SOME IDEAS FOR OPTIMUM FLAP-ALLERON SYSTEMS CONCERNING HANDLING QUALITIES AS WELL AS FLIGHT PERFORMANCE

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Introduction

Looking at the new open class gliders, you will find that there are very highly sophisticated aileron-camberflap systems. In former days there were two flaps only; nowadays there are up to 5 flaps on each wing, each of them doing a lot of work increasing the performance and controlling the glider.
It was of some interest just to find out, what these multiflap systems could effect in the 15m-class.

The Calculations

For the calculations a Multhopp-algorithm was used. Therefore, a FORTRAN-programm of Akaflieg Darmstadt was used running and POP-10 computer.
- Calculated Periods of Flight.
Calculations were done for four different periods of flight. First flying straight ahead at a low speed ($C_L = 1.2$), there is no aileron deflection. Second (4) when the ailerons are a little bit deflected, how much would the induced drag increase? How large might the roll factor become, and how large would be the induced drag then? The largest roll factor is reached, if either the local angle of attack, becomes too large, or the aileron deflection angle exceeds a maximum. As a criterion for the largest local angle of attack, the point of rapid increase of the airfoil's drag is used (Fig. 1). The fourth period of flight, which was calculated, was a steady rolling. Therefore the local angle of attack changed by another angle, which is a result of the roll rate. This extra angle is positive on the down- going wing and negative on the up-going one (Fig. 2).

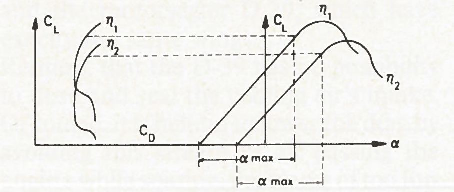

Fig. 1: Flap deflection angle $\eta_1 > \eta_2$.

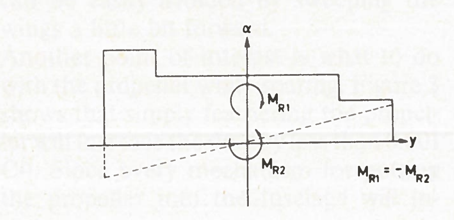

Fig. 2: —— α-distribution with aileron deflection → M_{R1} --- α-distribution because of rolling → M_{R2}.

- Calculated Distributions of the Angle of Attack (y).
These periods of flight were calculated for six different distributions of the angle of attack. At this point, it must be realised, that an elliptic lift distribution makes the induced drag a minimum, but because of reasons of handling qualities, this would not be the best lift distribution. There has to be a decrease to the angle of attack towards the wing tips. This will cause a better stall characteristic and make the ailerons work better.
So, the decrease of α starts at the spanwise coordinate Y_{kl}, the six cases having the following specified functions: (Fig. 3)

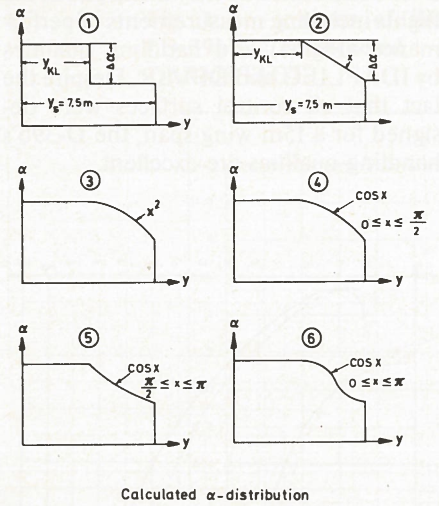

Fig. 3: Calculaded α-distribution.

1. A sudden decrease at Y_{kl}, than being constant through the remaining wing span.
2. Decreasing linearly up to the wingtip.
3. Following a square function x^2, $0 \leqq x \leqq 1$
4. Decreasing as a cosine function cos(x), $0 \leqq x \leqq \pi/2$
5. Decreasing as a cosine function cos(x), $\pi/2 \leqq x \leqq \pi$
6. Decreasing as a cosine function cos(x), $0 \leqq x \leqq \pi$

Note that only distribution #1 can be realised by two flaps only. This is the distribution nowadays used. All the other distributions make the use of more than 2 flaps necessary; in the case of distributions #2 to #5, three or four flaps will be enough. In this case, the jumps of α will be small enough, not to increase the induced drag. Thinking about the ailerons, aileron deflection starts at Y_{kl} too, and the local combined aileron and flap angle may reach the maximum deflection angle anywhere along the span at the time of maximum aileron application.

Results

The calculations for flight period #1 (Fig. 4) have shown, that it is useful to avoid a sudden change of the angle of attack near the wingtip. Furthermore, a $\Delta\ \alpha = 3°$ decrease of the angle of attack is slightly better than can decrease of $\Delta\ \alpha = 1.5°$. In fact, all α-distributions are found to be better than distribution #1.
Looking at flight period #2, the aileron deflection, there is no large difference concerning the different α-distributions or the size of the α-decrease. But performance will decrease a lot, if the aileron deflection begins later than 3 metres away from the fuselage.
Therefore, Figure 5 shows the relation of the moment of rolling and the induced drag C_R/C_{Di} depending on Y_{Kl}. Because of the influence of C_l on C_{Di}, the induced drag C_{Di} is normalized by $C_{Di_{elliptic}}$ to

$$\frac{C_R}{C_{Di}} * C_{wi_{elliptic}} = K * C_R$$

Another point of interest is, that of course, large aileron deflection makes the induced drag larger. But the induced drag, related to the roll factor, becomes smaller in this case.

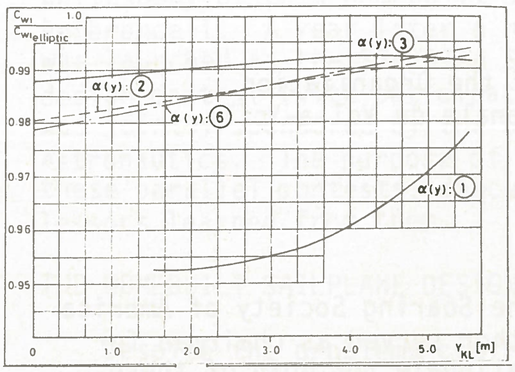

Fig. 4: Some characteristical results of the calculation to flight period # 1.

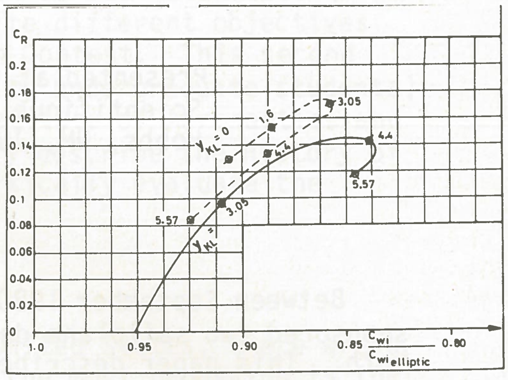

Fig. 6: Some characteristical to flight period # 4
— α-distribution ①
--- α-distribution ③

Looking at the results of flight period #3, α-distribution #1 is the worst again (Fig. 6). This calculation tells too, that aileron deflection should not beginn later than 3m. Otherwise, the maximum roll factor decreases rapidly, increasing the induced drag the same time.

Fortunately, calculations for flight period # have similar results, showing that α-distribution # 3 would be the best (Fig. 7).

As a result of another calculation, the flaps should end 0.35m away from the wingtip.

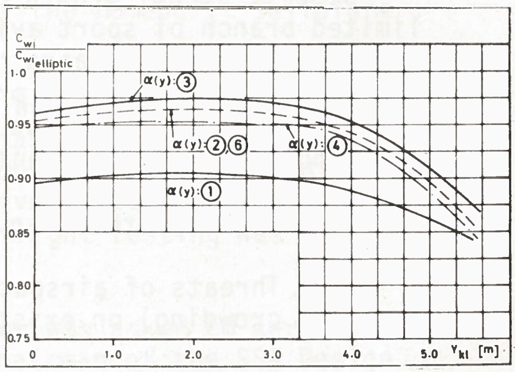

Fig. 7: Some characteristical results of the calculations to flight period # 4.

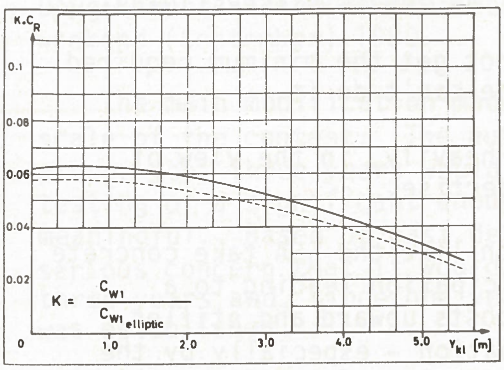

Fig. 5: Some characteristical results of the calculations to flight period # 2
— α-distribution ①
--- α-distribution ③

Conclusion

As a conclusion I suggest to use the third distribution of the angle of attack, the square law one. The decrease of Cwi/ $Cwi_{elliptic}$ should start at $Y_{kl} = 3m$. The size of the decrease depends very much more on the airfoil characteristic and on optimizing the handling qualities than on reducing the induced drag. Anyway, it should be between 1/3 and 1/2 of the camberflap deflection angle; the differential should be somewhere between 1:2 and 1:3.