

ESDU Bodies S.02.03.08

FOREBODY-AFTERBODY INTERFERENCE WAVE DRAG OF SIMPLE POINTED OR DUCTED BODY SHAPES WITH SHORT MIDBODIES

1. NOTATION AND UNITS

		SI	British
C_{Dw}	wave drag coefficient based on body maximum cross-sectional area πR_1^2		
l_a	afterbody length	m	ft
l_f	forebody length	m	ft
l_m	midbody length	m	ft
M	free-stream Mach number		
R_1	radius of maximum cross section of body or equivalent radius of non-circular body	m	ft
S_0	nose area of forebody and base area of afterbody	m ²	ft ²
S_1	maximum cross-sectional area of body	m ²	ft ²
<i>Subscripts</i>			
a	denotes afterbody		
f	denotes forebody		
i	denotes interference		

2. NOTES

When an afterbody is preceded by a short midbody the disturbance to the flow due to the forebody causes a significant increase in the wave drag of the afterbody as compared with the wave drag of the same afterbody behind an infinitely long midbody. Figures 1 to 4 give the interference wave drag coefficients, which are additive to the other calculated components of drag coefficient, for a number of simple body shapes with short midbodies.

Figure 1 gives C_{Dwi} for pointed conical forebodies and afterbodies joined by midbodies. Figure 2 gives C_{Dwi} for ducted conical forebodies and afterbodies joined by a midbody for the particular case when $l_f = l_a$ and the areas, S_0 , of the nose of the forebody and the base of the afterbody are equal. Sets of curves are plotted for $S_0/S_1 = 0.2, 0.4$ and 0.6 . Figure 3 gives C_{Dwi} for pointed parabolic forebodies and afterbodies joined by midbodies and Figure 4 gives C_{Dwi} for a truncated parabolic afterbody behind a pointed parabolic forebody (no midbody).

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The Figures are obtained by the use of slender-body theory (Derivation 1) in which it is assumed that the slope of the surface of the body in an axial plane is small and the external flow over the body is everywhere supersonic. It should be noted that according to this theory, the interference wave drag coefficient is independent of Mach number for a body having no discontinuity in surface slope (Figures 3 and 4).

Item No. Aero B.S.02.03.02 (incorporating B.S. 02.03.03 to 05) gives the wave drag coefficients for pointed or ducted, conical or parabolic forebodies, together with similar data for pointed or truncated, conical or parabolic afterbodies behind infinitely long midbodies.

The equivalent radius of a non-circular body may be obtained by equating πR_1^2 to the maximum cross-sectional area.

3. DERIVATION

The Derivation lists selected sources that have assisted in the preparation of this Item.

1. FRAENKEL, L.E. The theoretical wave drag of some bodies of revolution. ARC R & M 2842, 1951.

4. EXAMPLE

Find the total wave drag coefficient at a Mach number of 2.0 for a body of revolution having pointed ends of parabolic profile for which $l_f = 1.5$ m, $l_m = 1.5$ m, $l_a = 3$ m and $R_1 = 0.3$ m.

From the given, $\frac{(M^2 - 1)^{1/2}}{l_f / R_1} = 0.346$.

From Item No. Aero B.S.02.03.02 for the pointed parabolic forebody with $(M^2 - 1)^{1/2} / (l_f / R_1) = 0.346$, the forebody wave drag coefficient $C_{Dwf} = 0.137$.

Similarly, for the pointed parabolic afterbody with $l_a / R_1 = 10$, the afterbody wave drag coefficient $C_{Dwa} = 0.047$.

From Figure 3 of this Item with $l_f / l_a = l_m / l_a = 0.5$, the interference wave drag coefficient is given by

$$C_{Dwi}(l_a / R_1)^2 = 0.67$$

Thus
$$C_{Dwi} = 0.67 / (3 / 0.3)^2 = 0.0067.$$

Hence the total wave drag coefficient is given by

$$\begin{aligned} C_{Dw} &= C_{Dwf} + C_{Dwa} + C_{Dwi} \\ &= 0.137 + 0.047 + 0.007 \\ &= 0.191. \end{aligned}$$