6 Lift Augmentation/Modification

6.1 Trailing Edge Devices

6.1.1 Increasing of the Camber and/or the Surface

A modern aircraft should be designed to fly fast with the use of a reasonable amount of power, but it should also be able to fly slowly enough to use relatively short runways for take-off and landing. However, the use of large wings for low speed produces high drag at high speed; this is obviously a conflicting situation for the designer. A solution is to use so-called high lift devices. *Fig. PF 6.1.*

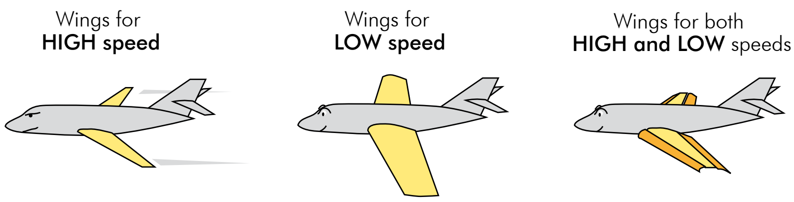


Fig. PF 6.1 Wing design optimisation

Let us start with a short review of lift. As already seen in the lesson on lift, the total quantity of lift is the result of many factors: the dynamic pressure, the lift coefficient and the wing surface area. If we consider the density of air as constant, the total lift can be changed by changing the dynamic pressure with the speed, the lift coefficient or the wing surface area.

Generally, lift can be increased at low speeds by the use of devices which give one or often a combination of the following: increased camber of the wing section (C_L), improved boundary layer (C_L) and increased wing area (S). *Fig. PF 6.2.*

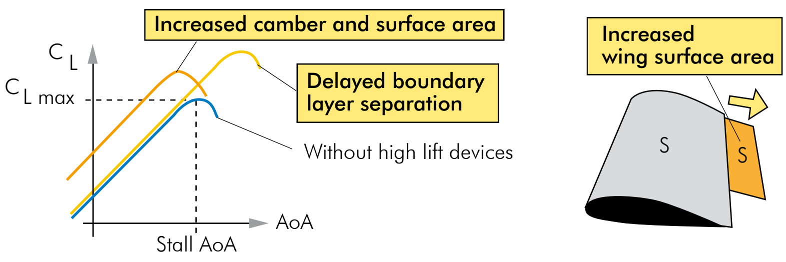


Fig. PF 6.2 High lift devices effects an C_L/α

Lift (L) = Dyn. press. (q) × Coeff. of Lift (C_L) × Wing Area (S).
At a given speed, lift depends on the C_L and the wing area S.

These high lift devices can be mounted both on the trailing edge and on the leading edge, and even if they have different aerodynamic influence, they are able to increase the maximum lift of the wing. However, sometimes it is necessary to reduce the lift and increase the drag. These lift reducing devices are called **spoilers.** (See paragraph 6.3.)

6.1.2 Different Types of Trailing Edge Flaps

There are many different types of trailing edge high lift devices. The most important thing to remember is that they all work in the same way. The high lift devices of the trailing edge, called **flaps**, produce the required increase in lift at a **lower geometrical angle of attack** of the main aerofoil than with a clean wing (clean wing = without any flap deflection).

However, the **effective chord line and the effective camber** changes with flaps selection. Flap deflection results in increased lift and drag at a given angle of attack and increases the maximum C_L. *Fig. PF 6.3.*

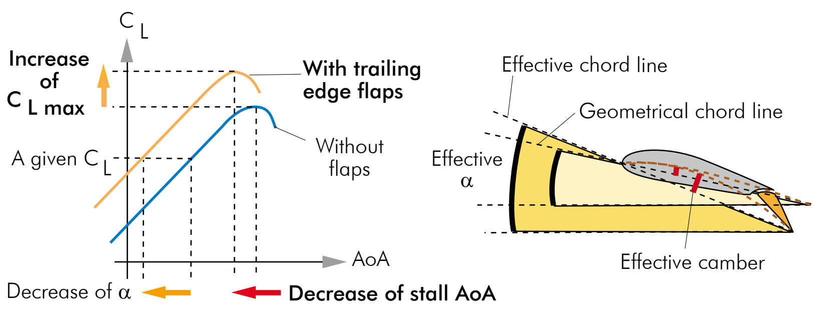


Fig. PF 6.3 Effects of trailing edge flaps

The flaps of the trailing edge increases $C_{L\ max}$ and produce the same amount of lift at a lower geometrical angle of attack than with a clean wing.

Wings with deflected flaps usually **stall at a lower AoA** than wings without flaps. This is due to the fact that the pressure gradients at the C_L max for both cases are roughly equal. *Fig. PF 6.4.*

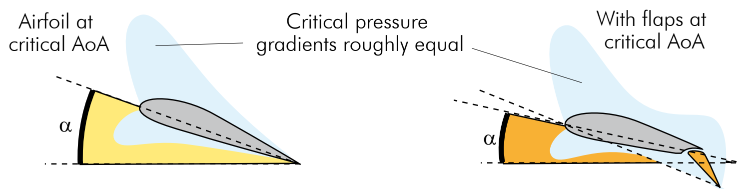


Fig. PF 6.4 Trailing edge flaps on stall AoA

The lower stall AoA is here measured to the chord line of the main aerofoil. The stall AoA measured from a chord line from the leading edge of the main aerofoil to the trailing edge of the flaps can be higher.

Flaps are designed to **increase the wing camber** which will increase the downwash and the circulation relative the aerofoil. It will also **move the CP rearwards** creating a **nose-down momen**t. (More about motion of CP and moment change in the chapter 8 Stability.)

Due to the change of shape of the wing, all or some of the components of parasite drag D_0 will increase, and the induced drag D_i will also increase due to the change in spanwise lift distribution. *Fig. PF 6.5.*

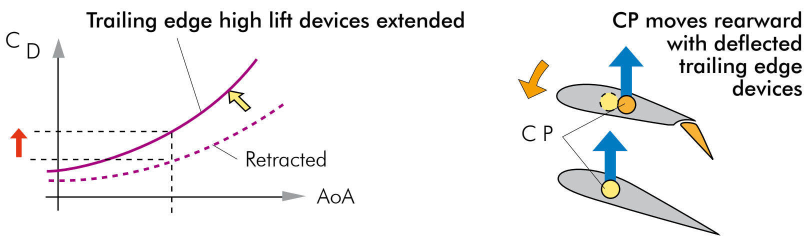


Fig. PF 6.5 Flaps on C_D /α and CP

Deflection of trailing edge flaps increase the lift at constant geometric AoA, It will also move the CP rearwards and increase both parasite and induced drag.

Here follow a few examples of some main types of flaps and their approximate increase in C_L. *Fig. PF 6.6.*

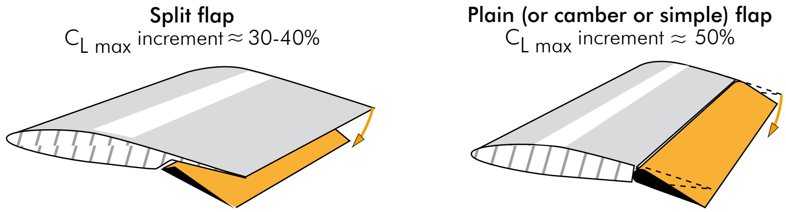


Fig. PF 6.6 Split flaps and plain flap

To improve the efficiency of the flaps, air can be accelerated through the **slot** between the wing and the flaps which makes the boundary layer above the flap more effective. *Fig. PF 6.7.*

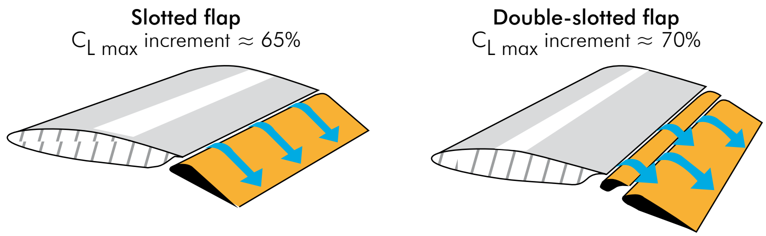


Fig. PF 6.7 Slotted flaps

Another type of flap is the **fowler** flap, which is designed to **move backwards to increase the total wing area.** When being moved backwards it also **moves downwards to increase the camber,** and finally it is **slotted** to increase the efficiency of the boundary layer. It can also be double-slotted or triple-slotted *Fig. PF 6.8.*

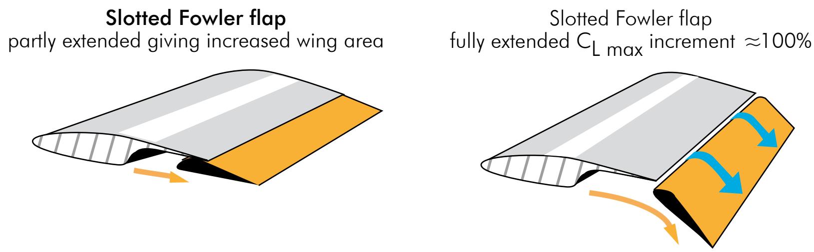


Fig. PF 6.8 Slotted Fowler flap

FOWLER FLAPS are first extended rearwards then deflected downwards which increases the wing surface and the $C_{L\ max}$. The effect of increased wing surface is taken into account in the C_L. So the S in the lift formula is always the clean wing surface.

The design of high lift devices can differ a lot and so can their effect. In next figures you see tables with different types of trailing edge high lift devices. The stall AoA are measured from the trailing edge of the flaps, i.e. the effective AoA. *Fig. PF 6.9.*

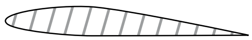
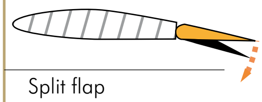
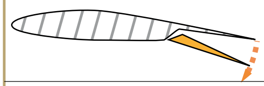
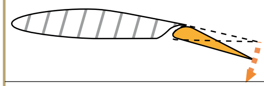
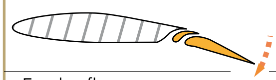
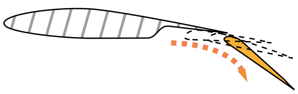
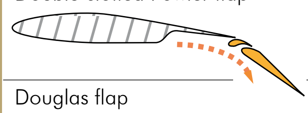
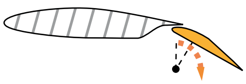
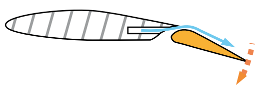
High-lift devices	Incr. of $C_{L\ max}$	a stall	Remarks
Basic airfoil 	-	15°	Effects of all high-lift devices depend on the shape of basic airfoil
Plain or camber flap 	50%	12°	Increased camber Much drag when fully lowered Nose-down pitching moment
Split flap 	30-40%	14°	Increased camber Even more drag than plain flap Nose-down pitching moment
Slotted flap 	65%	16°	Control of boundary layer. Increased camber. Stalling delayed Not so much drag
Double slotted flap 	70	18°	Same as single-slotted flap, only to a greater degree Triple slots sometimes used
Fowler flap 	90%	15°	Increased camber and wing area Best flaps for lift. Complicated mechanism. Nose-down pitching moment
Double-slotted Fowler flap 	100%	20°	Same as for Fowler flap, only to a greater degree Triple slots are sometimes used
Douglas flap 	-	-	Increased camber and wing area Rather simple mechanism Nose-down pitching moment
Blown flap 	80%	16°	Effects depend very much on details of arrangement

Fig. PF 6.9 Trailing edge flaps

Note: since the effects of the devices depend upon the shape of the basic aerfoil, and the exact design of the devices themselves, **the values given can only be considered as approximations.** To simplify the diagram the aerofoils and the flaps have only small angles, and not the angles giving maximum lift. The given nose-up or nose-down moment is only valid for the isolated wing, not for the whole aircraft which depends on the aircraft configuration. Stall AoA are in these tables the effective AoA. (Normally in this book, AoA is measured to the chord line from the trailing edge of the ordinary wing to the leading edge).

The lift/drag ratio can be changed very effectively by means of the flaps. Small flap deflections increases the margin to stall with only a moderate increase in drag, whiles greater flap setting is set to increase the drag. *Fig. PF 6.10.*

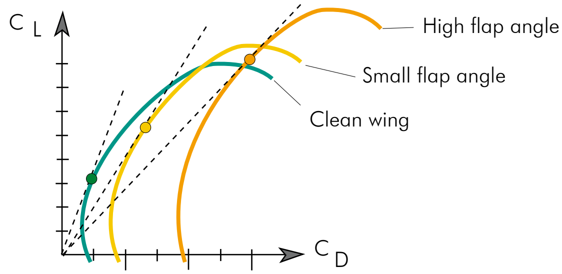


Fig. PF 6.10 Example of AoA that gives the highest L/D for different flap settings

Small flap deflections are therefore often used **during take-off and during approaches for landing.** The effect of flap deflection also increases the ground effect.

Small flap deflections are often used to increase the margin to stall with only a minor increment in drag.

With any flap extension, the increase in drag is always greater than the increase in lift. The greater the extension the worse L/D ratio you get. This full deflection of flaps is therefore normally used from final approach down to landing to allow a rather steep descent while maintaining low speed. *Fig. PF 6.11.*

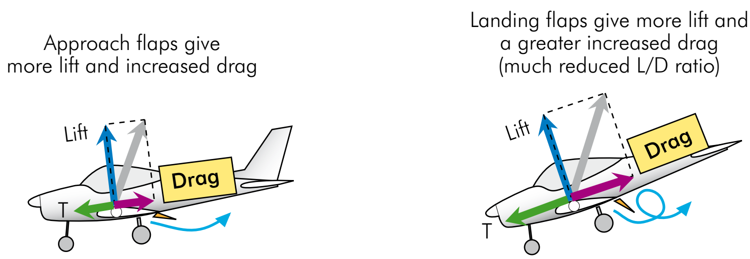


Fig. PF 6.11 Flap-settings and drag