Drag Force Anemometer Used in Supersonic Flow

To measure the drag on a flat cantilever beam exposed transversely to a flow field, the drag force anemometer (beam probe) uses strain gauges attached on opposite sides of the base of the beam (ref. 1). This is in contrast to the hot wire anemometer, which depends for its operation on the variation of the convective heat transfer coefficient with velocity. The beam probe retains the high-frequency response (up to 100 kHz) of the hot wire anemometer, but it is more rugged, uses simpler electronics, is relatively easy to calibrate, is inherently temperature compensated, and can be used in supersonic flow. The output of the probe is proportional to the velocity head of the flow, $\frac{1}{2}\rho u^2$ (where ρ is the fluid density and u is the fluid velocity). By adding a static pressure tap and a thermocouple to measure total temperature, one can determine the Mach number, static temperature, density, and velocity of the flow.

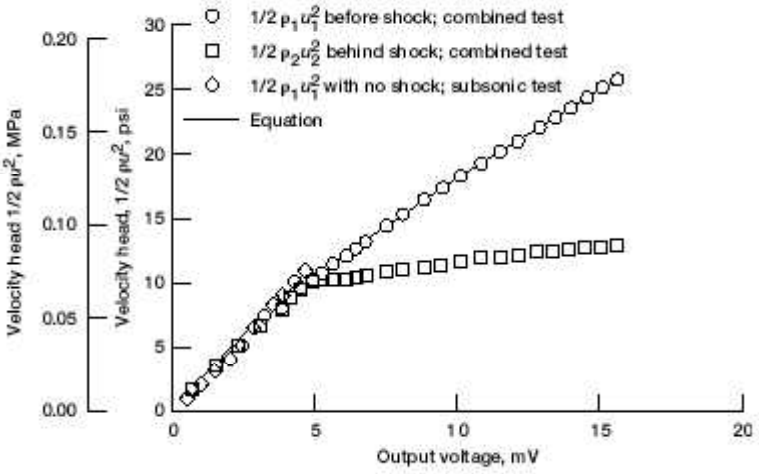
Normal shock produced by beam probe.

The use of the beam probe has heretofore been limited to subsonic flow applications. However, as can be seen from the photo, it is possible to design the probe to produce a normal shock in supersonic flow. Thus, using the equations for conservation of mass, energy, and momentum across a normal shock, researchers at the NASA Lewis Research Center related the parameters of the flow upstream of the shock front produced by the probe to those measured by the probe, downstream of the shock. In particular,

$$\rho_1 u_1^2 = [(\gamma-1)/(\gamma+1)]\rho_2 u_2^2 + [2\gamma/(\gamma+1)]\rho_2$$

(where γ is the ratio of specific heats, subscript 1 indicates a location upstream of the shock, and subscript 2 indicates a location downstream of the shock) relates the upstream and downstream velocity heads and, as shown in the graph, can be used to extend a subsonic calibration to supersonic flow (ref. 2). This year Lewis researchers used the drag

force anemometer in the flow field behind a supersonic flowthrough fan at Mach numbers to 2.7.



Velocity head calibration curve.

References

1. Krause, L.N.; and Fralick, G.C.: Miniature Drag Force Anemometers. NASA TM X-3507, 1977.

2. Richard, J.C.; and Fralick, G.C.: Use of Drag Probe in Supersonic Flow. AIAA J., vol. 34, no. 1, 1996, pp. 201-203.

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