Measurement of In-Flight Base Pressure on an Artillery-Fired Projectile

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Abstract

THE in-flight base pressure has been measured on conventionally fired artillery projectiles. No previous successful effort for such measurements and projectiles is apparent. A passively actuated base-sealing mechanism provided protection to the sensitive base-pressure instrumentation prior to gun muzzle exit and was released after exit to allow base-pressure sensing in flight. Comparisons are made of flight measurements with base-pressure data from wind-tunnel testing.

Contents

Improving the dynamic behavior (especially transonic instability) and the ballistic range of existing artillery-fired projectiles by modifying the boattail has been the purpose of certain previous design efforts and flight tests. Configurations that improve flight dynamic character were often predicted to cause a decrease in flight range, primarily because of adverse base-pressure changes. Such penalties in flight performance are usually unacceptable. The need to develop the capability to measure in-flight base pressure on an artillery-fired projectile was evident because of apparent difficulties in reproducing the actual base flow in a wind tunnel or in base-flow computer modeling.

The base-pressure instrumentation was protected during firing with a mechanism that responds without command to the in-gun acceleration and provides a seal in the high, gas pressure, and temperature environment. The mechanism then responds to the rapid decrease in base pressure after muzzle exit to expose the instrumentation to the in-flight base pressure. These in-flight base-pressure measurements on conventional artillery-fired projectiles are the first known to the author.

The base-sealing mechanism (Fig. 1) was made integral with the central structure of the projectile base. The device consists of a perforated (centerline hole) disk-spindle sealing bolt that forms the central portion of the projectile base. The bolt is inserted into the base and held against a spring and an O-ring seal (under the disk) by a nut threaded onto the spindle end. Two washers are captured between the nut and the projectile base. The aft washer is made of crushable foam, and the forward washer (against the nut) is made of Kennertium (a high-density metal). The centerline hole of the bolt is sealed at the forward end with a plug and an O-ring. The plug is at the center of, and integral with, a circular baffle plate that resides in a plenum to which the base-pressure transducer is attached (in the forward dome). Large axial perforations in the plate permit rapid communication of base pressure to the transducer if the bolt is unplugged.

During gun firing, the extreme setback acceleration causes the metal washer to crush the foam washer. The crushed foam allows the spring to move the disk-spindle bolt aft and disengages the plug and, thus, exposes the transducer to the base pressure. However, the sealing bolt does not move aft until muzzle exit, because the extreme breech and gun tube pressure loads on the disk overcome the spring force and the inertial forces associated with the bolt.

The in-flight base pressure was measured on two artillery projectiles. The basic configuration of the projectiles was that of the U.S. Army 155-mm M549 unit. The first round featured an M549 with a modified boattail (similar to the U.S. Army 155-mm M483 projectile). The second round was an external M549. The boattail modification provides a projectile that demonstrates improved transonic dynamic stability but increased base drag.

The M549 with modified boattail was fired at a gun elevation angle of 87 deg and a muzzle velocity of 1930 ft/s. The maximum breech pressure and setback acceleration were 25,000 psi and 5000 *g*, respectively. The corresponding conditions for the M549 were 48 deg, 2510 ft/s, 30,000 psi, and 8500 *g*.

The analog signal from the pressure transducer was monitored continuously and telemetered. The projectile was skin-tracked in flight with radar to determine space position and velocity histories. The freestream static pressure and temperature were determined as a function of altitude with a

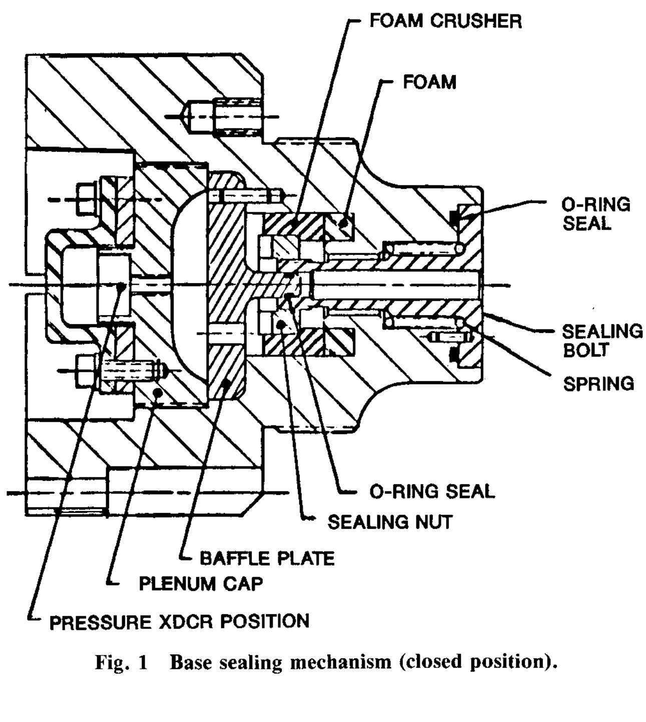

Fig. 1 Base sealing mechanism (closed position).

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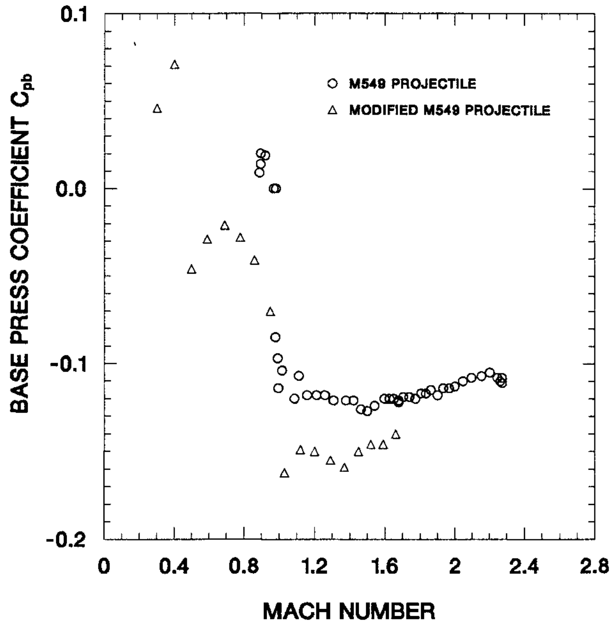

Fig. 2 Flight-test base-pressure coefficient.

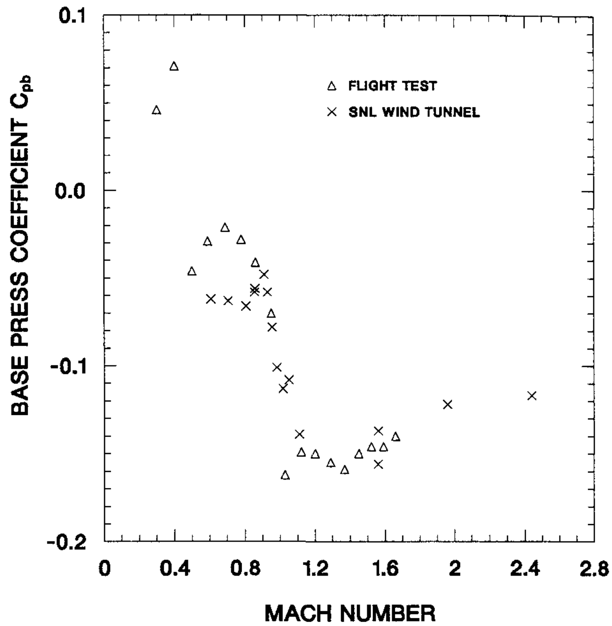

Fig. 4 Modified M549 projectile base-pressure coefficient comparison (flight test and wind-tunnel data).

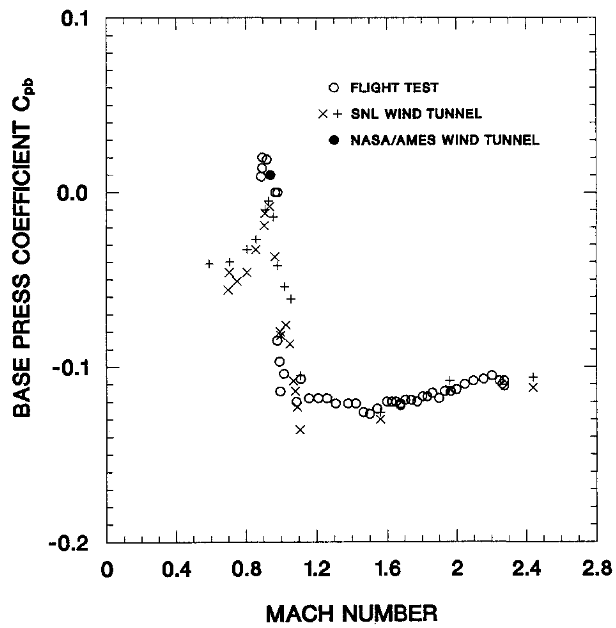

Fig. 3 M549 projectile base-pressure coefficient comparison (flight test and wind tunnel).

balloon-borne radiosonde. The base-pressure data were converted to a coefficient form using the measured freestream static pressure and the computed freestream dynamic pressure as references. The in-flight base-pressure coefficient data are presented in Fig. 2 as a function of the computed freestream Mach number.

A wind-tunnel study of several 0.197-scale 155-mm projectile models was conducted by Vaughn and Clark[1] at Sandia National Laboratories (SNL) prior to the base-pressure flight tests. These models were nonspinning but included rotating bands with groove patterns as engraved by the gun tube rifling. The measured base-pressure coefficient data from this tunnel study are presented in Figs. 3 and 4. The different symbols depicting the SNL wind-tunnel data in Fig. 3 represent two separate tunnel entries.

A recent experiment conducted by Miller and Molnar[2] in the NASA Ames 14-ft transonic wind tunnel included the measurement of base pressure on a 1.30-scale model of the U.S. Army M549/XM785 155-mm projectile. The shape was nearly the same as the M549. The model was tested with and without a grooved rotating band and with and without axial spin. The test was conducted at $M = 0.94$. The base pressure was measured at a radius of 79% of the base radius. The base-pressure coefficient measured with rotating band and with spin is presented in Fig. 3 as the NASA Ames wind tunnel.

The experiment conducted by Miller and Molnar[2] measured a base-pressure coefficient change (an increment of 0.024) with spin for the model with a rotating band. The spin rate applied during this tunnel test matched the muzzle exit condition of a full-scale projectile at $M = 0.94$; i.e., the flow over the rotating band ribs and grooves engraved by a gun tube rifling was parallel to or along these features. However, as the projectile velocity decreases in flight, the spin rate does not decrease proportionately. This process results in what might be termed "excess spin" in flight. The effects of spin on base pressure may be enhanced with this condition because of the rotational aerodynamic driving forces produced by the band ribs.

Further wind-tunnel studies might include the measurement of base pressure with variation in spin rate and radial location on the base at a series of Mach numbers.

References

[1]Vaughn, H. R. and Clark, E. L., Jr., "Preliminary Wind Tunnel Investigation of an Alternative 155 mm AFAP Shape," Sandia National Labs, Albuquerque, NM, Rept. SAND78-0139, Feb. 1978.

[2]Miller, M. C. and Molnar, J. W., "Wind Tunnel Measurements of the Magnus Induced Surface Pressures on a Spinning Artillery Projectile Model in the Transonic Regime," U.S. Army Armament Munitions Chemical Command, Aberdeen Proving Ground, MD, Rept. CRDEC-TR-96081, Sept. 1986.