

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: C_{Lmax} table

1.2 Lift-Drag Polar Estimation

Three main equations for lift-drag polar estimation are:

$$K_1 = K' + K'' \quad (1)$$

$$C_{D_0} = C_{D_{min}} + K'' C_{L_{min}}^2 \quad (2)$$

$$K_2 = -2K''C_{L_{\min}} \quad (3)$$

For most large cargo and passenger aircraft:

$$0.001 \leq K'' \leq 0.03 \quad (4)$$

$$0.1 \leq C_{L_{\min}} \leq 0.3 \quad (5)$$

$$K' = \frac{1}{\pi A R e} \quad (6)$$

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:

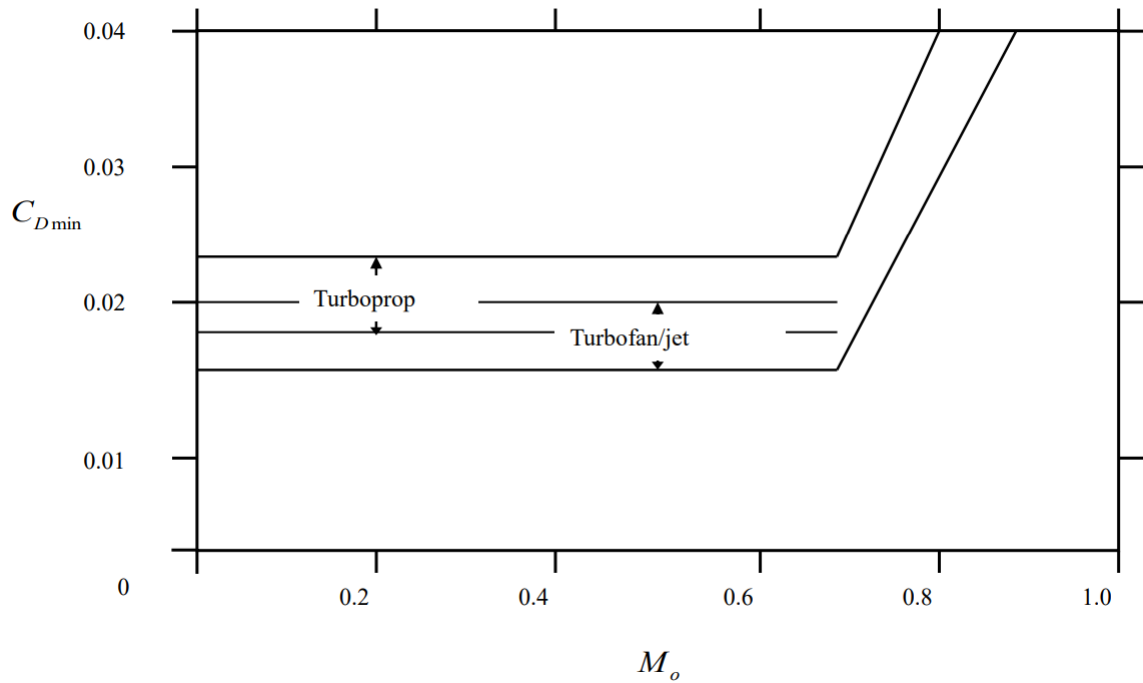


Figure 2: $C_{D_{\min}}$ for Cargo and Passenger Aircraft

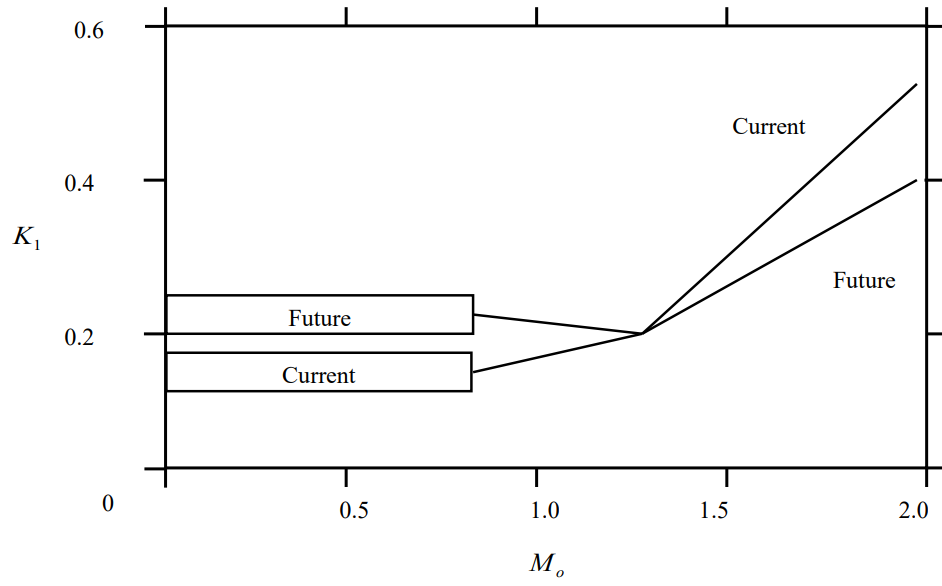


Figure 3: K1 for Fighter Aircraft

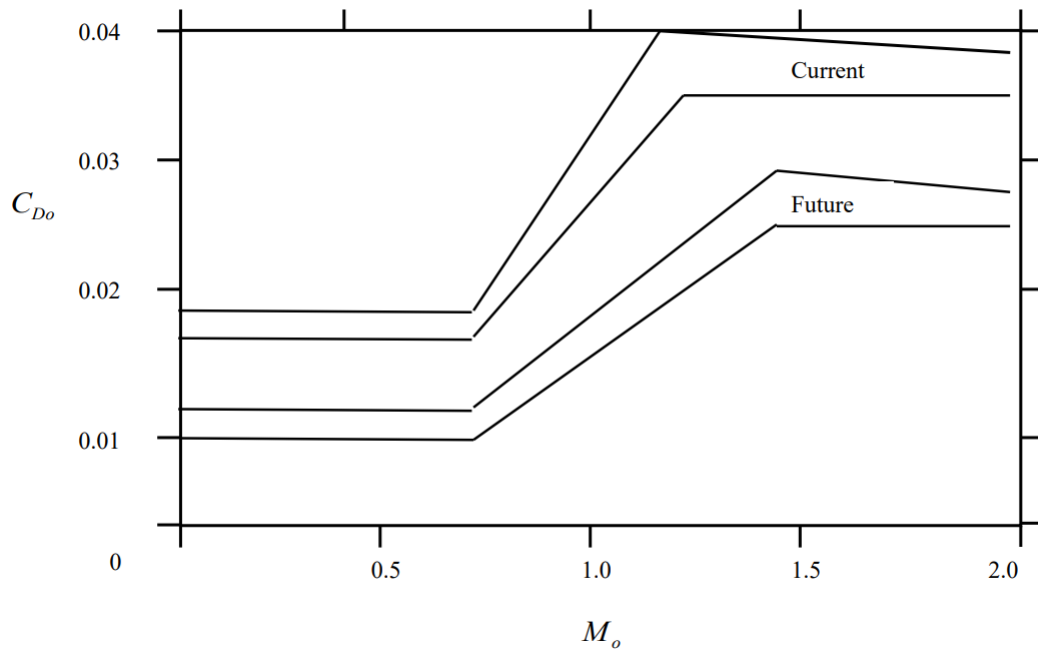


Figure 4: CD0 for Fighter Aircraft

2 Propulsion

Recall the definition of thrust lapse rate:

$$T = \alpha T_{SL} \quad (7)$$

And the density ratio definition:

$$\frac{\rho}{\rho_0} = \sigma \quad (8)$$

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

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

For a low-bypass ratio mixed turbofan engine with afterburner (wet: with afterburner, dry: without afterburner):

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

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

For an advanced turbojet with afterburning:

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

$$\alpha_{\text{wet}} = \alpha_{\text{max}} = \{0.952 + 0.3(M - 0.4)^2\} \sigma^{0.7} \quad (13)$$

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

$$\alpha = \sqrt{\sigma} \quad (14)$$

if $0.1 < M < 0.8$:

$$\alpha = \frac{0.12}{M + 0.02} \sqrt{\sigma} \quad (15)$$