WING DRAG DUE TO TWIST AND SWEEP FORWARD

By Richard H. Johnson

Since the effects of wing twist and sweep forward are important to the design of modern sailplanes and little aerodynamic information on this subject is available to most designers, it was decided that a generalized study should be made available at this time. There are many who advocate elimination or reduction of aerodynamic twist in sailplane wings and also the incorporation of sweep forward in lieu of wing twist to achieve desirable stall characteristics. The following is written to aid designers in their choice of wing twist and/or wing sweep.

Figure 1 shows the five wing planforms that were used in this study. The aspect ratios used were 6, 14, and 22.9. To answer questions about swept forward planforms the aspect ratio 14 wing was studied with sweep angles of 0°, −10°, and −20°. Three different airfoil sections were used with the three aspect ratios. The drag polars for these airfoils are shown in Figure 2. All three airfoils shown are considered by the author to be suitable sailplane airfoils for wings of their respective aspect ratios. For structural reasons the higher aspect ratio wings were assigned the thicker sections. Actually, the choice of airfoil sections had little effect on the results of this study and any airfoil section could have been used with similar results.

The induced drag was calculated for each of the straight wings with no twist and also for these same wings with finite values of twist. These calculations were made for wing lift coefficients between zero and 1.4 by the method described in reference (1). All wing twists considered in this study are linear, that is the wing is twisted so that the leading and trailing edges are straight lines. These results are shown in Figures 3 through 5 as the family of three induced drag curves on each figure. Induced drag is that drag resulting from the formation of lift and its magnitude depends on the distribution of downwash across the span. With the untwisted wings at their angles of attack for zero lift there is no lift anywhere along the span and therefore no induced drag exists. However, for the twisted wings at their respective angles of attack for zero lift the inboard portion of the wings is producing positive lift and the outboard portion is producing negative lift, and although the net result is zero, there still results an induced drag due to the formation of this lift.

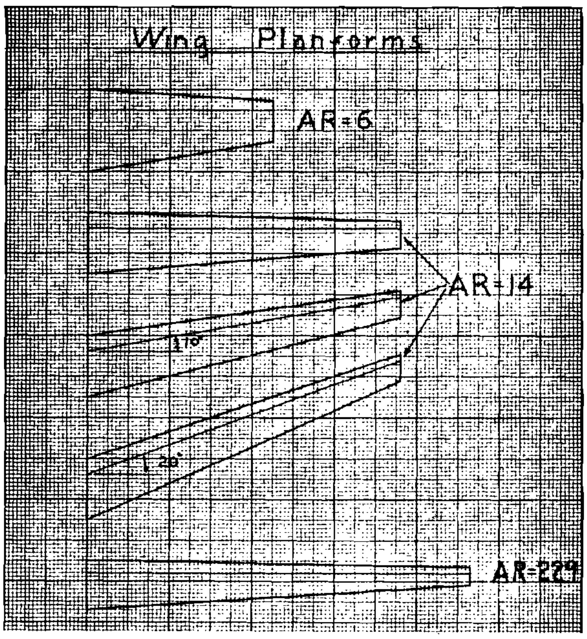

FIG. I
Wing Planforms Used In Study

Figure 6 shows the induced drag of the aspect ratio 14 wing with no twist but having sweep forward angles of 0°, 10°, and 20°. The sweep angles are measured between the lateral axis and the line joining the quarter chord points of the airfoil sections. This figure shows that all of these wings produce no induced drag at zero wing lift coefficients but at finite lift coefficients the induced drag of the swept wings is higher than that of the straight wing.

In Figure 7 is shown the increment of induced drag that the twist or sweep added to the drag of the straight untwisted wings. Note that the increment of induced drag that is added by the twisted wings is essentially constant at all lift coefficients and is little affected by changes in aspect ratio. Also the magnitude of this increment of induced drag increases approximately as the square of the twist angle.

The increment of induced drag that the sweep forward added to the aspect ratio 14 wing appears to be proportional to the sweep angle, and for a given sweep angle, increases approximately as the square of the lift coefficient.

The drag of a complete wing is made up of the sum of the induced and profile drags. Therefore to look at the total drag of these wings it is necessary to add the profile drag of whichever wing section one wishes to use to the previously discussed induced drag of Figures 3 through 6. As mentioned before the sections used in this analysis and their profile drag polars are shown in Figure 2. Due to the span lift distributions some sections of the wing will operate at higher lift coefficients than the wing lift coefficient and other sections along the span will operate at lower lift coefficients. The total lift of a wing is the summation of the lift along the entire span and likewise the total profile drag of a wing is the summation of the section profile drags which correspond to these section lift coefficients.

The profile drag was calculated for each of the wings for wing lift coefficients between zero and 1.4. Shown in Figures 3 through 6 are these profile drags added to the previously discussed induced drags. It is seen that these induced plus profile drag curves are very nearly the sum of the profile drag curves of Figure 2 and induced drag curves except that at the larger twist angles the definiteness of the low drag "bucket" of the low drag airfoils, used on the