Schaufele Annotations
Chapter 4 Preliminary Wing Design

Selection of Wing Loading (W/S)

During the conceptual design process, it is important to think in terms of wing loading (W/S), where W is the maximum takeoff gross weight (MTOGW) and S the wing reference area, rather than simply the reference wing area for the airplane. Similarly, think in terms of airplane thrust to weight ratio (T/W), where T is the all-engine sea level static installed thrust, rather than simply the engine thrust. The reason for this is twofold. First, airplanes in the same class will tend to have the similar values of T/W and W/S, because these are two important parameters that define aircraft performance (there are several others, such as $C_{L_{max}}$ for takeoff and landing, and cruise L/D). This is illustrated in Schaufele Fig. 4-1. Most similarity parameters are non-dimensional, but W/S is not. However, W/S is an important part of the definition of lift coefficient, defined in 1-g flight by

$$C_L = \frac{L}{qS} = \frac{1}{q}\frac{W}{S}$$

So if a class of aircraft fly at about the same speed, and have the same lift coefficient for that condition (which is usually the case), they will have the same wing loading. Second, during the design process, the value of MTOGW to meet the mission requirement will keep changing as more knowledge is gained or more assumptions made about performance, but T/W and W/S will not, at least not by much.

The wing reference area is usually defined by the trapezoidal area, where two sides of the trapezoid are straight lines that lie on the longest straight portion of the wing leading edge and the longest straight portion of the wing trailing edge. The other two sides are the wing tip and the wing root at the centerline of the airplane. The "longest straight portion" can be open to interpretation, so it is important to know what the assumptions are. The net result is that the wing reference area is usually somewhat less than the wing total planform area. At Boeing the reference wing area is defined by the "Wimpress" area, which includes areas of the wing planform that lie outside the trapezoid. The Wimpress area is therefore more representative of the wing lifting surface, but somewhat more time-consuming to measure.

Wing Thickness Distribution

Schaufele Fig. 4-8 is an important chart in determining wing characteristics as function of desired cruise Mach number. There are different ways of defining M_{DIV} as described in the annotation to Chapter 12, and in this book M_{DIV} is defined as $M_{DIV} = \Delta C_{D_c} + 0.0016$. Raymer states that typically $M_{CR} = M_{DIV}$, but this is based on the Boeing definition of M_{DIV} which is $M_{DIV} = \Delta C_{D_c} + 0.0020$, which results in a value of M_{DIV} which is about M 0.02 higher than the Schaufele definition. So we can say that by the Schaufele definition of M_{DIV}, $M_{CR} = M_{DIV} + 0.02$.

As a check on this derivation, the characteristics of the Airbus A330 wing are (Ref. 10.1)

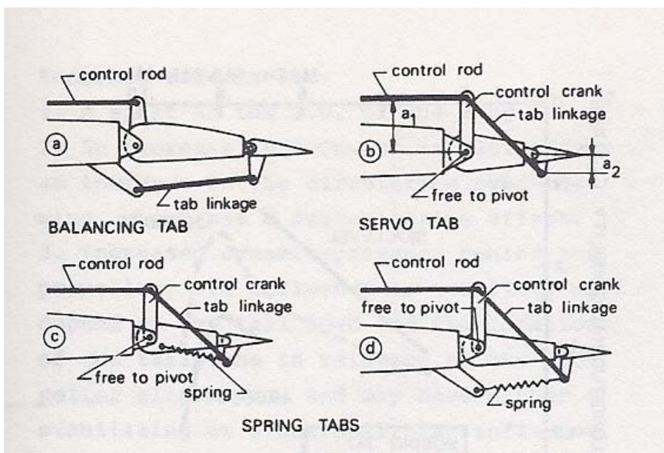
- Λ = 30 deg
- t/c = 12.8 %

Assuming cruise $C_L = 0.50$, Fig. 4-8 shows a value of $M_{DIV} = 0.80$, so that $M_{CR} = 0.82$. This is consistent with the value of $M_{CR} = 0.82$ in Ref. 10.1.

Lateral Control Devices

In Fig. 4-16, you can see that the DC-9 aileron has two tabs (small aerodynamic control surfaces) on the trailing edge of the port (LHS looking forward) aileron. The outer tab is a trim tab and is usually operated by a transverse wheel in the cockpit for trimming the aircraft in roll. This requirement might occur if more fuel is burned from the fuel tanks on one side than on the other.

The inner tab is the control tab (also called a servo tab), as shown in sketch 'b' in Fig. 4.1. On the DC-9 the flight controls do not move the ailerons directly. The controls move the control tab, but in a direction opposite to the required direction of the aileron itself. The aileron is freely pivoted on its hinge. Because of the greater moment arm of the control tab, it will apply a moment to the aileron which will move the aileron in the opposite direction. The aileron has a much larger area than the control tab and therefore applies a much larger force on the wing, and consequently a larger rolling moment on the airplane than that applied by the tab. The benefit is that the required actuation forces are much smaller, such that the control cables are connected directly to the control tabs with no hydraulic boost. The force on the control column required to move the ailerons turned out to be so small that on the DC-9-40 springs were added to the control system to provide additional feel for the pilot.



Source: Torenbeek

Fig. 4.1 Tab Mechanisms

A balance tab (sketch 'a') is not the same as a control (or servo) tab. A balance tab also operates in the opposite direction to the main control surface. For a control system with balance tabs, the control system actuates the main control surface, and the balance tab is mechanically linked to the control surface such that it moves in the opposite direction. This serves to reduce the hinge moments on the control surface, and thus the required actuator size. Balance tabs are on many other airplanes. Spring tabs are variations on the control tab. At high q the tab carries a large control force in relation to the spring force. The action of the spring tab is then comparable to the servo tab. At low q the spring force is large in relation to the force on the tab and system 'c' behaves like a plain control, whereas system 'd' acts more or less like a balance tab.

Another variant is the anti-balance tab, in which the tab operates in the same direction as the control surface. This results in a somewhat greater control power, and much greater moment on the control surface hinge. This requires a much greater applied control force by the pilot. This system may be used if the required control forces are deemed to be too small.

References

10.1 Wikipedia Commons (www.wikipedia.com)