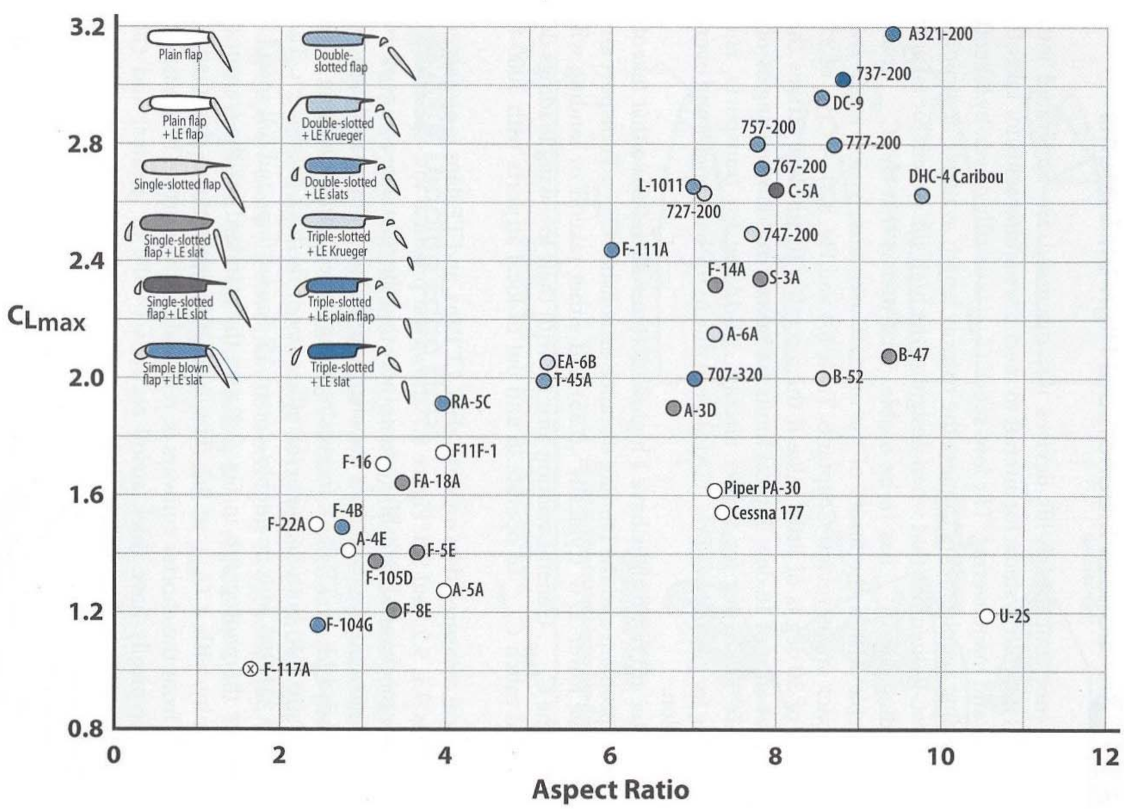
5.3.3 Takeoff Distance

In Raymer Fig. 5.4 the curves for propeller aircraft are for constant speed (i.e. variable pitch) propellers. Variable pitch propellers are able to change the propeller pitch as a function of aircraft speed. For fixed pitch propellers the selected pitch is usually optimized for climb so they operate at off-design condition at takeoff resulting in a much lower efficiency. These curves are therefore invalid for fixed pitch props. The units on the horizontal axis may be confusing. *T/W* and *BHP/W* are not numerically equal, but the propeller curves have been adjusted for the numerical values for *BHP/W*, and the jet values apply to the numerical values of *T/W*. If you try to calculate the equivalent thrust for a propeller-driven aircraft and then use the *T/W* scale, you will get the wrong answer.

The curves in Fig. 5.4 for jet aircraft represent FAR takeoff field length. This value is the greater of the balanced field length and factored all-engine takeoff field length. As Raymer states on page 129 these two values may, or may not, be the same, depending on whether the balanced field length is greater than the all-engine takeoff to 35 feet factored by 1.15.

To plot the takeoff constraint on a *T/W* vs. *W/S* plot, Eq. (5.9) must be modified to express *T/W* as a function of *W/S*.



Source: Nicolai & Carichner – Aircraft Design

Fig. 5.3.3.1 Typical Values of $C_{L_{max}}$

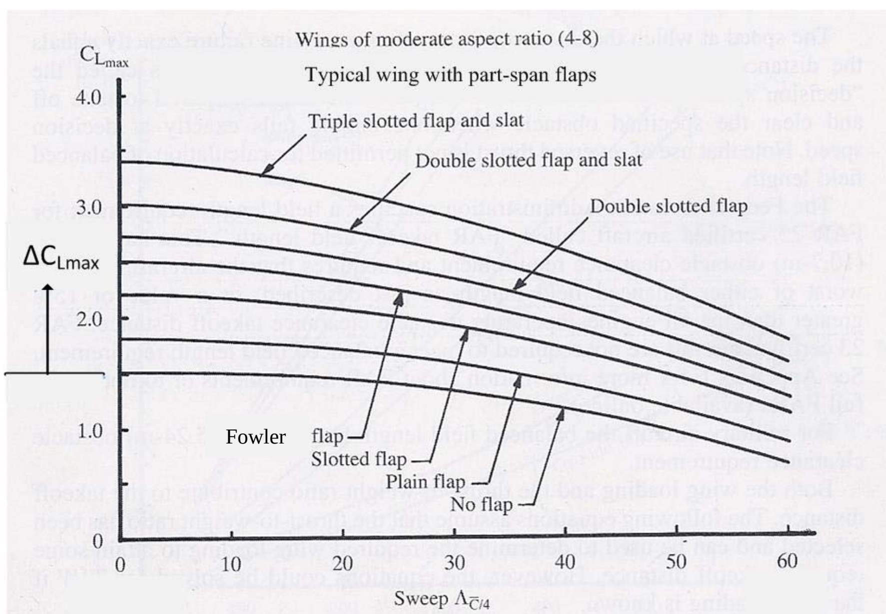
The rearranged form of Raymer Eq. 5.9 is

$$\left(\frac{T}{W}\right)_{ref} = \frac{\left(\frac{W}{S}\right)_{ref}}{TOP\,\sigma\,C_{L_{TO}}} \qquad (5.3.3.1)$$

The value of TOP is obtained from Raymer Fig. 5.4 for a given required takeoff field length and class of aircraft. For FAR takeoff lines, $C_{L_{TO}} = (C_{L_{max}})_{TO}$, as Raymer explains on page 131.

The choice of flap system is beyond the conceptual design stage, and requires detailed performance and weight tradeoffs, as mentioned in the Annotation to Section 5.3.2. At this stage, it is best to select a flap system that is the same as that used on competitive aircraft.

Typical values of $(C_{L_{max}})_{Land}$ are shown in Fig. 5.3.3.1. Raymer suggests that $(C_{L_{max}})_{TO}$ is 80% of $(C_{L_{max}})_{Land}$.



Source: Raymer

Fig. 5.3.3.2 $C_{L_{max}}$ for Typical Wing with Part-span Flaps

Using data from Torenbeek, a slightly more refined method is to assume that:

$$(\Delta C_{L_{max}})_{TO} = 0.55\,(\Delta C_{L_{max}})_{Land}$$

(Ref. 5.3.3.1, Fig. 7.24). To take a simplistic example for an unswept wing (although typically an aircraft with this flap configuration will have a swept wing) with tripleslotted flap and slat, from Raymer Fig. 5.3 (shown above), we see that in the clean (no flap) conditions

$$(C_{L_{max}})_{No\ flap} = 1.5$$

And with flaps set in the landing condition

$$(C_{L_{max}})_{Land} = 3.4$$

The increase in maximum lift coefficient due to landing flaps is therefore given by:

$$(\Delta C_{L_{max}})_{Land} = 3.4 - 1.5 = 1.9$$

so $(\Delta C_{L_{max}})_{TO} = 0.55 \times 1.9 = 1.05$

then $(C_{L_{max}})_{TO} = (C_{L_{max}})_{No\ flap} + (\Delta C_{L_{max}})_{TO} = 1.5 + 1.05 = 2.55$

This yields a slightly lower value of $(C_{L_{max}})_{TO}$ than Raymer's suggestion does.

A more detailed calculation of maximum lift with high lift devices is given in Raymer Section 12.4.6.

References:

5.3.3.1 Torenbeek, E., "Synthesis of Subsonic Airplane Design", Delft University Press, 1976