6.3.3 Empty Weight Fraction

In Raymer Table 6.1, the Jet Transport coefficients appear to correlate most closely with the manufacturer's empty weight (MEW, or W_{me}) for aircraft with aluminum primary structure. If the airframe structure is to use a significant amount of composites, then the MEW must be factored by the appropriate value to account for it.

For business jets and commercial aircraft, empty weight matching is based on operating empty weight (OEW), so that

$$W_0 = W_{oe} + W_{fuel} + W_{payload} \tag{6.3.3.1}$$

From data in Schaufele (Ref. 6.3.3.1), Chapter 10, the following can be estimated

- shorter range (transcontinental) aircraft:
  $W_{oe} = 1.05\ W_{me}$
- longer range (intercontinental) aircraft:
  $W_{oe} = 1.06\ W_{me}$

It should also be noted that when the mission profile is defined by NBAA or FAR Part 121 requirements, Raymer Equation (6.2) is not used.

Raymer Equation (6.8) is given as

$$\frac{W_i}{W_{i-1}} = 0.97 - 0.99$$

The lower value should be used for turbojet-powered aircraft, and the higher value for high bypass ratio turbofan-powered aircraft.

Raymer Equation (6.10) shows an approximation for estimating the weight ratio for supersonic acceleration. A more accurate method is described in Sections 17.6.5 and 19.3.4. This method requires that the climb segment be broken down into several smaller segments, and is more amenable to computer analysis.

Raymer Equation (6.13) contains several variables that will not be evaluated until later in the design process. The utility of the equation at this stage is therefore questionable. It can be derived from:

$$\frac{L}{D} = \frac{C_L}{C_D} = \frac{C_L}{C_{D_0} + K C_L^2} = \frac{1}{\frac{C_{D_0}}{C_L} + K C_L} \tag{6.3.3.2}$$

The induced drag factor K is defined as

$$K = \frac{1}{\pi A e}$$

where A = Aspect ratio
e = Oswald efficiency factor (see Raymer Section 12.6.1 and Annotation)

We can then substitute

$$C_L = \frac{n}{q}\left(\frac{W}{S}\right) \quad \text{where } n = 1 \text{ for cruise} \qquad (6.3.3.3)$$

As a first estimate for C_{D_0}, it can be assumed that

$$C_{D_0} = C_{fe}\left(\frac{S_{wet}}{S_{ref}}\right) \qquad (6.3.3.4)$$

using an appropriate value of C_{fe} from Raymer page 430.

Raymer Equation (6.13) is valid for a specified value of dynamic pressure, q. Unfortunately the optimum value of q is not known at this stage because it is based on maximizing the term $\frac{V}{C}\left(\frac{L}{D}\right)$ in the Breguet range equation. The planned value of speed and altitude at mid-cruise will have to be used.

References

6.3.3.1 Schaufele, R.D., "The Elements of Aircraft Preliminary Design", Aries Publications, 2007.