Base Pressure Studies of Ring-Mounted Bodies of Revolution

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Nomenclature

d_b = base diameter
d_r = diameter of ring
L = length
M_∞ = freestream Mach number
p_b = base pressure
p_{bo} = base pressure in absence of ring
p_∞ = freestream static pressure
R = diameter of ratio of ring to base = d_r/d_b
Re = freestream Reynolds number
t = thickness of ring
x = distance of the leading edge of the ring from the nose.

Introduction

THE drag of a rocket vehicle increases by mounting a circular ring on the body of the vehicle. The increase in drag results in reducing the range, impact velocity, and/or increasing the time of flight of the vehicle. By proper selection of the diameter and position of the ring on the body, the drag can be conveniently controlled to provide wider flexibilities in range, impact velocity and time of flight for the same vehicle as demanded by a particular application.

A volume of theoretical and experimental research work on the base pressure and near-wake flow phenomenon is available. The effect of angle of attack,[1] base mass addition,[2] following body presence[3] on the base flowfield structure and base pressure has also been recently reported. However, little information is available on the effect of ring mounting on an axisymmetric test body.

This paper presents the experimental results of the effect of axial location and diameter ratio of a disk shaped circular ring on the base pressure of a flat-based axisymmetric body at Mach number 2.067.

Experimental Setup and Test Procedure

The study was conducted on an intermittent blowdown type supersonic wind tunnel with a test section of 100 mm × 50 mm at a freestream Mach number 2.067 and Reynolds number 3.4×10^6.

A flat based test model was supported in the tunnel by a sting of 3.0 diameter. The sting was attached to a circular disk, forming a part of the side wall of the test section.

The test model consisted of a 9.6-mm diameter, 50-mm long cone-cylinder body with seminose angle of 15° and nose radius of 1.2 mm. Three-mm thick circular disks of inside diameter of 9.6 mm, and outside diameter of 14.3, 15.9, 17.3, 19.1, 20.6 and 23.7 mm were used as rings.

With the ring mounted on the body, the test model was supported in the test section at zero angle of incidence. After making the probe connections with the multilimb mercury manometer/pressure gage, the flow in the tunnel was established by opening the main valve. The freestream static pressure and the base pressure readings were taken for different locations of ring mounting between $2d_b$ and $4d_b$ measured from the nose of the test model to the leading edge of the ring for the various diameters of the ring at a stagnation pressure of 5.1 kg/cm^2. Figure 1 schematically represents the experimental setup.

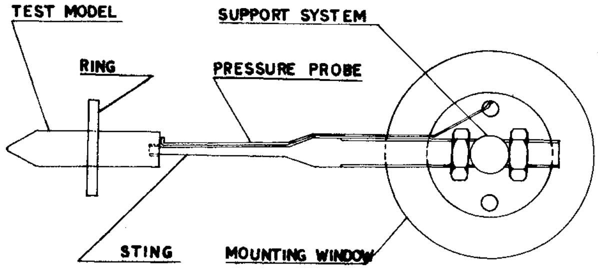

Fig. 1 Schematic diagram of experimental setup.

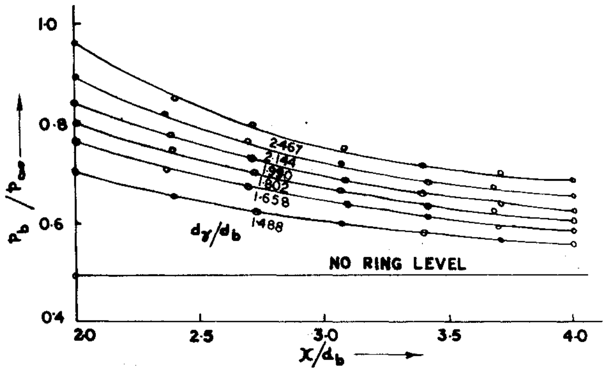

Fig. 2 Base pressure variation with diameter and location of ring mounting.

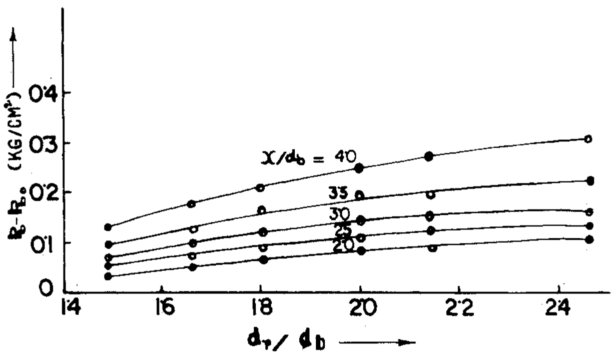

Fig. 3 Effect of ring mounting an base pressure.

Results and Discussions

The experimental base pressure results for different diameter ratios and axial locations of ring mounting are presented in Fig. 2. The (p_b-p_{bo}) values for different diameter ratios and axial locations of ring mounting are presented in Fig. 3.

The base pressure is found to increase monotonically as the ring is moved from the base towards the nose of the test body. The increase in base pressure with ring mounting can be explained by the effect of the wake of the ring on the flow conditions, at the downstream edge of the test body and its contribution in accelerating the boundary-layer growth. It is natural that only a limited expansion at the downstream edge of the test model will materialize due to flow deceleration by the ring and the interaction of its wake with the flow at the base of the test body. A ring mounting therefore will result a weaker expansion yielding a higher base pressure in supersonic flow. The increase of base pressure is obvious if the flow becomes subsonic. The expansion will be further limited in strength as the ring is moved towards the nose. Also, location

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of rings very close to the nose may altogether alter the shock structure appearing at the nose, thus decreasing the effective Mach number at the base and increasing base pressure.

It is also observed that base pressure increases with the diameter ratio of the ring for the same location of ring mounting. However, the effect is more pronounced for location of ring mounting closer to the nose than to the base. This phenomenon is linked with the strength of the shock wave generated at the leading edge of the ring. When the ring is mounted near the base, the expansion by the ring will be practically independent of the diameter. However, the shock generated at the leading edge of the ring will increase in strength with diameter ratio resulting in a slight rise in base pressure. As the ring is moved towards the nose of the test body, the interaction of the wake of the ring with the flow at the downstream edge of the base becomes more severe whereas the tip shock strength of the ring remains unchanged. When the ring is moved close to the nose, it is possible that the pressure field created due to tip shock propagates to the nose of the test body through the subsonic portion of the boundary layer on the test body thereby altering the shock structure at the nose of the test body. Under such circumstances, the shock wave at the nose of the test body may as well become normal indicating at least a change to a sonic condition which results in a very weak expansion and thus a very high base pressure.

Conclusion

From the results and the discussions of the previous section the following conclusions may be drawn: 1) the ring mounting increases the base pressure of the body under consideration; 2) as the ring is moved closer to the nose, the base pressure increases; and 3) as the ratio of the diameter of the ring to that of the body increase, the base pressure increases.

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ERRATA

Mass Properties of Sphere-Cone Entry Vehicles

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Avco Systems Division, Wilmington, Mass.
[JSR **10**, 815-817 (1973)]

LINE 2 of Eq. (4) should read

$$4(Ba^3/L^3-e^{KL})/K^2L^2+6C\times$$

Line 1 of Eq. (5) should read

$$gI_y'/\pi\rho_0L^5\tan^2\theta_c=\{e^{KL}(2a/L+1)/KL-4e^{KL}/K^2L^2$$

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