Engineering Notes

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Aerodynamics of Asymmetric Sabot Discard

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Introduction

SABOTS are employed to reduce the sectional density of projectiles, permitting the attainment of high in-bore accelerations. Once free of the gun, the sabots must be discarded in order to decrease the drag of round. It has been demonstrated[1-3] that aerodynamic interference during this process can adversely affect the projectile trajectory and increase on-target dispersion. While the flowfield associated with symmetric sabot discard geometries has been investigated,[4,5] there is no body of information describing the asymmetric case. The present paper will discuss the results of an experimental program to obtain preliminary data on asymmetric discard.

Of the post-separation disturbances, aerodynamic interference during sabot discard has been shown to be most significant.[3] Either favorable or unfavorable interference may be observed. For example, a projectile launched with a high initial yaw rate may have this rate damped during the discard process. Alternatively, asymmetries in the sabot discard have been shown to induce significant projectile yaw rates.

A typical sabot discard flowfield is presented in the spark shadowgraph of Fig. 1. The high degree of confinement provided by the tightly grouped sabot components causes the boundary layer on the projectile to separate. Relatively strong shocks are associated with this separated flow. Additionally, asymmetry in the separation is noticed in comparing the upper and lower surfaces. In order to better define these disturbances, data are required which examine the actual flow associated with asymmetric discard.

Model Design and Test Procedure

The pressure distributions on models of a projectile and sabot component were measured in the hypersonic leg of the NASA Langley Unitary Plan Facility. The projectile was mounted on a sting extending from a window blank, while the sabot was mounted on the main trapeze of the wind tunnel. Two asymmetric configurations were tested: the projectile with a single sabot component, and the projectile with three sabot components, one of which is moved relative to the others. Baseline data on a symmetric discard configuration have been previously reported.[5]

The projectile is a stainless-steel cone-cylinder having a diameter of 50.8 mm, a length-to-diameter ratio of 10.5, and a 30 deg total included angle conical nose. Fifty static pressure orifices are positioned on the surface between the 120-deg planes of symmetry. The sabot is brass and has cylindrical inner and outer surfaces of radii 25.4 and 76.2 mm, respectively. The leading edge of the sabot has a 40-deg chamfer. Fifty pressure orifices are located on the surfaces facing the projectile. Pressures were measured by Scani-Valve transducers external to the tunnel. The static sabot components are fabricated from brass to the identical geometry of the actuated component; however, they are not instrumented. The two static sabot components are mounted at zero angle of attack and at a separation distance of 3.81 cm from the surface of the projectile. The baseline configuration is defined as the actuated sabot component aligned symmetrically with respect to the static sabot components.

Tests were conducted at Mach 4.5, which is representative of flight Mach numbers. Reynolds number similarity could not be achieved during the tests: test Reynolds number is 6.6×10^6/m and free flight Reynolds number is 89.0×10^6/m. However, as previously noted,[5] viscous interactions are observed in the experimental results and a closer duplication in Reynolds number would have been worthwhile.

Test Results

To assess the influence of asymmetry on the projectile surface pressure, data were taken for specific geometries. In Fig. 2a, the baseline configuration is compared with a similar, asymmetric case obtained by removing the static sabot components while leaving the actuated sabot segment in place. The two pressure profiles are taken along the plane of symmetry. The general features are quite similar, clearly showing the arrival (and reflection) of the sabot shock wave. The peak pressures are comparable for the single and triple sabot cases. For the single sabot component, the pressure ahead of the peak approaches the undisturbed level, i.e., the freestream pressure. With three components in place, mutual reinforcement of the impinging shocks apparently separates the boundary layer completely around the periphery of the body. Downstream of the intersection, the pressures rapidly decay as the corner expansion from the sabot arrives at the surface.

The influence of mutual reinforcement from adjacent sabot components is further illustrated in Fig. 2b. This plot presents the variation in projectile centerline pressure with forward displacement of the free sabot in the three-sabot arrangement.

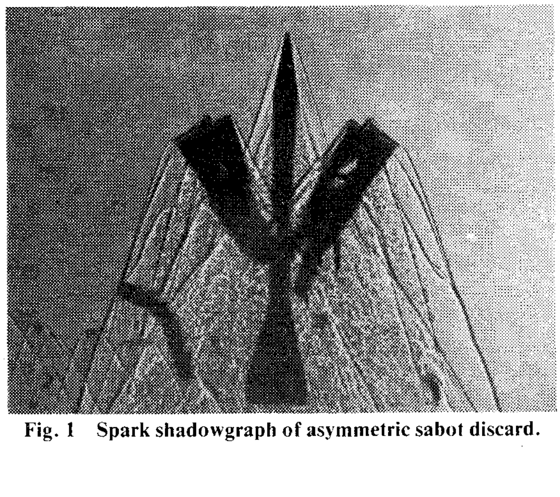

Fig. 1 Spark shadowgraph of asymmetric sabot discard.

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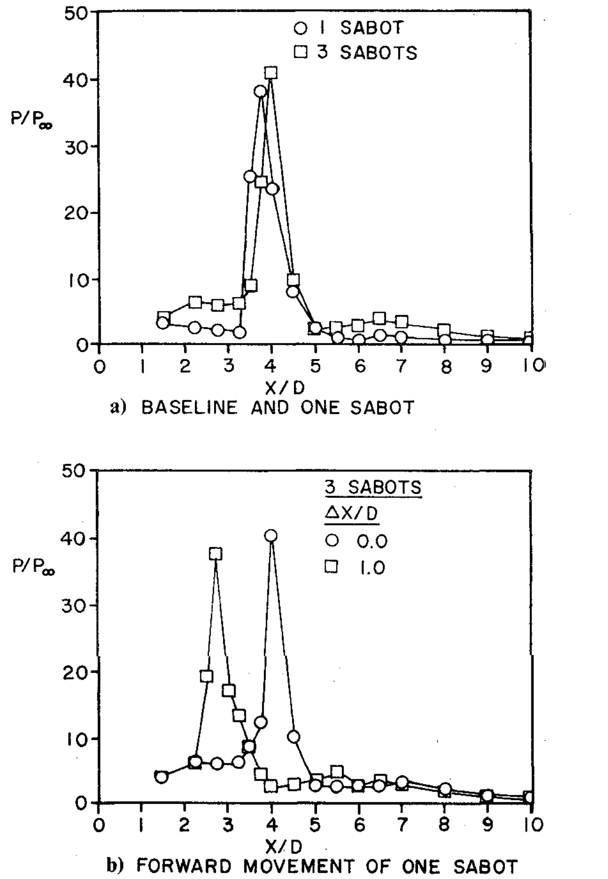

Fig. 2 Projectile surface pressure ($\Delta Y/D = 0.75$, $\alpha = 0$ deg, $\phi = 0$ deg).

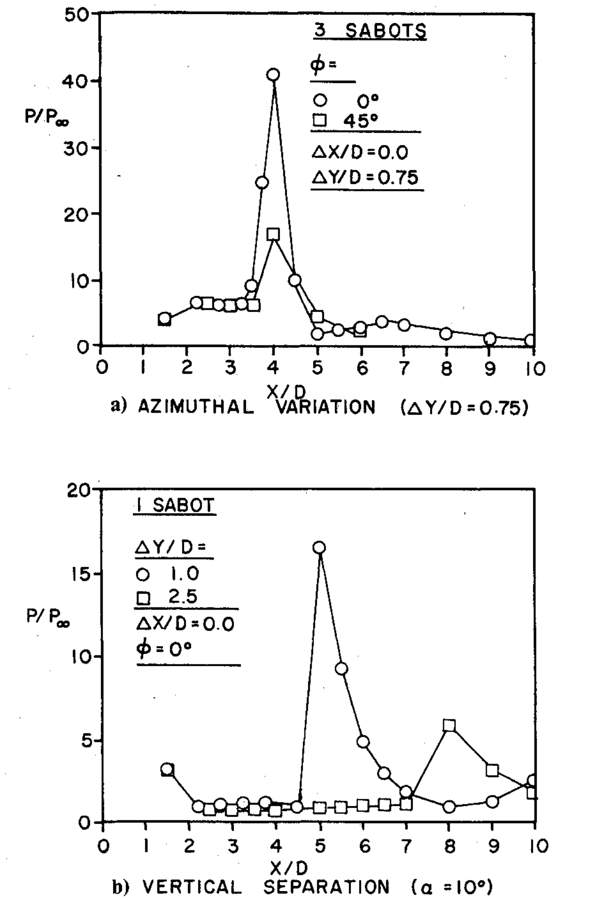

Fig. 3 Projectile surface pressure.

It is noted that the pressure pulse moves forward with the component and only relatively minor changes are observed. This indicates that, as expected, the incident shock from the facing sabot component dominates the surface pressure distribution on the projectile. The glancing shocks from adjacent components do not significantly influence or reinforce the primary interaction.

Further emphasis of this point is obtained by comparing azimuthal pressure distributions for the geometry of the baseline configuration (Fig. 3a). For azimuthal angle, ϕ, of 0 and 45 deg, the pressure distributions for the single and triple sabot component cases are essentially identical. The most significant difference is observed in the region of the pressure plateau forward of the shock intersection. It is noteworthy that the level of the pressure in this region is roughly constant in both the axial and the azimuthal direction. As the azimuth angle increases, the peak pressure decreases significantly reflecting the change in the local flow deflection angle around the periphery of the cylinder. Again, the similarity between the pressure profiles for the single asymmetric sabot case and the symmetric triple configuration is taken to indicate that mutual reinforcement by adjacent sabot components is not significant.

During the discard sequence, the sabot components pitch to positive angles of attack, α, and move laterally away from the projectile. Pressure distributions representative of the trends due to this motion are presented in Fig. 3b for the single sabot displacing laterally while at a 10 deg angle of attack. As the sabot moves away from the projectile, the peak pressure decays and the location of the peak displaces aft. This behavior is obviously expected as the source of disturbance becomes more distant. The effect of angle of attack is to displace the leading edge of the sabot away from the projectile surface, also bringing about decreased peak pressures and aft motion of the shock impingement point.

Summary and Conclusions

Results of wind tunnel tests to examine the interference aerodynamics between asymmetrically discarding sabot components and the flight body have shown that the basic features of the flowfield are similar to those previously observed in tests of symmetric discard.[5] The results indicate that the projectile surface pressure distribution is dominated by the facing sabot component. Adjacent components do not provide significant reinforcement of the impinging shock waves, but do influence the separated flow ahead of the shock impingement. The resulting pressure distribution in the separated region is largely uniform in the axial and azimuthal direction. Thus, the asymmetric sabot discard problem can be approximated by solving for the flowfield associated with one sabot component. This solution may then be applied locally to determine the interaction with the facing section of the projectile surface, thus avoiding a complex multibody solution.

References

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