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Abstract

Abstract is written with the font 10 times new roman, not more than 250 words. The content includes: background, aim(s), method, results, conclusion(s). Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm.Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm.Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm. Mmmmmm mmmmmmmmmmmmmmm mmmmmmm mmm.

Keywords: Aerodynamics, Forebody and afterbody, Next keyword, Projectile, Supersonic speed.

1. Introduction

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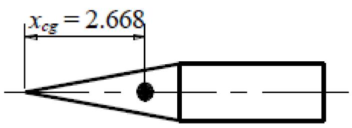

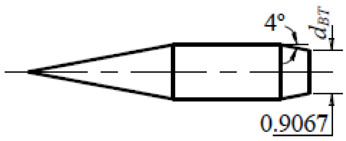

(a) Pointed-cone cylinder. **(b) Cone cylinder boat-tail (4°).**

Fig. 1. Investigated shapes of projectiles (Geometry and dimensions).

2. Prediction of Aerodynamic Coefficients

Analytical methods and design charts used for the prediction of zero-lift drag normal-force-curve slope while the design charts are produced from semi-empirical characteristics are adapted from Refs. [1, 4-6] and converted to numerical data, as outlined in *Appendix A*.

2.1. Zero-lift drag coefficient C_{D0}

The total zero-lift drag coefficient of the body is usually considered to be of three components; friction drag, wave drag, and base drag as shown in Eq. (1). These different components are further discussed in the following sub-sections.

$$C_{D_0} = C_{D_{fr}} + C_{D_w} + C_{D_b} \quad (1)$$

2.1.1. Friction drag coefficient

For fully-turbulent and compressible flow, the friction coefficient is given by Eq. (2) [6, 7]

$$C_{D_{fr}} = \frac{0.455()^{-2.58}}{(1+0.21M^2)^{0.467}}\frac{S_{wet}}{S_{ref}} \quad (2)$$

2.1.2. Wave drag coefficient

The main contribution to the wave drag arises from nose and afterbody. The magnitude of the wave drag depends primarily on the Mach number, the shape and body is simply the summation of the nose and afterbody wave drags

The wave drag of pointed cone-cylinder $(C_{Dw})_{cone}$ and pointed ogive-cylinder $(C_{Dw})_{ogive}$ can be obtained from Fig. A-1 (*Appendix A*) as a function of nose fineness ratio λ_N, and Mach number. For blunted cone-cylinder the wave drag bluntness D_0 using Eq. (4) [2, 4, 7]

2.2. Normal-force-curve slope $C_{N\alpha}$

The total normal-force-curve slope of nose-cylinder-boattail body is determined by the summation of the normal-force-curve slopes of the nose (with the effect of cylindrical part) and afterbody.

$$C_{N_a} = \left(C_{N_a}\right)_N + \left(C_{N_a}\right)_{BT} \quad (7)$$

where $(C_{N\alpha})_{cone}$ is the normal-force-curve slope of pointed cone withβ/λ'_N and

3. Computer Programme: Validation and Verification

To ensure the validity and accuracy of the calculations, the results are compared to typical projectile configurations (as shown in Figs. 2 and 3) are selected for this purpose. The specifications of the models and test conditions are shown in Table 1.

Table 1. Test model Specifications and test conditions.

	Model No. 1 [8]	**Model No. 2 [9]**
Configuration Type	Cone-cylinder	Ogive-cylinder
Body Diameter, *d* (inches)	1	6
Reference length, L_{ref}	*d*	*d*
Testing angle of attack (deg.)	0 – 6	0

Figure 2 shows that at low angles of attack the normal force coefficients are in excellent agreement with the experimental data. The figure also shows that the current results are closer (average percentage error less than 0.5%)

to the experimental data than those predicted analytically (average percentage error about 6%) by Saadi [9].

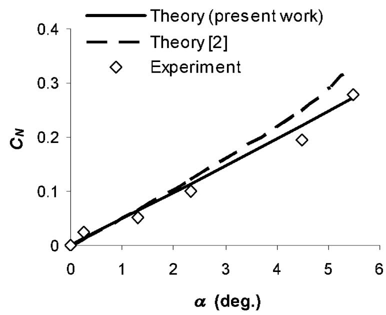

Fig. 2. Variation of normal force vs. angle of attack at M = 1.77.

At low angles of attack the normal force coefficients are in excellent agreement with the experimental data as shown in Fig. 3. This is expected due to the assumption of small angle of attack. The figure also shows that the current results are closer (average percentage error less than 0.5%) to the experimental data than those predicted analytically (average percentage error about 6%) by Saadi et al. [10]. This is expected as the analytical methods .

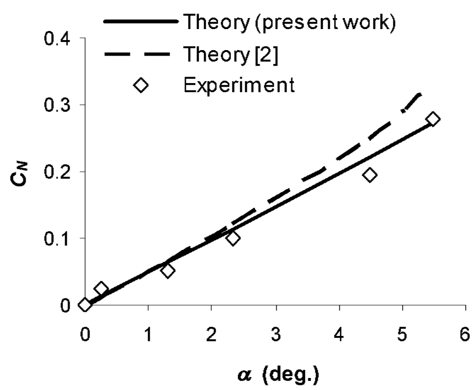

Fig. 3. Variation of normal force vs. angle of attack at M = 1.77.

4. Results and Discussion

The prediction of the aerodynamic coefficients of the investigated projectiles shown in Fig. 1 was carried using the methods and the computer programme described above. The effects of forebody and afterbody shapes on the aerodynamics at supersonic speeds are analysed in this paper.

4.1. Effect of forebody

Figure 4(a) shows the effect of nose shape on C_{D0} with cylindrical afterbody as a function of Mach number. The drag of cone-cylinder combination was the lowest at the considered Mach numbers. It is clear that the bluntness of nose causes the drag to increase.

For conical, ogival, and blunted cone forebody shapes, an inherent static stability occurs for a centre-of-gravity location of about 40% body length at Mach number above around 1.6, 1.8 and 2 respectively. Such a centre-of-gravity location may not be difficult to achieve with a projectile [11].

4.2. Effect of afterbody

For the projectile configuration comprising conical forebody and boattail, the effect of boattail shape on the drag is shown in Fig. 5(a) as a function of Mach number. For that the higher the angle of boattail the lower is the drag.

5. Conclusions

An investigation has been made of the effects of forebody and afterbody shapes of a curves. Some concluding observations from the investigation are given below.

- A pointed cone-cylinder produced the lowest drag at the considered Mach number, and the highest drag was produced by the blunted cone-cylinder.
- Configurations with boattail have higher wave drag but appreciably lower base drag with a resultant decrease of total drag. The decrease of the boattail angle increases the base drag but reduced the projectile wave drag with a resultant decrease of the total drag.

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Appendix A

Computer Programme

A. 1. Introduction

A computer code, for the prediction of projectile aerodynamic characteristics as a empirical methods presented in section 2.

The computer programme can serve two main purposes: firstly, in the design provide a complete picture of the projectile over its whole flight.

A. 2. Programme Structure and Description of Subroutines

Fortran-77 language is used in programming the prediction methods. Each estimation convenience. The main flow chart of the programme is shown in Fig. A-1.

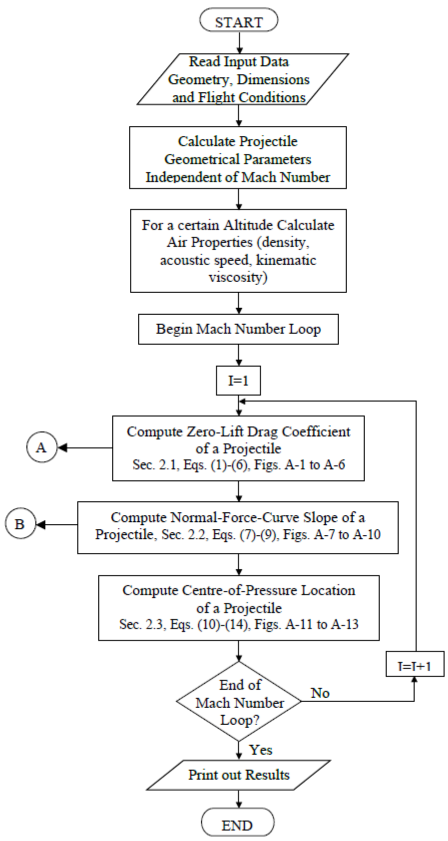

Fig. A-1. Main flow chart of the computer programme used in this study.