

WAVE DRAG OF FLAT PLATES WITH BLUNT NOSES AT ZERO INCIDENCE

1. NOTATION AND UNITS

		SI	British
b	plate span	m	ft
C_{Dw}	wave drag coefficient of nose based on thickness t_n , defined as $\frac{1}{\frac{1}{2}\gamma p_1 M_1^2 t_n} 2 \int_0^{t_n/2} (p - p_1) dy$		
l	length of nose	m	ft
M_1	free-stream Mach number		
p	static pressure at point defined by ordinate y on nose surface	N/m ²	lbf/ft ²
p_1	free-stream static pressure	N/m ²	lbf/ft ²
t_n	maximum thickness of nose, assumed elliptical in shape	m	ft
y	thickness ordinate of nose measured from centre-line	m	ft
γ	ratio of specific heat capacities, taken as 1.4 for air		

2. NOTES

Figure 1 gives the wave drag coefficients at zero incidence for two-dimensional parallel-sided sections with leading edges of elliptical shape. The profiles considered are those whose leading-edge section is formed by a semi-ellipse, the axis of symmetry being parallel to the free-stream direction. The leading-edge shapes include sections with a flat leading edge and sections with a semi-circular leading edge, which are the special cases of the elliptical section when $l/t_n = 0$ and 0.5 respectively.

The top curve in Figure 1 gives the maximum possible drag of a blunt-nosed section calculated on the assumption that the pressure over the nose is everywhere equal to the stagnation pressure behind a normal shock wave. The curve for the flat leading-edge section is obtained theoretically in Derivation 1. Experimental results given in Derivation 3 for a limited Mach number range agree closely with this curve. For the semi-circular leading edge the curve is obtained from the experimental data of Derivations 2, 3 and 4. On the basis of this curve and the theoretical maximum curve, the limited data given in Derivation 3 for the other leading-edge profiles have been extrapolated empirically to cover a wider range of Mach number. For the profiles with values l/t_n greater than 1 it is not possible to indicate reliable extrapolation beyond a Mach number of 2.

The parts of the curves shown as full lines are based on the experimental results while the curves extrapolated to higher Mach numbers are shown dotted.

The scatter of the experimental data is within ± 10 per cent of the appropriate full line curve.

ESDU Wings S.02.03.10

It must be emphasised that this Item is not intended to be used for the estimation of the wave drag of blunt noses of two-dimensional aerofoil sections and indeed, in general, would give incorrect answers if used in this way.

3. DERIVATION

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

- | | | |
|----|------------------------------|---|
| 1. | MACCOLL, J.W.
Codd, J. | Theoretical investigations of the flow around various bodies in the sonic region of velocities. ARC Rep. 9315, 1945. |
| 2. | GOWEN, F.E.
PERKINS, E.W. | Drag of circular cylinders for a wide range of Reynolds numbers and Mach numbers. NACA tech. Note 2960, 1952. |
| 3. | HOLDER, D.W.
CHINNECK, A. | The flow past elliptic-nosed cylinders and bodies of revolution in supersonic air streams. <i>Aeronaut. Q.</i> , Vol. IV, Part 4, 1954. |
| 4. | NPL | Unpublished tests at the National Physical Laboratory. |

4. EXAMPLE

Find the wave drag at a free-stream Mach number of 1.75 and free-stream static pressure of $3.6 \times 10^4 \text{ N/m}^2$ of a flat plate 0.01 m thick and 0.6 m span having an elliptical leading-edge profile with $l/t_n = 4$.

From Figure 1 for

$$l/t_n = 4 \quad \text{and} \quad M_1 = 1.75$$
$$C_{Dw} = 0.595.$$

The wave drag is given by the equation

$$\begin{aligned} \text{wave drag} &= \frac{1}{2} \gamma p_1 M_1^2 t_n b C_{Dw} \\ &= \frac{1}{2} \times 1.4 \times 3.6 \times 10^4 \times (1.75)^2 \times 0.01 \times 0.6 \times 0.595 \\ &= 276 \text{ N}. \end{aligned}$$