



Effect of angle of attack on base axial force and drag of cylindrical bodies with conical boat-tails

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EFFECT OF ANGLE OF ATTACK ON BASE AXIAL FORCE AND DRAG OF
CYLINDRICAL BODIES WITH CONICAL BOAT-TAILS

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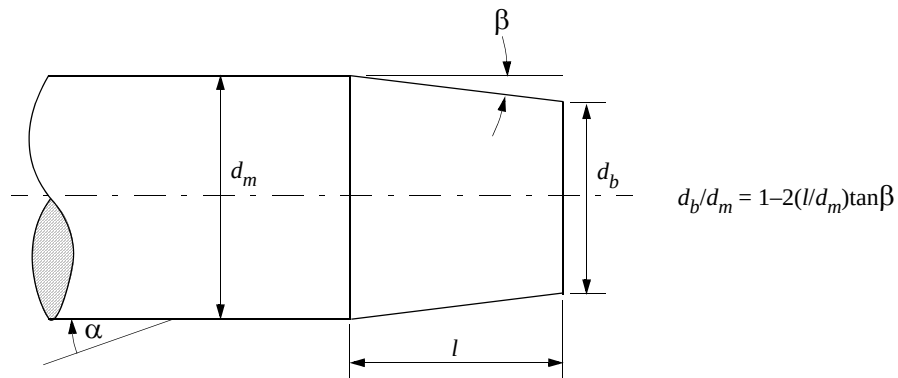
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EFFECT OF ANGLE OF ATTACK ON BASE AXIAL FORCE AND DRAG OF CYLINDRICAL BODIES WITH CONICAL BOAT-TAILS

1. NOTATION AND UNITS (see Sketch 1.1)

		<i>SI</i>	<i>British</i>
C_{Ab}	base axial force coefficient, based on body maximum cross-sectional area		
C_{Db}	base drag coefficient, based on body maximum cross-sectional area		
C_{pb}	mean base pressure coefficient		
d_b	base diameter	m	ft
d_m	body maximum diameter	m	ft
F	ratio of mean base pressure at angle of attack to mean base pressure at zero angle of attack		
l	boat-tail length	m	ft
M	Mach number		
R	Reynolds number based on body length		
α	angle of attack	degree	degree
β	boat-tail angle	degree	degree
<i>Subscripts</i>			
BT	value for boat-tailed body		
cyl	value for cylindrical body		
α	body at given angle of attack		
0	body at zero angle of attack		



Sketch 1.1 Body geometry

2. INTRODUCTION

This Item provides an empirical means of estimating the base axial force and drag of axisymmetric cylindrical bodies, both with and without conical boat-tailing, at angle of attack. The method requires the value for the base drag at zero angle of attack which is obtained from Item Nos 76033 (Derivation 1), 78041 (Derivation 3) and 79022 (Derivation 4) for subsonic, transonic and supersonic speeds, respectively.

The method is based on two extensive sets of wind-tunnel tests reported in detail in Derivations 2 and 7 and summarised in Derivations 5 and 8. In both series of tests the wind-tunnel models were supported by a side sting rather than the usual base-mounted sting thus avoiding undesirable interference in the base region. The data at zero angle of attack taken from other Items require that a sufficiently long cylindrical section of body exists upstream of the base for forebody/afterbody interference effects to be negligible in order that the base region can be treated as aerodynamically disconnected. Experience at zero angle of attack suggests that forebody and afterbody drags may be regarded as independent when the cylindrical midbody section is more than about three body diameters in length. In the absence of any further supporting data it is suggested that the same lower limit should be applied here. However, as angle of attack increases the situation is made more complex by the presence of body vortices, see Section 4.

The method is applicable at Mach numbers up to 5 and requires that the boundary layer be fully turbulent. Data are given at angles of attack up to 25° and 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

3.1 Method for Cylindrical Bodies at Angle of Attack

Item Nos 76033, 78041 and 79022 provide data for the base drag (or base pressure) coefficient of cylindrical bodies at zero angle of attack. In order to extend the use of these data to non-zero angles of attack the wind-tunnel test data of Derivations 2 and 7 have been used to derive an empirical factor, F , the ratio of the base pressure coefficient at a given angle of attack to that at zero angle of attack. Figure 1 shows the

variation of F with Mach number and angle of attack. This factor may be directly applied to the base pressure data for cylindrical bodies at zero angle of attack from Item Nos 76033, 78041 and 79022 which, for convenience, have been summarised in Figure 2 for the whole Mach number range, extended to $M = 5$. The equation for the base pressure coefficient is

$$(C_{pb})_{\alpha, cyl} = F(C_{pb})_{0, cyl} \quad (3.1)$$

The base axial force and drag coefficients may be obtained from the equation

$$(C_{Ab})_{\alpha, cyl} = \frac{(C_{Db})_{\alpha, cyl}}{\cos \alpha} = -(C_{pb})_{\alpha, cyl} = -F(C_{pb})_{0, cyl} \quad (3.2)$$

3.2 Method for Cylindrical Bodies with Conical Boat-tails

In addition to testing a cylindrical body the study reported in Derivation 2 included tests on fourteen boat-tailed configurations in the Mach number range 0.5 to 1.0. Those data indicated that, for the range of boat-tail shapes tested (see Section 4), the increase in base pressure obtained by boat-tailing was substantially independent of angle of attack. In the method this simplification is carried through to transonic and supersonic Mach numbers. The base pressure coefficient of a boat-tailed body at angle of attack may be estimated as

$$(C_{pb})_{\alpha, BT} = (F - 1)(C_{pb})_{0, cyl} + (C_{pb})_{0, BT} \quad (3.3)$$

Hence, the base axial force and drag coefficients may be evaluated from

$$(C_{Ab})_{\alpha, BT} = \frac{(C_{Db})_{\alpha, BT}}{\cos \alpha} = \left(\frac{d_b}{d_m} \right)^2 (F - 1)(C_{Db})_{0, cyl} + (C_{Db})_{0, BT} \quad (3.4)$$

where F and $(C_{Db})_{0, cyl}$ are given in Figures 1 and 2, respectively, and $(C_{Db})_{0, BT}$ is taken directly from Item No. 76033, 78041 or 79022.

4. ACCURACY AND APPLICABILITY

In the development of Figure 1 the data were restricted to just two sources. This was because both of these studies were series of tests specifically designed to measure base pressures. In both cases the tests employed models mounted from the (leeward) side to avoid the large sting interference effects that are known to occur with base-mounted models, and pressure taps were used to deduce a mean base pressure; five in the case of Derivation 2 and eighty-nine in the case of Derivation 7. This was felt to be particularly important to obtain a reliable value of mean base pressure at angle of attack.

As noted in the Introduction, at zero angle of attack a minimum midbody length of three body diameters is required to ensure that the base region can be treated as aerodynamically disconnected from the forebody. It is recommended that the same lower limit is applied for this Item, although there are no further experimental data to support this.