Wing Fences

(While we’ll use the term “wing fence” in this article, this item may also be identified by the terms “boundary layer fence,” “potential fence,” or simply “fence.”)

Wing fences have been used on swept wing aircraft for fifty years. The MiG-15, one of the earliest examples of their use, incorporated two fences on each wing. The F-86 used them as well. Fences can also be seen on more recent production aircraft like the Fiat G 91 and the BAe Hawk and Harrier.

Despite their use on aircraft flying at supersonic and near supersonic speeds, wing fences are also of use on low speed swept wing aircraft such as man carrying sailplanes and RC models. The Akaflieg Braunschweig SB-13 and a rendition of Hans-Jürgen Unverferth’s CO8 by Glyn Fonteneau and Dave Camp serve as examples within those realms.

Wing fences have both an interesting history and an interesting effect.

A wing fence is nothing more than a flat plate which is attached perpendicular to the wing and in line with the free stream air flow. Wolfgang Liebe is credited as being the inventor of the device, for which he received a German patent in 1938, during his work on the Messerschmitt Bf 109B.

The Messerschmitt Bf 109B had a rather peculiar stall. The stall initiated at the wing root, and a cross span flow very near the leading edge then travelled outward toward the wing tip at high speed. The result of this aerodynamic behavior was that the entire wing stalled at essentially the same time, a very dangerous characteristic. Installation of a wing fence prevented the cross span flow, thus eliminating the stall problem.

That a solid plate in the path of cross span flow close to the wing surface would obstruct the flow, as was seen on the Bf 109B, may seem obvious. In actuality, however, the mechanism of operation was more covert in that the beneficial effect was provided by the initiation of a sideslip and the resulting vortex generated by the fence.

Wing fences on swept wings have been found to be very beneficial to inhibiting the nasty stall behaviors which result from severe angles of sweep, but their operation in this environment is entirely different than on a straight wing such as the Bf 109B.

As we mentioned in the opening parenthetical paragraph, wing fences have had other terminologies applied to them. “Boundary layer fence” is the most common, so let’s take a critical look at that nomenclature for a moment.

The boundary layer is that region next to the surface of a solid body where there is an appreciable loss of total pressure. That is, the velocity is a fraction of the free stream flow. The boundary layer thickness is usually defined as the distance normal to the surface in which the velocity rises to 99% of that of the main flow. The boundary layer is in reality not very thick, usually a matter of a few millimeters, even on full size aircraft.

With the above definition in mind:

• If a wing fence is constructed to be the same height as the boundary layer thickness, it is not effective. In fact, fences must be quite high to have any effect at all.

• The boundary layer gets thicker toward the trailing edge of the wing, so if fence height were based on the boundary layer thickness the fence would be highest at the trailing edge of the wing. Yet extending the length of a fence much beyond 50% chord does not increase its effectiveness in the slightest.

• Wing fences are generally more effective when they wrap around the leading edge.

The term "boundary layer fence" is, as illustrated by the above points, a misnomer. Wing fences do not affect the boundary layer directly, but rather do so indirectly by having an impact on the potential flow, the flow in which the vorticity is zero. The term "potential fence" is derived from the action of the fence on the potential flow.

Wing fences on swept wings work in a very complex way, and their action is not completely understood, but we'll attempt to make the fundamental concepts easier to understand.

Begin by thinking of a swept wing panel mounted in a wind tunnel and its associated lift distribution, as shown in Figure 1. Note that if the right wall is removed we have a right wing panel for a swept back wing; if the left wall is removed we have the left wing panel of a swept forward wing.

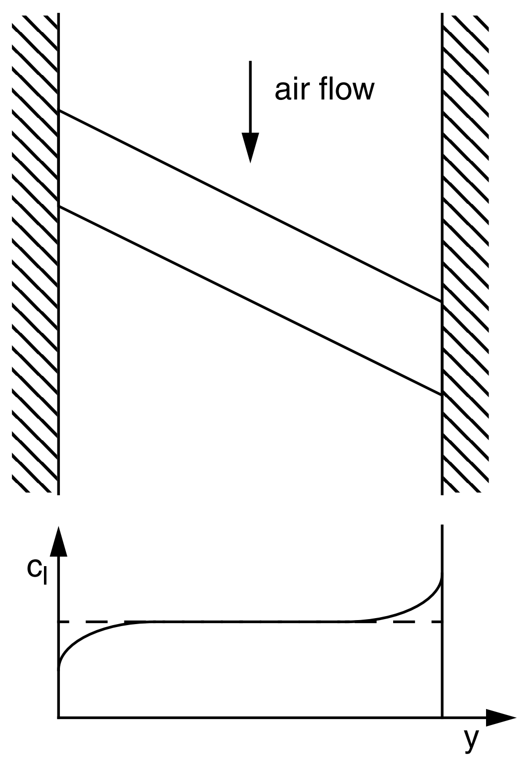

Figure 1. Schematic of swept wing in wind tunnel and associated lift distribution.

From a slightly different perspective, by removing the walls and attaching a “mirror” wing panel to either the left or right end of the existing wing, we have a complete wing, swept either backward or forward, and an associated lift distribution as depict in Figure 2. We can consider a win fence to be aerodynamically equivalent to a tunnel wall. This effect is demonstrated in a more comprehensive way in Figure 3.

Installing a wing fence changes the lift distribution on a swept back wi as depicted in Figure 4. Note that o the inside of the fence the c_l is high while on the outside of the fence th c_l is lower. This shifting of the load the inside of the fence is very beneficial to stall behavior.

The c_{lmax} should be located in the area approximately 40% of the semi-span from the wing root. At a high angle of attack, this should be the area of the wing which stalls, leaving the wing root and the wing tip to continue providing lift and a slight pitch down moment.

When high angles of attack lead to separated flow, the boundary layer directly involved at a fundamental level. Corrective measures must influence the boundary layer in suc a way that flow separation is limite or controlled to some extent. As previously said, wing fences do no directly influence the boundary layer. Rather, they influence the potential flow which in turn effects the boundary layer. In general terms, the c_l load on the wing tips is reduced, the boundary layer is maintained in such a way that separation is

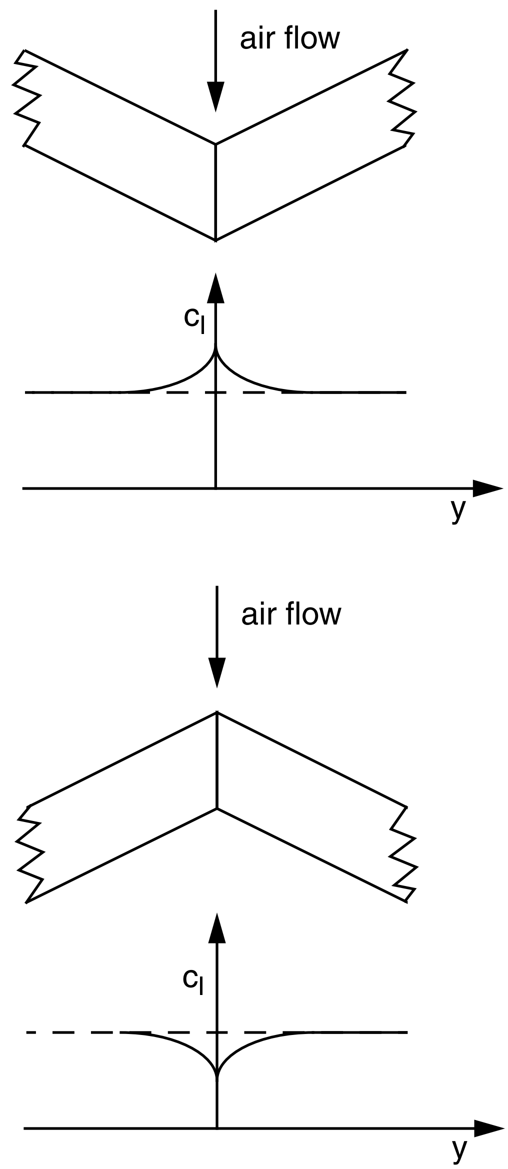

Figure 2. Swept wing segments and associated lift distributions.

inhibited, and the stall behavior is made more benign.

Rarely do wing fences extend farther than 1/3 of the wing chord. The forward third of the chord is the area of greatest lift. It is also the area where the sweep effect and the "mirror" principle, described in Figures 1 through 4, are most effective.

For use on RC sailplanes, wing fences are usually constructed using a profile similar to those shown in Figure 5 and are fabricated of stiff cardstock or plastic. They can be conveniently attached with tape for easy removal, replacement, and/or experimentation. The most common location for wing fences is between 40% and 60% of the wing span. A location directly in front of the inner edge of the aileron or elevon has

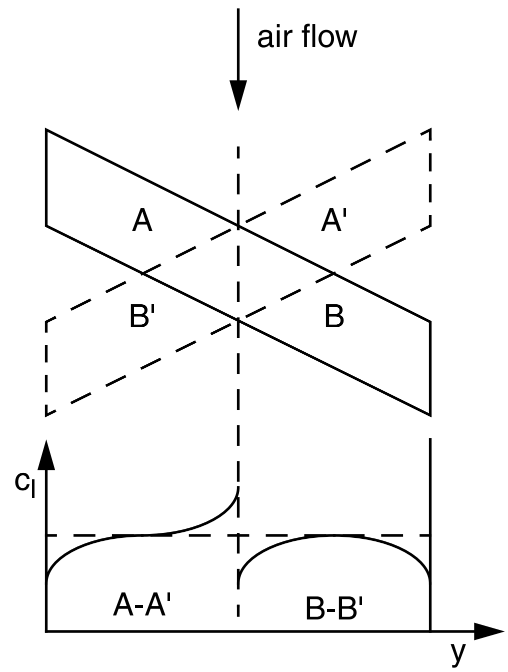

Figure 3. "Mirror" swept wings and associated lift distributions.

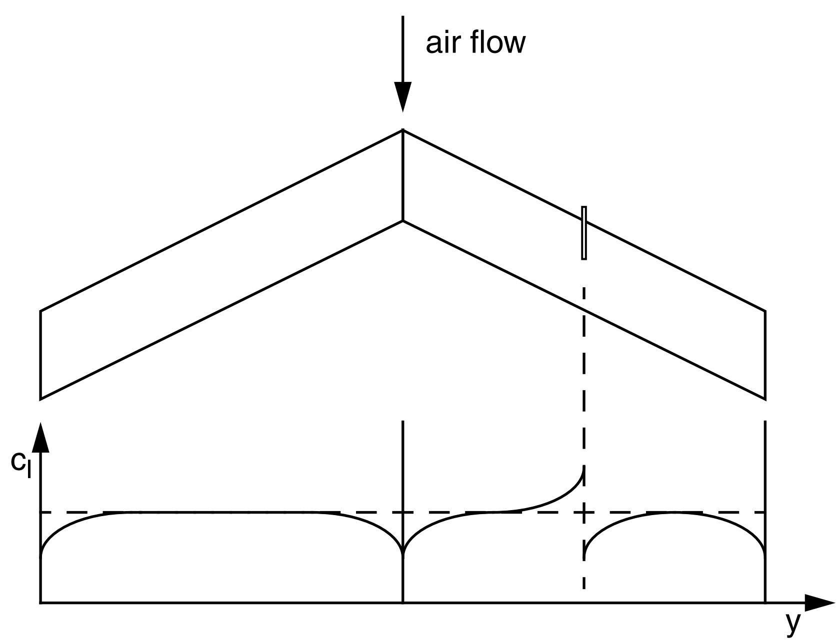

Figure 4. Complete swept wing with fence on right wing and associated lift distributions.

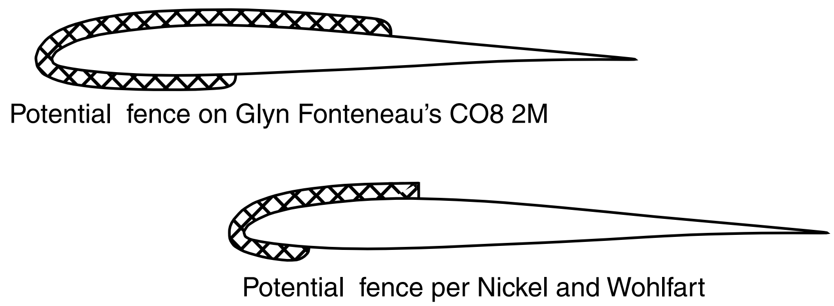

Figure 5. Examples of wing fences.

shown to be very effective at controlling adverse stall behaviors and maintaining control surface effectiveness at high angles of attack. Installing two fences on each wing panel, at 1/3 and 2/3 of the semi-span, has been found to be effective on high aspect ratio wings with steep sweep angles.

Wing fences are sometimes not easily seen. Most airliners have their engines mounted below the wing on pylons. The pylon itself serves as a fence for the lower surface, and the leading edge pylon fairing often comes over the leading edge, serving as a fence for the upper surface.

Controlling air flow to improve swept wing flight characteristics can be accomplished through a number of means - wing slots (as described in our August 1994 column), leading edge slats, and the "saw tooth" leading edge to name just a few. Wing fences are attractive, however, because they can be fabricated quickly, attached readily, and modified easily without affecting the main airframe in any way. So far as cost and ability to experiment, they are the best suited solution.

Comments, questions, and suggestions for future columns may be sent to us at either P.O. Box 975, Olalla WA 98359-0975, or <bsquared@halcyon.com>.

Resources

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