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Foredrag of spherically-blunted conical forebodies at zero incidence in supersonic flow for Mach numbers up to 5

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FOREDRAG OF SPHERICALLY-BLUNTED CONICAL FOREBODIES AT ZERO INCIDENCE IN SUPERSONIC FLOW FOR MACH NUMBERS UP TO 5

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FOREDRAG OF SPHERICALLY-BLUNTED CONICAL FOREBODIES AT ZERO INCIDENCE IN SUPERSONIC FLOW FOR MACH NUMBERS UP TO 5

1. NOTATION AND UNITS

		SI	British
A	base area of cone, $\pi D^2/4$	m^2	ft^2
C_{DF}	foredrag coefficient, $(\text{foredrag})/(\frac{1}{2}\gamma p_1 M_1^2 A)$ (see Section 2)		
D	base diameter (see Sketch 1.1)	m	ft
d	diameter of cone at point of tangency with spherical blunting (see Sketch 1.1)	m	ft
l_f	forebody length (see Sketch 1.1)	m	ft
M_1	free-stream Mach number		
p_1	free-stream static pressure	N/m^2	lbf/ft^2
R	base radius	m	ft
R_{lf}	Reynolds number based on free-stream flow conditions and forebody length		
r_n	radius of nose blunting, $(d/2) \sec \delta$ (see Sketch 1.1)	m	ft
γ	ratio of specific heat capacity at constant pressure to specific heat capacity at constant volume, taken as 1.4 for air		
δ	cone semi-apex angle	deg	deg

1.1 Definitions of geometry

Sketch 1.1 illustrates the geometry of a spherically-blunted cone, which can be fully defined in terms of the fineness ratio, l_f/D , and the semi-apex angle, δ . The nose blunting ratio, d/D , is related to these parameters by

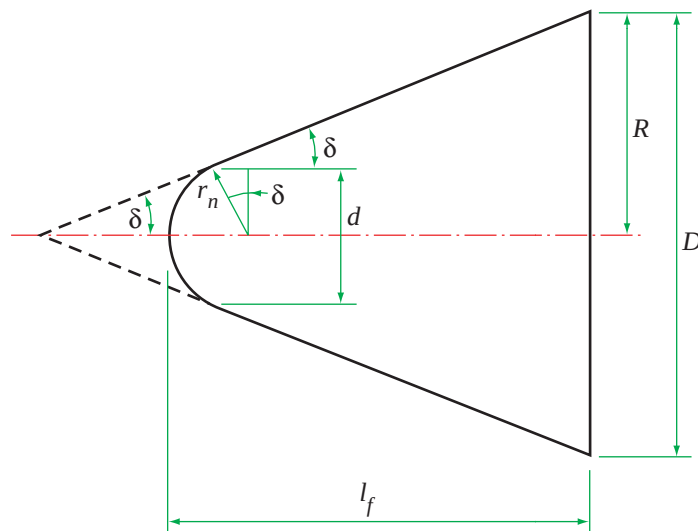
$$\frac{d}{D} = (1 + \sin \delta) \left(1 - 2 \frac{l_f}{D} \tan \delta \right). \quad (1.1)$$

Figure 1 presents a carpet giving l_f/D as a function of d/D and δ for the full blunting range from $d/D = 0$ (i.e. a sharp cone) to $d/D = 1$ (i.e. a spherically-curved face, which becomes a hemispherical forebody when $\delta = 0$).

Nose blunting can also be defined in terms of r_n/R (as used in Item No. 82028 (Reference 6)). The relationship between r_n/R and d/D is

$$\frac{r_n}{R} = \frac{d}{D} \sec \delta. \quad (1.2)$$

(Item No. 82028 gives a graphical presentation of r_n/R as a function of l_f/D and δ .)



Sketch 1.1 Geometry of spherically-blunted cone

2. INTRODUCTION

This Item provides a means of estimating the foredrag of spherically-blunted cones at zero incidence in supersonic flow over the Mach number range $1 \leq M_1 \leq 5$. In this Item “foredrag” is defined as the drag due to those parts of the body ahead of the base, *i.e.* it is the sum of the pressure drag and skin friction drag of the forebody. Item No. 82028 (Reference 6) is a companion Item giving the forebody pressure drag only, for Mach numbers of 3 and above, see Section 4.

3. FOREDRAG

Figures 2a to 2f present the foredrag coefficient, C_{DF} , for spherically-blunted cones at zero incidence as a function of M_1 and δ for a range of values of d/D . These Figures are based on correlations of experimental data from Derivations 1, 3 and 4 and theoretical data from Derivation 2. The broken lines in the Figures indicate areas in which data have been extrapolated or interpolated.

In Sketch 3.1 the foredrag coefficient is shown as a function of d/D for several values of l_f/D at $M_1 = 3$. The trends illustrated in Sketch 3.1 apply to any Mach number over the range covered by this Item. For constant values of l_f/D and M_1 a certain degree of blunting can result in a reduction in C_{DF} below the value for a sharp cone. The range of l_f/D over which blunting is not necessarily detrimental to C_{DF} decreases as M_1 increases. The reduction in drag is largely due to two factors affecting the pressure drag, the major contributor to foredrag. Firstly, with a small degree of blunting the over-expansion ahead of the junction between the nose blunting and the conical surface carries over to the conical surface. This region of negative pressure contributes a force on the conical surface in opposition to the drag due to the pressure distribution