Undoubtedly the best solution, both for high as well as low speed, is the rectangular-tapered wing shown in Figure 8. Surprisingly enough the rectangular-tapered wing keeps its favorable drag characteristics even when the twist of $-3°$ is confined to the tapered section only (see Figure 9). It might be mentioned that the aspect ratio A only has a very small effect on the absolute values of ΔC_{di}. The curves shown are for an aspect ratio A=15, but the values of ΔC_{di} are valid to a good approximation up to A=25.

* * *

The second criterion for choosing the planform and twist is the anticipated stalling characteristics of the wing in slow flight. In order to render this often dangerous condition harmless, the pilot should, if possible, feel the stall almost automatically, and the controllability of the aircraft should still be maintained, even if flown below the normal stalling speed. One should therefore ensure that the airflow at the outer wing (within the aileron region) separates later than that of the inner wing. One possibility is to choose suitable profiles for the inner and outer wing. A second consideration must be the effective angle of attack of a wing portion which is affected by planform and twist.

In Figure 10, for example, the variation of the local C_L values, which are proportional to the local angle of attack, is shown for a rectangular and two tapered wings. Following the choice above, the angle of twist is $\varepsilon = -3°$ for tapers and $\lambda = 1.0$ and 0.6 and is $\varepsilon = 0°$ for $\lambda = 0.4$.

As expected, the inner portion of the rectangular wing gives the largest and the outer portion the smallest angle of attack, thus would seem to guarantee docility in the stall. It is however not to be overlooked that the average C_L value of the whole wing lies 15% below the maxmium C_L value in the middle of the wing. This means that the docility of the wing involves an overall loss of lift. In other words, a slight increase in minimum speed is necessary.

A compromise yielding better results would presumably derive from using a tapered wing with $\lambda = 0.6$, while a tapered wing with $\lambda = 0.4$ and 0° twist clearly shows too large an angle of attack of the wing at about the point where the ailerons begin.

Figure 11 shows the spanwise distribution of lift coefficient for a double-tapered wing and two rectangular-tapered wings. This shows that the rectangular-tapered wing with the taper beginning at two-thirds of the semi-span will be better than any other shape, insofar as the stall characteristics are influenced by wing plan, since it has in the whole aileron region a lift coefficient value which is lower at the inner wing by $\Delta C_L = 0.06\text{-}0.10$.

So far we have not taken into account the fact that the wing has elasticity and develops extra twist at high speed. Allowing for this, a ΔC_{di} for $-7°$ is shown in Figures 3 through 9.

With a knowledge of the elastic distortion it is easy to work out how large the real ΔC_{di} at high speed will be.

WINGS WITH FLAPS

Also of interest is the wing with flaps where the flaps are extended over only a part of the span. For the present purposes it is not important whether the lift distribution is changed by increasing the camber, the chord, or by a combination of both possibilities. If, for example, the wing chord is increased over two-thirds of the semi-span by 20% then, owing to the uneven lift distribution, a considerable extra induced drag will result which will be about 30% in excess of that of the untwisted rectangular wing. At the same time the angle of attack within the aileron region (compared with untwisted wings) will be greater than in the inner wing. Therefore in sailplanes the change of camber or wing chord should, if possible, run along the whole span.

Although for circling and high-speed flight one only need consider small flap changes of about 15% up and 10% down, it is still difficult to safeguard the aileron effectiveness in slow flight. We know from experience that even with simple cambered flaps and Reynolds numbers $0.5\text{-}0.7 \times 10^6$ increased separations occur even with flaps 15° down.

To sum up, it is shown that a rectangular wing with a tapered tip and little twist, and with the taper beginning at about two-thirds of the semi-span, would give a very good aerodynamic compromise. The extra induced drag will still be very small even with about $-3°$ twist, and the flying characteristics in slow flight should be more docile than with other planforms.

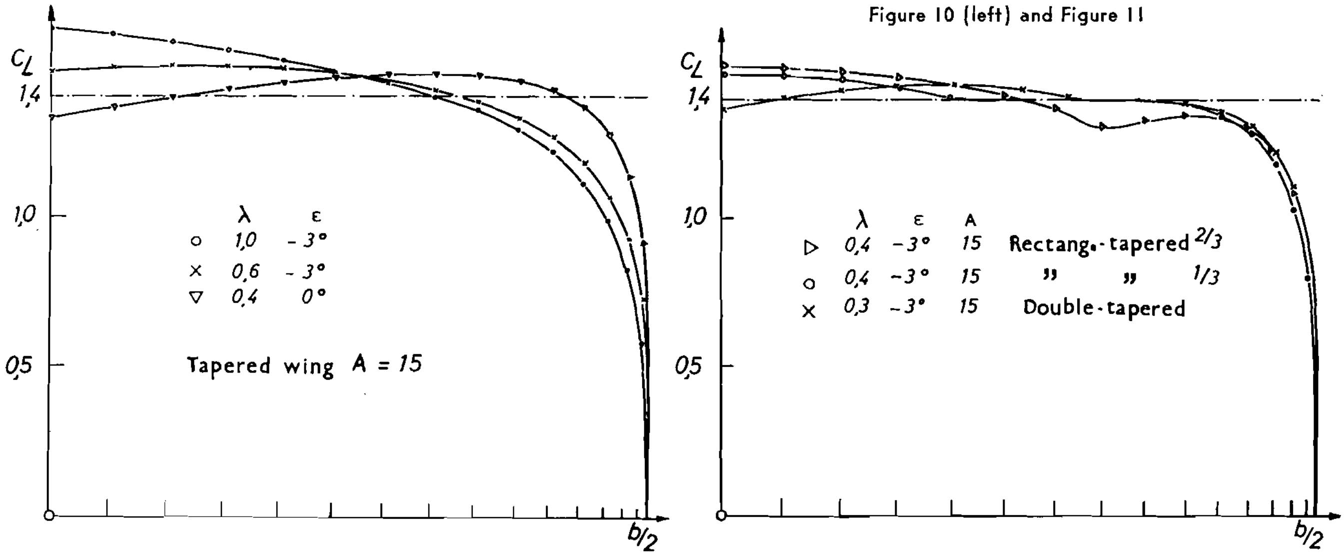

Figure 10 (left) and Figure 11