Interaction of Gun Exhaust Flowfields

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Abstract

INTERACTIONS between the air column forced out ahead of a projectile and the subsequent propellant gas exhaust are observed experimentally. By comparing data taken at fully ambient conditions with that acquired in firings from an evacuated gun tube, the interactions are demonstrated to significantly influence the near muzzle flow, a region through which the projectile passes and within which muzzle devices are located.

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Experiments[1] show the formation of two impulsive jets at the muzzle of guns during firing. The precursor, Fig. 1a, develops as the air in the gun tube is forced out ahead of the bullet. Following projectile separation, the propellant gases are released, Fig. 1b. Both flows have similar structures. The gun gases form a supersonic, underexpanded jet while the displacement of the surrounding air generates a blast wave. Typically, the muzzle pressure changes by an order of magnitude after shot ejection, resulting in a rapid expansion of the propellant gases over the projectile and through the boundaries of the precursor jet. The spatial and temporal variations in the precursor flow influence the development of the primary, propellant gas-driven blast.

To define the extent of the precursor/propellant gas interaction, a 20-mm cannon was fired over a range of projectile launch velocities between 260 and 1050 m/s. The flowfield structure was observed through sequential, spark shadowgraphs while pressure was measured along selected radials. To isolate the interaction effects, data were taken for two conditions: one with the gun tube evacuated ahead of the projectile and, the second, with the gun tube at ambient pressure.

At the lower launch velocities, the precursor flow begins early in the firing cycle, since the column of air ahead of the projectile is not significantly compressed. The exhaust occurs at low pressure; therefore, the plume has negligible lateral expansion and is confined to a narrow region along the axis of symmetry. Upon release, the propellant gases expand into the relatively undisturbed air external to the precursor jet forming a blast wave which is described accurately by theory.[2] Along the axis, the high wavespeed in the precursor jet combined with the blocking effect of the projectile impedes formation of the blast wave sufficiently to prevent its observation on the spark shadowgraphs.

At higher launch velocities, greater compression of the tube air results in increased lateral expansion of the precursor plume, Fig. 1a, and in interaction with the propellant gases over the complete forward area of the flow, Fig. 1b. For the

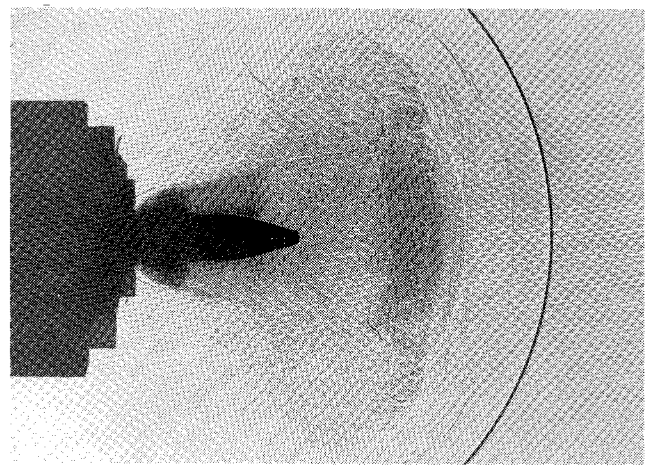

Fig. 1a Precursor flow at instant of projectile exit, $V_p = 1050$ m/s.

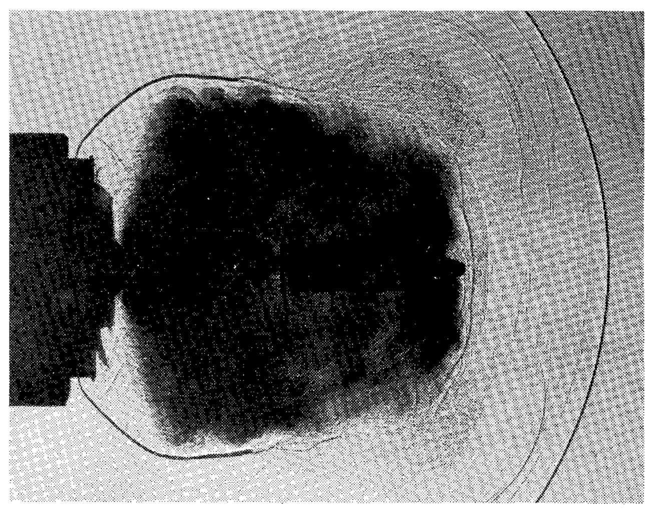

Fig. 1b Propellant gas flow with ambient tube, $V_p = 1050$ m/s.

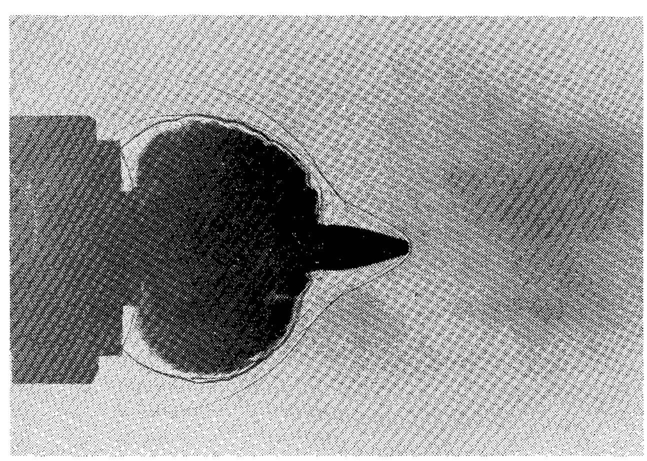

Fig. 1c Propellant gas flow with evacuated tube, $V_p = 1050$ m/s.

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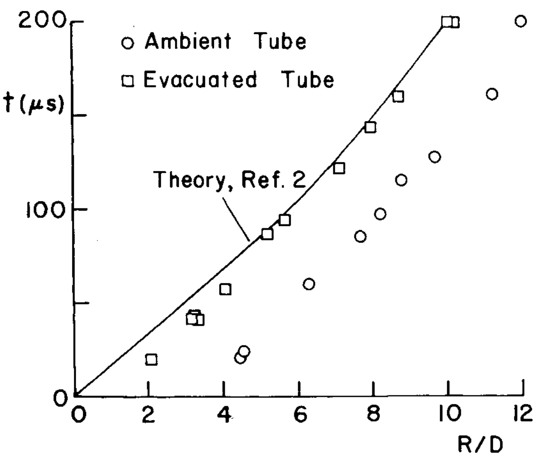

Fig. 2 Motion of blast wave along axis of symmetry.

firings at a velocity of 1050 m/s, a characteristic shock bifurcation or forward bulge is noted. This property is highlighted by comparison with a spark shadowgraph taken at a similar time for a firing with the evacuated tube, Fig. 1c. In this case, the precursor flow is eliminated by placing a Mylar diaphragm across the muzzle and an O-ring around the projectile forward of the rotating band. The gun tube is then evacuated to 30 μm Hg prior to firing.

The measured trajectories along the axis of symmetry, Fig. 2, indicate the influence of the flowfield interactions. At any given time, the blast wave for the ambient tube is displaced further from the muzzle than is that for the evacuated tube. It is interesting to note that the difference in the two locations corresponds roughly to the length of the supersonic core of the precursor jet. Comparison with the numerical model of Erdos and DelGuidice[2] shows good agreement for the evacuated tube data; however, the ambient blast trajectory is not well represented. This follows directly from the nature of the model which neglects both the precursor flow and the projectile.

The importance of gasdynamic interactions is further emphasized by examining the pressure measurements. In Fig. 3, the static overpressure immediately behind the blast wave is plotted along a ray 10 deg off the axis of symmetry. Near the muzzle, the pressure measured with the ambient tube is significantly lower than for the evacuated case. This is to be

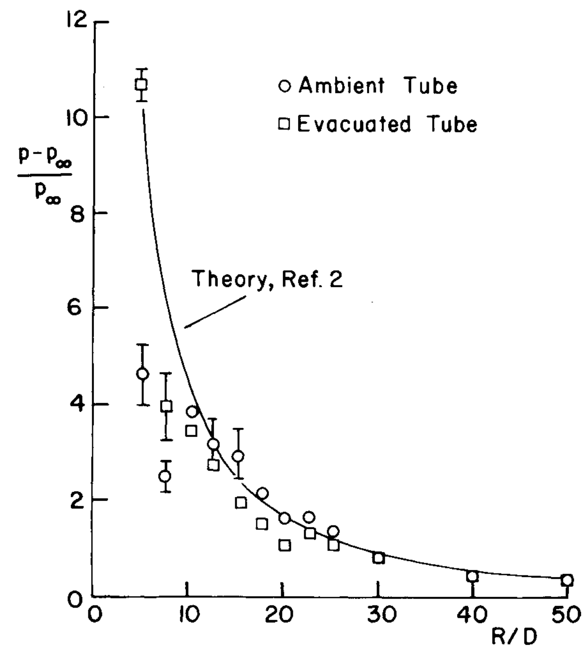

Fig. 3 Peak static pressure (behind blast wave) measured along 10-deg ray.

expected since the higher wavespeed in the precursor flow acts to lower the strength of the blast formed when the projectile separates. The data for the ambient tube follows a non-monotonic behavior as the radial distance increases. Passage of the blast through various features of the precursor flow can be associated with this behavior. Interaction effects cease to be measurable after 30 nozzle diameters. Again, the predictions of the numerical model agree with the data taken for the evacuated tube firings.

These results indicate the need to incorporate the interactions between the precursor and propellant gas flowfields into the analysis of near-field muzzle gasdynamics.

References

[1]Schmidt, E. M. and Shear, D. D., "Optical Measurements of Muzzle Blast," *AIAA Journal*, Vol. 13, Aug. 1975, pp. 1086-1091.

[2]Erdos, J. and DelGuidice, P., "Calculation of Muzzle Blast Flowfields," *AIAA Journal*, Vol. 13, Aug. 1975, pp. 1048-1056.