Preliminary Estimates

1 Aerodynamics

1.1 Maximum coefficient of lift ($C_{L,max}$)

$C_{L,max}$ is important in constraint analysis during takeoff and landing.
For fighter aircraft:

1. Clean wing: between 1.0 and 1.2
2. Wing with a leading edge slat: between 1.2 and 1.6

For cargo and passenger aircraft:

High Lift Device		Typical Flap Angle (deg)		$C_{Lmax}/\cos(\Lambda_{c/4})$	
Trailing	**Leading Edge**	**Takeoff**	**Landing**	**Takeoff**	**Landing**
Plain	--	20	60	1.4-1.6	1.7-2.0
Single Slot	--	20	40	1.5-1.7	1.8-2.2
Fowler	--	15	40	2.0-2.2	2.5-2.9
Double slotted	--	20	50	1.7-2.0	2.3-2.7
Double slotted	slat	20	50	2.3-2.6	2.8-3.2
Triple slotted	slat	20	40	2.4-2.7	3.2-3.5

Figure 1: Clmax table

1.2 Lift-Drag Polar Estimation

Three main equations for lift-drag polar estimation are:

$$K_1 = K' + K'' \tag{1}$$

$$C_{D_0} = C_{D_{\min}} + K''C_{L_{\min}}^2 \tag{2}$$

$$K_2 = -2K''C_{L_{\min}} \tag{3}$$

For most large cargo and passenger aircraft:

$$0.001 \le K'' \le 0.03 \tag{4}$$

$$0.1 \le C_{L_{\min}} \le 0.3 \tag{5}$$

$$K' = \frac{1}{\pi A R e} \tag{6}$$

Here e is the **wing planform efficiency factor**, is a coefficient that reflects the aerodynamic efficiency of a wing's planform shape, the value is usually between 0.75 and 0.85. AR is the wing aspect ratio, usually between 7 and 10.

Some estimated values:

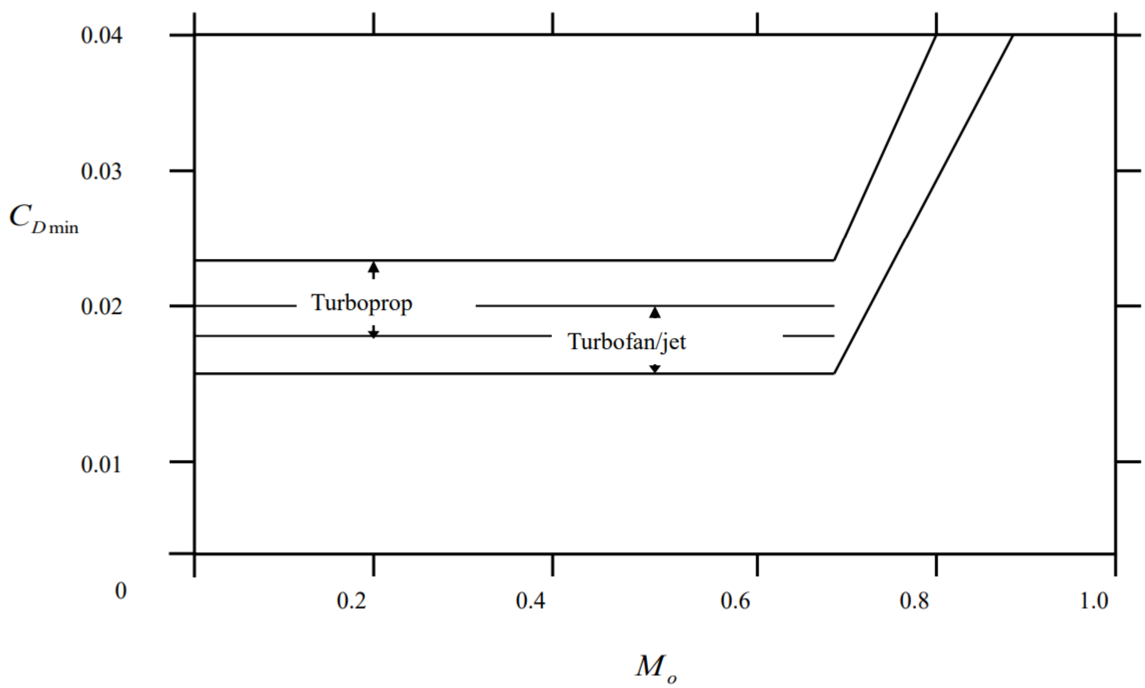

Figure 2: CDmin for Cargo and Passenger Aircraft

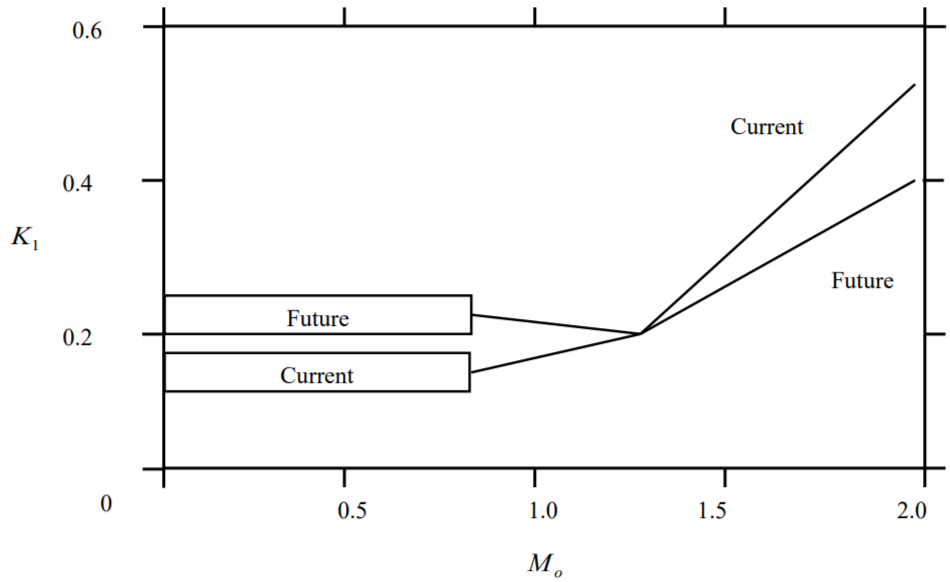

Figure 3: K1 for Fighter Aircraft

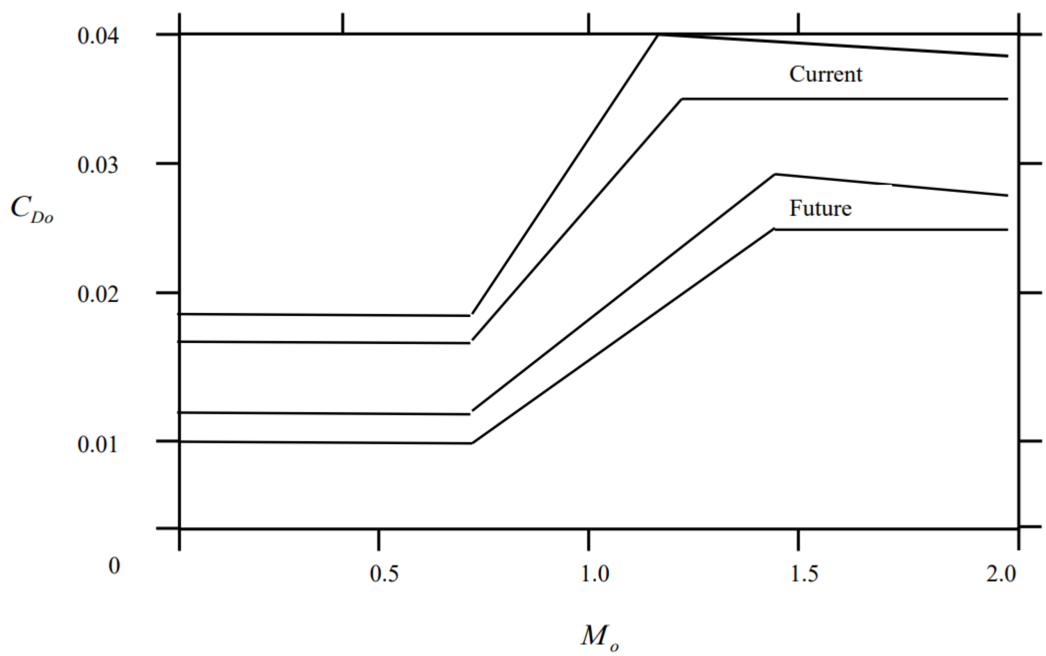

Figure 4: CD0 for Fighter Aircraft

2 Propulsion

Recall the definition of thrust lapse rate:

$$T = \alpha T_{SL} \tag{7}$$

And the density ratio definition:

$$\frac{\rho}{\rho_0} = \sigma \tag{8}$$

For a high bypass ratio turbofan engine ($M < 0.9$):

$$\alpha = \left\{0.568 + 0.25(1.2 - M)^3\right\} \sigma^{0.6} \tag{9}$$

For a low-bypass ratio mixed turbofan engine with afterburner:

$$\alpha \approx \alpha_{\text{mil}} = 0.72 \left\{0.88 + 0.245(|M - 0.6|)^{1.4}\right\} \sigma^{0.7} \tag{10}$$

$$\alpha_{\text{wet}} \approx \alpha_{\text{max}} = \left\{0.94 + 0.38(M - 0.4)^2\right\} \sigma^{0.7} \tag{11}$$

For an advanced turbojet with afterburning:

$$\alpha_{\text{dry}} = \alpha_{\text{mil}} = 0.76 \left\{0.907 + 0.262(|M - 0.5|)^{1.5}\right\} \sigma^{0.7} \tag{12}$$

$$a_{\text{wet}} = a_{\text{max}} = \left\{0.952 + 0.3(M - 0.4)^2\right\} \sigma^{0.7} \tag{13}$$

For an advanced turboprop, if $M \leq 0.1$:

$$a = \sqrt{\sigma} \tag{14}$$

if $0.1 < M < 0.8$:

$$a = \frac{0.12}{M + 0.02}\sqrt{\sigma} \tag{15}$$