12.5 Parasite (Zero-Lift) Drag

Equivalent Skin Friction Method

The values of equivalent skin friction coefficient for different classes of aircraft (Raymer Table 12.3) may be used to estimate the *L/D* of a conceptual design based only on total wetted area and wing span, as described in the annotations to Section 3.4.

Component Buildup Method

The zero-lift drag of an aircraft is defined as:

$$C_{D_0} = \frac{D}{q\,S_{ref}} \tag{12.5.1}$$

where D is the total zero-lift drag of the aircraft, q is the dynamic pressure, and S_{ref} is the wing reference area, which is usually (except at Boeing) taken as the gross area of a trapezoid that most closely represents the wing (as described in Fig. 14.5). Boeing uses a wing reference area called the Wimpress area, which includes other parts of the wing planform that contribute to lift. Wing reference area has no particular aerodynamic significance apart from being a reference area that all aerodynamicists working on a project can (with luck) agree upon to use as a reference.

This equation may also be written as

$$C_{D_0} = \sum_{comp} \left(\frac{D_c}{q} \right) \frac{1}{S_{ref}} \tag{12.5.2}$$

where the summation sign indicates the summation of the values of D/q for all components of the aircraft including interference effects, and D_c is the drag of an individual component. The term D/q is often called the equivalent flat plate area, because the term has the units of square feet (or square meters) and is numerically roughly equal to the drag of a flat plate which is held normal to the flow.

One of the biggest difficulties that students encounter when accumulating the drag of aircraft components is in converting the drag coefficients of the components (for which the reference area is either wetted area or cross-sectional area) into drag coefficients referenced to the wing. It may be easier to convert the drag of all components into D/q format, sum them, and then divide by the wing reference area, and this procedure will be described here.

Aircraft components may be broken down into three categories, which are defined in the three terms of Eq. (12.24). These are

- Components that are streamlined for which the reference area is usually the wetted area of the component.

- Components that are bluff (such as landing gear or circular rigging wires) for which the reference area is usually the frontal (or maximum cross sectional) area.
- Other drag effects, such as leakage and protuberances, which may be expressed as a percentage of the total drag of the aircraft.

Skin friction coefficient is defined as

$$C_f = \frac{D}{q\,S_{wet}} \tag{12.5.4}$$

So in the first term of Eq. 12.24, the numerator is

$$\sum \left(C_{f_c}\, FF\, Q_C\, S_{wet_C} \right) = \sum \left(\frac{D_c}{q} \right) \tag{12.5.5}$$

which contains appropriate corrections to C_f to account for form factors and interference. So the first term is effectively summing *D/q* for all streamlined components and dividing by the wing reference area.

The second term is also the summation of all *D/q* for bluff components (although no summation sign is shown in Eq. 12.24) divided by wing reference area. To find the value of *D/q* for any component, an aerodynamicist will turn to his copy of Hoerner, which is undoubtedly sitting on his desk, or in a bookshelf within arm's reach. There he will be able to find the value of drag coefficient of pretty much any kind of body. The drag coefficient is multiplied by the reference area of the component on the aircraft being designed (usually the frontal area for a bluff component) to find the value of *D/q* for the particular component using the formula:

$$\left(\frac{D}{q} \right)_{comp} = C_{D_{comp}}\, S_{frontal} \tag{12.5.6}$$

In Table 12.5 Raymer lists some values of drag coefficient of bodies in terms of *(D/q)*/(frontal area). So if there is a collection of components that have no significant interference effects, the values of *D/q* for each component may easily be found (assuming the frontal area is known), and then summed directly. Note that in Table 12.5 for a "Round strut or wire" the value of *D/q* is for supercritical (i.e. turbulent) flow. If the airplane cruise speed is low and the wire diameter is small the flow around the wire could be subcritical, in which the value of *D/q* would be about 1.17 according to Hoerner. The transition Reynolds Number for circular wires is about 3×10^5 (Hoerner 3-9 Fig 12).

In Table 12.5.1 the values of *D/q* for streamlined components are calculated using Eq. (12.5.5). Use the mean aerodynamic chord (MAC) for lifting surfaces and the overall length (OAL) for non-lifting surfaces. The values of *D/q* for bluff components are calculated using Eq. (12.5.6). These values are all summed, factored by leakage and protuberance drag factor, and then divided by the wing reference area. A table such as this may be set up in a few minutes in Excel and then populated with the appropriate values or formulae to find the value of C_{D_o}. Notations in italics are either values or equations.

Streamlined Components	S_{wet}	Length	Re	Cf	FF	Q	D/q	C_D
Wing		*MAC*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.30)*	*See p. 332*		
Horiz Tail		*MAC*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.30)*	*See p. 332*		
Vert Tail		*MAC*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.30)*	*See p. 332*		
Fuselage		*OAL*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.31)*	*See p. 332*		
Nacelles		*OAL*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.32)*	*See p. 332*		
Pylons		*OAL*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.30)*	*See p. 332*		
Ext. tanks		*OAL*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.32)*	*See p. 332*		
Weapons		*OAL*	*Eq. (12.26)*	*Eq. (12.27)*	*Eq. (12.32)*	*See p. 332*		
$\sum(D/q)_{smooth}$								
Bluff Components	$S_{frontal}$						D/q	C_{Dcomp}
(Flaps)								
(Wheels)								
(Struts)								
$\sum(D/q)_{bluff}$								
Leak & Prot								%
Wing S_{ref}								
C_{D0}								

Table 12.5.1 Zero-Lift Drag Buildup