Following Body Effects on Base Pressure in Supersonic Stream

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Nomenclature

D_B = diameter of the base of the test body
D_F = diameter of the following body
x = axial distance of the front face of the following body behind the test body
p_B = base pressure
p_∞ = freestream static pressure
R_D = diameter ratio $= D_F/D_B$

Introduction

SEVERAL authors[1-3] have reported the dependence of base pressure on Reynolds number, Mach number, and fore and after body shape. Considerable study has also been made on free shear layer,[4] its point of reattachment and reattachment pressure ratio, and its relation with base pressure. However, little information is available on the behavior of base pressure in the pressence of a following body.

When the lower stage of a rocket vehicle is staged, the base pressure of the upper stage is seriously affected as long as it is in the proximity of the lower stage. Ignoring the transient effects caused by the varying axial position of the following body, its effect on the base pressure characteristics of a body of revolution provides useful information, by physically simulating the post-staging conditions.

This paper presents the results of an experimental investigation of the effect of a following body on the base pressure of an axisymmetric, blunt-nosed body in a supersonic stream. The axial position and the diameter of the rear body have been varied to determine the effects of these parameters on base pressure.

Experimental Setup and Test Technique

Experiments were conducted on an intermittent, blowdown-type supersonic wind tunnel with a test section of 100 mm x 50 mm.

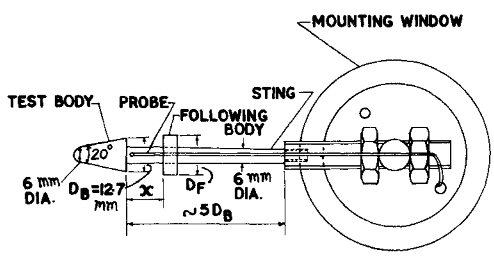

Fig. 1 Schematic of test setup arrangement.

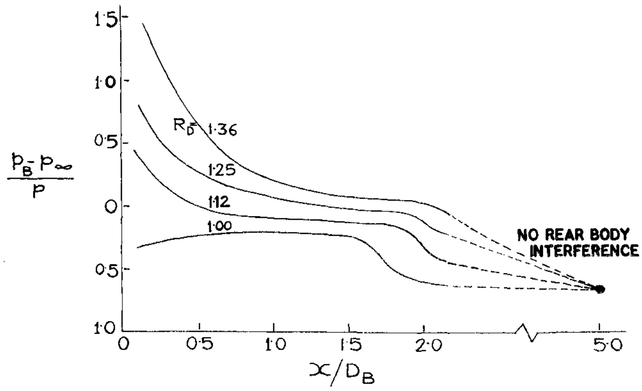

Fig. 2 Variation of base pressure in presence of following body.

A sting-supported test body of base diam 12.7 mm consisting of a 20° blunt-nose cone (6 mm nose diam) was used at zero angle of incidence. Four different diameters were selected for the following body, viz., 12.7 mm, 14.2 mm, 15.9 mm and 17.3 mm.

Base pressure was measured by a single, 1.5 mm diam probe located just behind, and 2 mm below the edge of base, passing through the following body. Figure 1 schematically represents the experimental set up. The freestream static pressure, atmospheric pressure and the base pressure probes were connected with a multilimb mercury manometer/pressure gage.

The tests were conducted at a freestream Mach number of 2.067 and Reynolds number of 6.85 x 10^4/mm. All readings were taken at a stagnation pressure of 5.1 kg/cm^2.

Results and Discussion

Figure 2 shows the effect of the following body on base pressure for various diameter ratios and axial positions. When the following body is at the largest separation distance tested from the test body, a part of its diameter lies outside the narrow envelope of dead air region and shear layer, formed behind the test body. A strong tip shock is thus produced which increases the base pressure. A following body of unit diameter ratio is fully submerged in this envelope when it moves very close. The tip shock at this position disappears and the expansion wave produced at the downstream edge of the test body becomes limited resulting in a lower base pressure. As the diameter of the following body increases, a leading tip shock of increased strength is produced. The shock tends to nullify the expansion wave produced at the downstream edge of the test body, and ultimately replaces the same when the following body is moved closer.

The experimental observations, therefore, reveal that the presence of the following body changes the base pressure significantly and hence affects the base drag and stability characteristics, the closer positions being more influencial. The decrease in the base pressure with unit diameter ratio suggest that staging of same diameter bodies result in lower base drag and better stability of the upper stage.

References

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Index category: Jets, Wakes, and Viscid-Inviscid Flow Interactions.

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