Schaufele Annotations
Chapter 8 Engine Sizing and Arrangement

Engine Size for Takeoff Field Length

The procedure in this section is to find the required engine size to meet a given takeoff field length (TOFL) requirement. Often this will be defined in terms of $(T/W)_{ref} = T_{static}/W$, where T_{static} is installed sea level static (SLS) thrust with all engines operating.

From Figure 8.4, for a given TOFL the required Takeoff Parameter (TOP) can be determined.

The Takeoff Parameter in this figure is defined as:

$$TOP = \frac{W^2}{\sigma S\, T C_{L_{max_{TO}}}}$$

where T is thrust at $0.7\ V_{TO}$.

Rearrange this equation as

$$\left(\frac{T}{W}\right)_{0.7\ V_{TO}} = \frac{W}{S}\frac{1}{TOP\ \sigma C_{L_{max_{TO}}}}$$

You can solve this equation for known values of

TOP (determined from the figure), $\frac{W}{S}$, σ and $C_{L_{max_{TO}}}$.

In this exercise, obtain W from Chapter 3, S from Chapter 4, $C_{L_{max_{TO}}}$ from Fig 4.4 and σ from the required conditions.

However, reference thrust is for installed SLS conditions, so a correction is required.

Find $\frac{T_{0.7\ V_{TO}}}{T_{static}}$ for a given bypass ratio using Fig 8.5

$$C_{L_{max_{TO}}} = \frac{L}{\frac{1}{2}\rho V_{stall_{TO}}^2 S}$$

$$\text{so } V_{stall_{TO}} = \sqrt{\frac{2}{\rho C_{L_{max_{TO}}}}\frac{W}{S}}$$

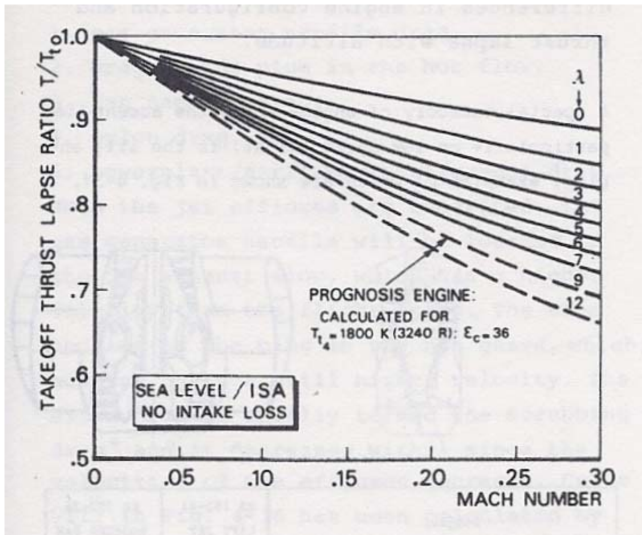
$$V_{TO} = 1.2\ V_{stall_{TO}} = 1.2\sqrt{\frac{2}{\rho C_{L_{max_{TO}}}}\frac{W}{S}}$$

$$\text{So } 0.7\ V_{TO} = 0.84\sqrt{\frac{2}{\rho C_{L_{max_{TO}}}}\frac{W}{S}}$$

The speed of sound can be found from Figure 1-9 and hence the appropriate value of M to enter Fig 8-5 from which you can find $\frac{T_{0.7\ V_{TO}}}{T_{static}}$

$$\text{Then } \left(\frac{T}{W}\right)_{ref} = \left(\frac{T}{W}\right)_{0.7\ V_{TO}}\frac{T_{static}}{T_{0.7\ V_{TO}}}$$

Schaufele Fig 8-6 shows that when the Mach number is zero the value of Thrust/T_{static} is about 97%. That suggests that the static thrust as defined in this figure is the uninstalled static thrust. The value of reference thrust in all calculations in this book is installed static thrust. All curves in the figure should have a value of 1.0 when the Mach number is zero. Figure 8.1 is a better representation of thrust as a function of Mach number and bypass ratio (λ in this figure) for which the reference thrust is the installed static thrust.



Source: Torenbeek

Figure 8.1 Takeoff Thrust Ratio

Engine Size for Operational Rate of Climb

Schaufele assumes that at the top of climb the aircraft is flying at its cruise speed, and cruise L/D. In equations (8-6) and (8-10), use the cruise L/D that you have estimated (using Fig. 3-8, 3-9 or other method). It must be assumed that values of cruise L/D in Fig. 3-8 and 3-9 are at $(M*L/D)_{max}$.

Selection of Thrust/Weight Ratio

Select the greater of the values of thrust/weight for the three conditions:

- Takeoff Field Length
- Operational Rate of Climb
- Initial Cruise

The value of $(T/W)_{SLS}$ should be somewhere between 0.25 and 0.35 (thrust is the thrust of all engines at sea level static condition, installed, and weight is the maximum takeoff gross weight).