SYNOPTIC: Supersonic Jet Penetration (up to Mach 4) into a Mach 2 Airstream, Frederick P. Povinelli, Louis A. Povinelli, and Martin Hersch, NASA Lewis Research Center, Cleveland, Ohio; *Journal of Spacecraft and Rockets*, Vol. 7, No. 8, pp. 988–992.

Jets, Wakes, and Viscid-Inviscid Flow Interactions; Supersonic and Hypersonic Flow; Hypersonic Airbreathing Propulsion

Theme

Success of a supersonic combustion ramjet depends on understanding the fuel injection and mixing processes in supersonic flow. This paper presents experimental results on the penetration of sonic and supersonic gas injection into a supersonic crossflow. The data are correlated and are compared to other correlations and data in the literature.

Content

Helium was injected from a flat plate normal to a Mach 2 airstream. Interchangeable nozzles of 0.080 in. throat diameter d^* were used to give an injection Mach number range from 1 to 4. Jet-to-freestream total-pressure ratio P_{oj}/P_{oa} varied from 3.5 to 9.6, and jet-to-freestream dynamic-pressure ratio q_j/q_a from 2 to 11. Concentration measurements at three downstream locations x were made; and the penetration y was defined by the 1% He boundary. Results are shown in Fig. 1. Penetration increases with increasing Mach number, total pressure ratio, and downstream distance. For equal P_{oj}/P_{oa} and mass flow, penetration increased as much as 25% in going from sonic to Mach 4 injection.

Existing correlations in the literature did not fully describe the data. Penetration varied with $(q_j/q_a)^{0.5}$ but only for a given M_j and x/d^*. Dividing penetration by mass flow correlated the data for all M_j for a given x/d^* only.

A multi-variate regression analysis was used to correlate the data in the form

$$y/d^* = 1.52(P_{oj}/P_{oa})^{0.507}(M_j)^{0.114}(x/d^* + 0.5)^{0.286} \quad (1)$$

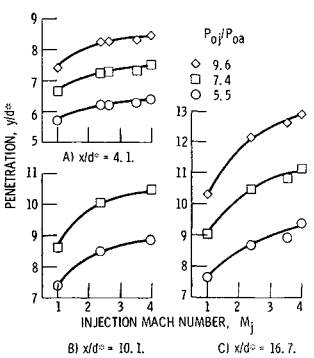

Fig. 1 Effect of injection Mach number on penetration.

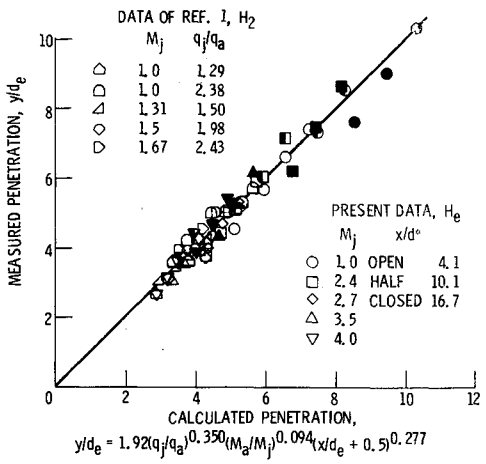

Fig. 2 Comparison of measured penetration and penetration calculated from correlation Eq. (2).

The penetration calculated from this equation and the measured penetration were within ±7%. In comparing the results to other supersonic injection data in the literature, a correlation form was obtained which was based on injector exit diameter d_e rather than throat diameter d^*. The data of Ref. 1 for hydrogen injection into a Mach 2.72 airstream, and the data of this study were correlated as shown in Fig. 2 with the form

$$y/d_e = 1.92(q_j/q_a)^{0.350}(M_a/M_j)^{0.094}(x/d_e + 0.5)^{0.277} \quad (2)$$

It is possible that better agreement and an exponent closer to 0.5 on q_j/q_a were not obtained because of the wide range of variables between the two studies. Other correlation forms may exist which would incorporate the variables in a different fashion and which would show a more consistent dependence on the variables over wide ranges of conditions.

Reference

[1] Orth, R. C. and Funk, J. A., "An Experimental and Comparative Study of Jet Penetration in Supersonic Flow," *Journal of Spacecraft and Rockets*, Vol. 4, No. 9, Sept. 1967, pp. 1236–1242.