



Effect of stabilising fins on base drag of cylindrical bodies at supersonic speeds

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EFFECT OF STABILISING FINS ON BASE DRAG OF CYLINDRICAL BODIES AT SUPERSONIC SPEEDS

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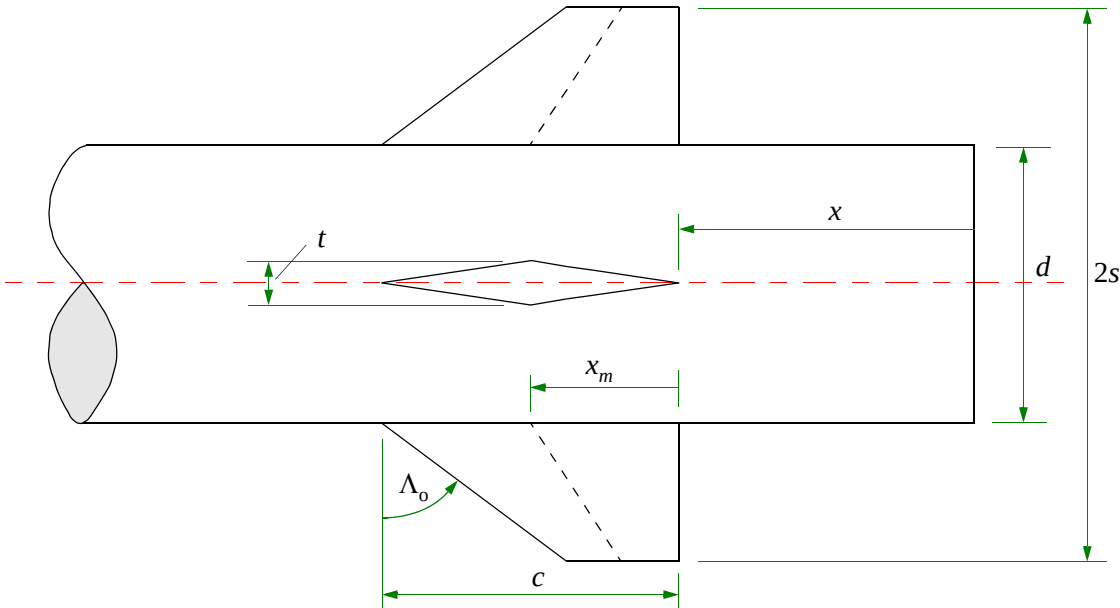
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EFFECT OF STABILISING FINS ON BASE DRAG OF CYLINDRICAL BODIES AT SUPERSONIC SPEEDS

1. NOTATION AND UNITS (see Sketch 1.1)

		SI	British
A	net fin aspect ratio, $2(2s-d)/(c(1+\lambda))$		
C_{Db}	base drag coefficient for body alone, based on S_b		
C_{DbF}	base drag coefficient for body in presence of fins, based on S_b		
ΔC_{Db}	increment in base drag coefficient due to presence of fins		
C_{pb}	base pressure coefficient for body alone		
C_{pbF}	base pressure coefficient for body in presence of fins		
ΔC_{pb}	increment in base pressure coefficient due to presence of fins		
c	fin root chord	m	ft
d	body diameter	m	ft
k	empirical factor in Equation (3.3)		
M	Mach number		
N_F	number of fins		
R	Reynolds number based on body length		
s	fin semi-span	m	ft
S_b	base area, $\pi d^2/4$	m ²	ft ²
t	fin maximum thickness at root chord	m	ft
x	distance of fin root trailing edge upstream of base	m	ft
x_m	distance of point of fin maximum thickness forward of root trailing edge	m	ft

β	$(M^2 - 1)^{1/2}$		
Λ_0	leading-edge sweep of fin	degree	degree
λ	fin taper ratio		



Sketch 1.1 Body geometry

2. INTRODUCTION

This Item provides a means of estimating the effect of stabilising fins on the (jet-off) base drag of axisymmetric cylindrical bodies at zero angle of attack at supersonic speeds ($M \geq 1.5$). The method provides an increment to the value for the base drag of the body alone at zero angle of attack which is obtained from Item No. 79022 (Reference 5).

The method, given in Section 3, is based on a simple theoretical model outlined in Appendix A, with an empirical factor to fit four sets of wind-tunnel tests reported in Derivations 1 to 4. The method requires that a sufficiently long cylindrical section of body exists upstream of the fins for forebody/fin interference effects to be negligible. Experience suggests that about three body diameters is sufficient. The method has been derived, principally, for bodies with either cruciform or planar fins, which may be located with their trailing edges flush with or upstream of the base. The method has, however, been presented in generalised form which allows estimates to be made for other fin arrangements, see Section 4.

The method is applicable at supersonic speeds for Mach numbers over the range 1.5 to 5 and requires that the boundary layer be fully turbulent. Details of the applicability of the method and a guide to its accuracy are given in Section 4. A worked example illustrating the application of the method is given in Section 6.

3. METHOD

The increment in base pressure of a cylindrical body due the addition of fins, whose trailing edges are flush with the base, is given by

$$\Delta C_{pb} = -\Delta C_{Db} = -\frac{N_F}{4\beta^2} \left(\frac{t}{d}\right) \quad \text{for} \quad \frac{x_m}{\beta} \leq d \quad (3.1)$$

and

$$\Delta C_{pb} = -\Delta C_{Db} = -\frac{N_F}{4\beta} \left(\frac{t}{x_m}\right) \quad \text{for} \quad \frac{x_m}{\beta} > d . \quad (3.2)$$

These semi-empirical equations originate from a comparison between the predictions of a simple, theoretical model, which considers a single fin in combination with a planar representation of the body, and wind-tunnel test data for bodies with two or four stabilising fins fitted flush with the base (Derivations 1 to 4), see Appendix A.

Derivations 2 and 4 provide base pressure data for bodies with fins mounted upstream of the base. To allow for the decreasing influence of the fins on the base pressure as they are located further from the base, an empirical factor k has been derived from the test data in terms of the correlating parameter $x/(\beta d)$, which models the effect of upstream location and Mach number. The factor varies from a value of unity for fins flush with the base, $x/(\beta d) = 0$, to a value of zero when the Mach line originating from the fin root trailing edge intercepts the far side of the body at or upstream of the base, i.e. $x \geq \beta d$. A reasonable representation of the data was obtained with the equation

$$k = (1 - x/(\beta d))^2 \quad \text{for} \quad 0 \leq \frac{x}{\beta} \leq d . \quad (3.3)$$

Equations (3.1) and (3.2) then become

$$\Delta C_{pb} = -\Delta C_{Db} = -\frac{kN_F}{4\beta^2} \left(\frac{t}{d}\right) \quad \text{for} \quad \frac{x_m}{\beta} \leq d \quad (3.4)$$

$$\text{and} \quad \Delta C_{pb} = -\Delta C_{Db} = -\frac{kN_F}{4\beta} \left(\frac{t}{x_m}\right) \quad \text{for} \quad \frac{x_m}{\beta} > d \quad (3.5)$$

to cater for fins upstream of the base.

To obtain the base pressure (or drag) coefficient for the fin/body combination the value for the increment in base pressure is added to the estimate for the body alone, i.e.

$$C_{pbF} = -C_{DbF} = C_{pb} + \Delta C_{pb} . \quad (3.6)$$

For convenience the relevant data for the body alone, taken from Item No. 79022, are presented in this Item in Figure 1 and have been extended to $M = 5$.