during these maneuvers, but it can never completely eliminate them. The reason is that the required rudder deflection is not in general proportional to aileron deflection. In fact, they frequently must go in the opposite directions(!), as in the case of a slow tight sustained turn.

Flight path geometry and sideslip

Figures 1a and 1b show the geometry of steady turning flight, with and without rudder deflection. In each case, the vertical tail tries to yaw the glider so that the apparent wind at the tail lines up with the tail's zero-lift line. In other words, the vertical tail seeks its zero-lift position.

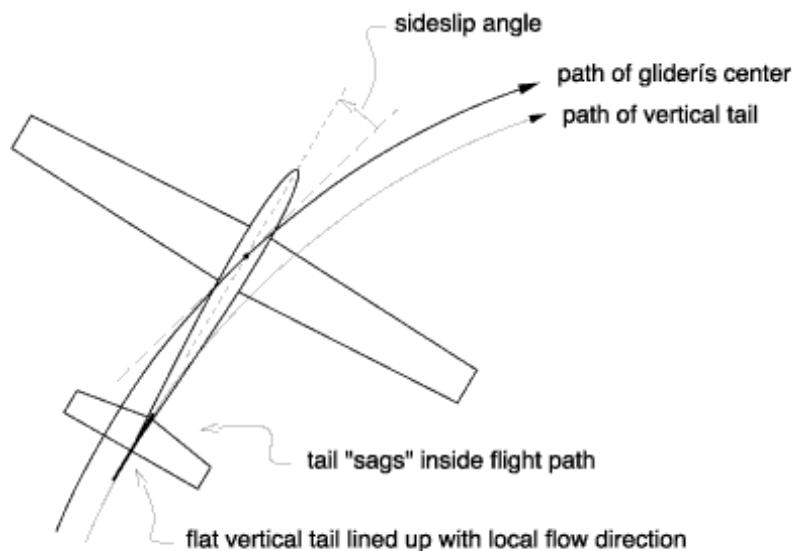


Figure 1a. Zero rudder deflection in sustained tight turn produces sideslip.

In Figure 1a, no rudder deflection is used, resulting in the tail "sagging" inside the glider's flight path, and a sideslip is present. In Figure 1b, the rudder is deflected such that the sideslip is eliminated. The tail now rides outside of the glider's path, giving the illusion of skidding (negative sideslip), although the wing in fact sees zero sideslip all along the span. This is likely to be the lowest-drag flight orientation.

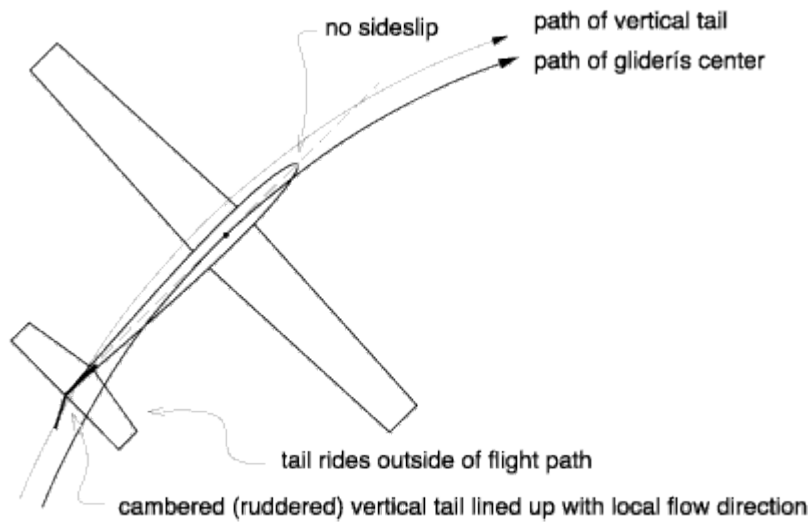


Figure 1b. Rudder deflection for zero sideslip.

A simple experiment

As a motivation for learning effective ruddering, first do a simple flight experiment in calm air, sketched in Figure 2.

Establish a straight slow glide, and note the L/D and sink rate.

Apply 20 degrees (or about 50%) left rudder, and just enough right aileron to keep the wings level. Some elevator may also be required to maintain pitch trim. The glider will now fly at a 10-15 degree right sideslip.

Note the reduction in L/D and increase in sink rate.

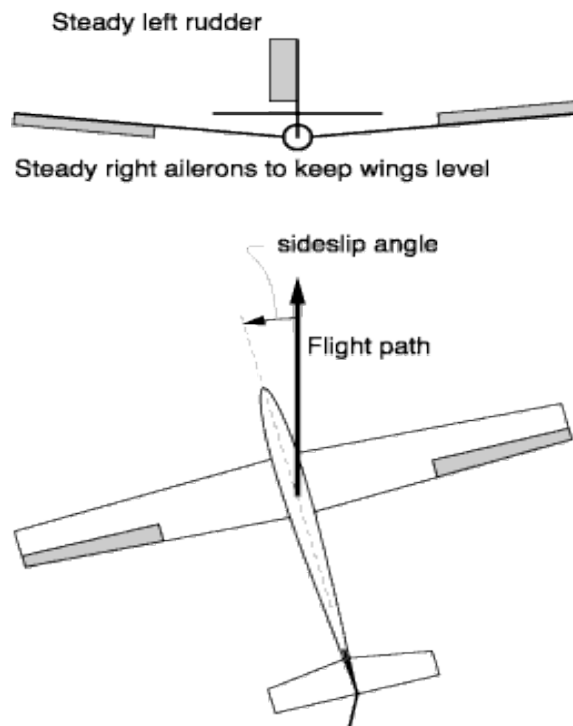


Figure 2. Straight sideslipping flight.

Such sideslip angles and resulting performance losses are typical in aggressive thermalling maneuvers at slow speeds if the left thumb is asleep. In turbulent thermals it is not uncommon to occasionally see sideslip angles of 30 degrees or more, with each such sideslip excursion resulting in considerable altitude loss. Skillful ruddering will prevent these from occurring.

Rolling into a turn

To prevent the appearance of sideslip in a turn like that shown in Figure 1a, it is necessary to coordinate the rudder input appropriately with the ailerons. The example here, calculated with a simulation program, shows the control inputs required for one specific Discus-Launched Glider, flying at a particular weight and airspeed, and reaching a specific bank angle. The required control inputs for another set of conditions or another type of glider will of course be different. The control input values shown are intended merely to be representative to allow visualizing what's going on.

Figures 3a and 3b show turn-entry maneuvers for a DLG in a fairly slow glide at 11 mph, $CL = 0.7$, close to the minimum-sink speed. In each case, right aileron is applied, ramping up from 0 to 10 degrees over a 0.5 second interval, and then immediately ramped back down to 0 degrees over the next 0.5 seconds. The glider reaches a 30 degree bank angle over the entire 1.0 second interval. Consider two different rudder actions during this roll entry maneuver:

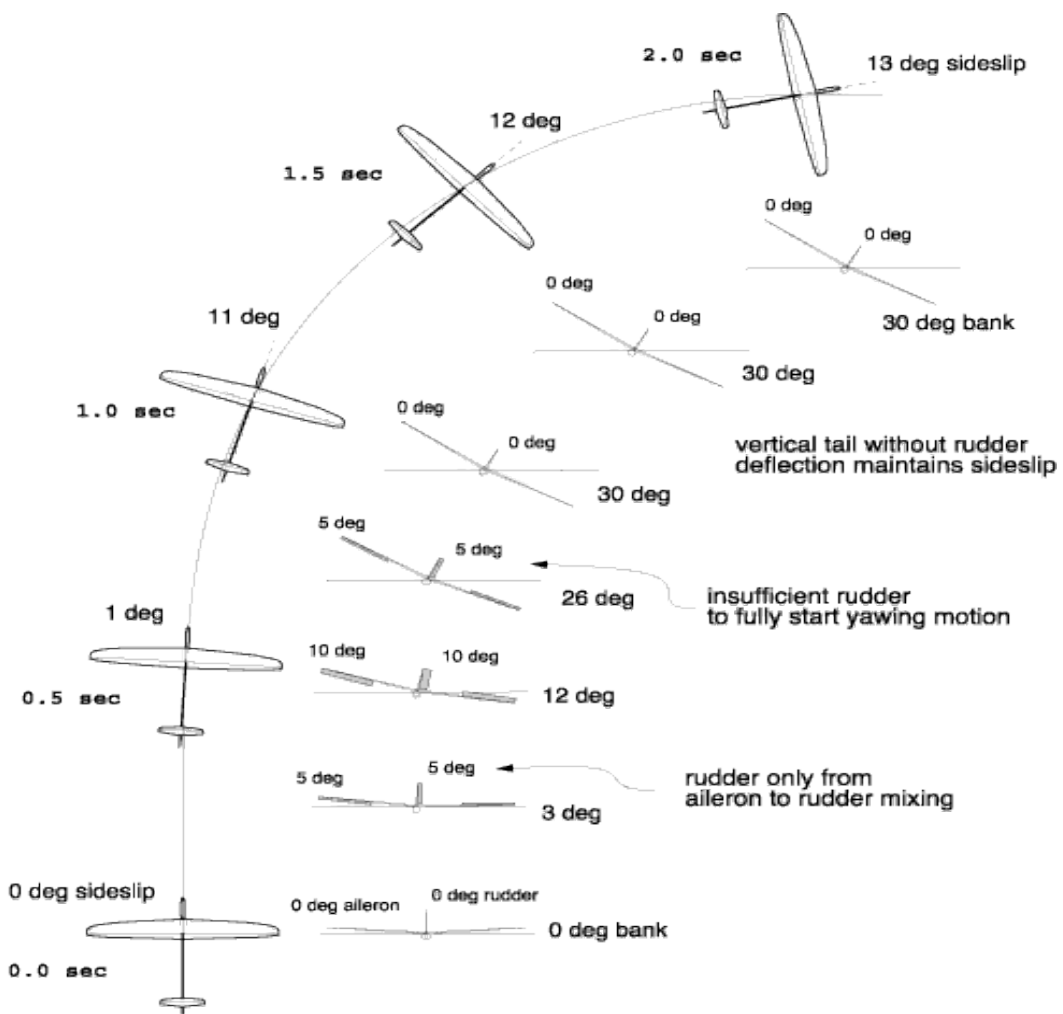


Figure 3a. Sideslip development during turn entry with no independent rudder input.

a) 1:1 Aileron to rudder mixing, left thumb asleep.

In this case the right rudder exactly follows the right ailerons in the ramp up and ramp down over the 1.0 second interval. Figure 3a shows the resulting glider motion. Note that a severe sideslip develops during the ramp-down as the slaved rudder is (incorrectly) neutralized along with the ailerons. The large sideslip is sustained throughout the subsequent steady turn.

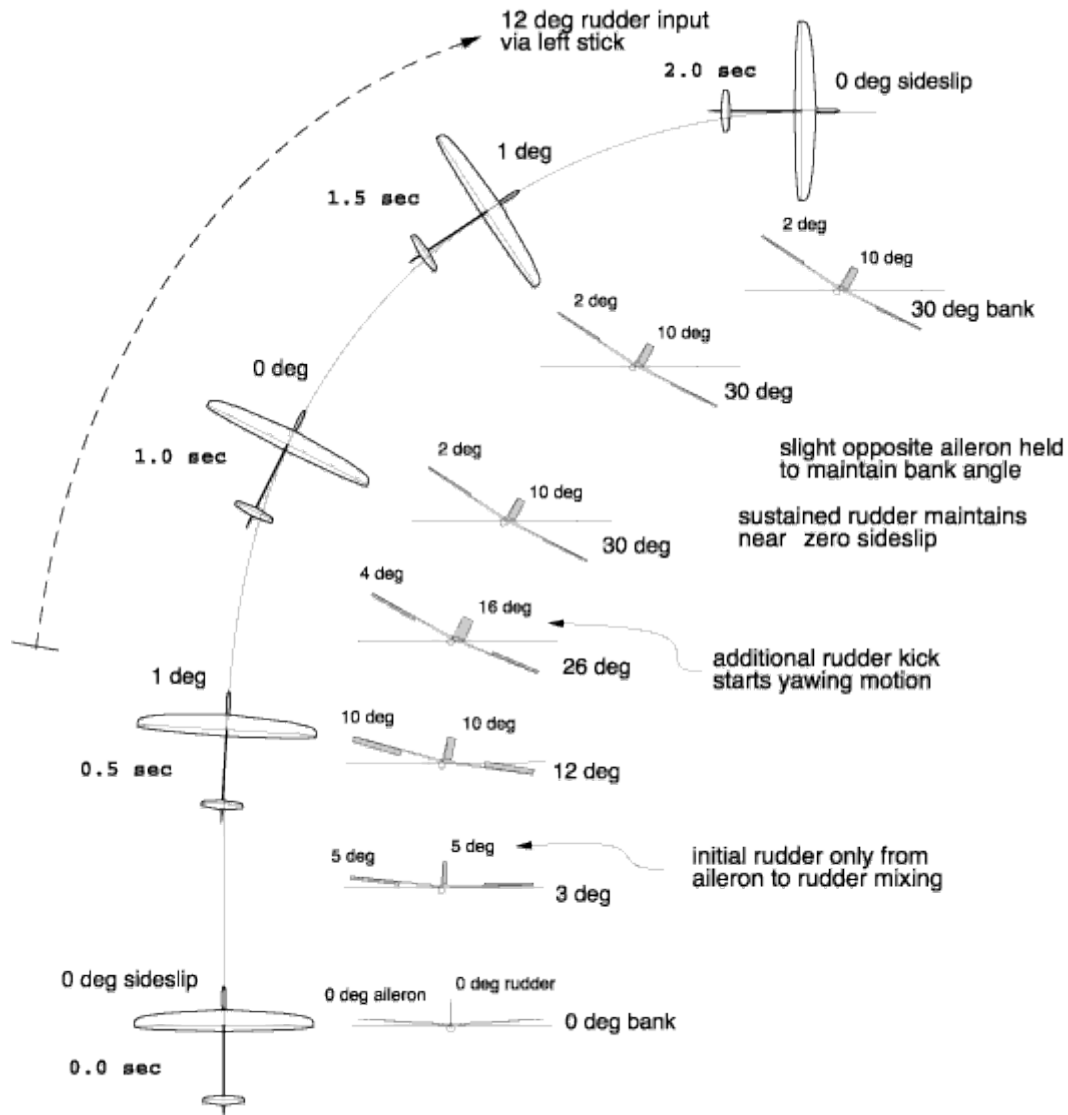


Figure 3b. No sideslip during turn entry and in sustained turn with proper rudder input.

b) 1:1 Aileron to rudder mixing, left thumb applies proper rudder deflection.

In this case, substantial right rudder is independently applied by the left thumb as the intended bank angle is approached and the ailerons are neutralized, as shown in Figure 3b. This right rudder is then sustained throughout the subsequent steady turn, producing a minimal slideslip angle. Note that this rudder action cannot possibly be achieved with any kind of mixing. A trained left thumb is required.

Sustained banked turn

a) Left thumb asleep.

The last aircraft position in Figure 3a shows the 13 degree sideslip which results when no rudder is held during the turn.

The slight aileron deflection required to sustain this steady turn depends on the amount of sideslip and the dihedral angle (zero aileron deflection is shown). With little or no dihedral, some opposite aileron must be held to maintain the bank angle and prevent rolling into the turn. With generous dihedral, some rolling moment is already provided by the sideslip/dihedral combination (just like in a poly glider), and the required held aileron deflection may be either into or out of the turn.

b) Proper ruddering into the turn.

The last aircraft position in Figure 3b shows the control deflections required for a slow, tight, steady sustained turn without sideslip.

The lack of sideslip means that some opposite aileron must be held to prevent rolling further into the turn, regardless of the amount of dihedral. In fact, one way to discern if a sufficient amount of rudder is being held (in addition to observing the sideslip) is to note the average aileron stick position which is being held to maintain the steady bank. Adjust the rudder until the ailerons must be held slightly opposite. This will produce efficient nearly zero-sideslip circling flight.

Effects of airspeed

How much rudder input is required depends considerably on the flight speed. In general, the higher the flight speed, the less rudder action is required. The examples in Figures 3a and 3b are for a slow thermalling turns. In contrast, the same glider in a fast upwind glide will require little or no ruddering.

Other types of gliders

DLGs have unusually long tail arms relative to their turning radius, and hence require considerable rudder input in steady turns. This in fact makes them excellent left-thumb trainers, because the sideslip resulting from poor ruddering is relatively easy to see.

Large TD gliders are likely to have short tails relative to their turning radius, and also a smaller vertical tail volume. The main consequences of this are:

- More initial rudder kick is needed to start the yawing motion upon turn entry. The 16 deg rudder deflection position in Figure 3b may need to have a somewhat larger momentary rudder input.

- Less steady rudder needs to be held into the turn to maintain zero sideslip. With relatively little aileron differential, the drag of the inside downward aileron may in fact produce a sufficient yawing moment to eliminate the need for any rudder at all.

In any case, correct ruddering for a specific glider must be learned by observing the sideslipping, and by noting whether some small amount of opposite aileron is properly being used to maintain a turn.