Visualization of Shock Wave by Electric Discharge

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Theme

OPTICAL systems such as schlieren systems, Mach-Zehnder interferometers, and shadowgraphs have been used as typical methods to observe shock waves around models.[1] However, any shock shape cannot necessarily be observed by these optical systems. For instance, it is difficult to measure a cross-section of a shock wave around a model, especially that around a winged body as shown in Fig. 1. In this case the shock shape in the shaded region (dotted line) cannot be observed by any optical method, because a part of the optical axes is intercepted by the body.

In this paper, an observing method of shock waves by using an electric discharge has been tried. The principle of the method is based on the fact that a radiation intensity of an electric discharge depends on gas densities. When an electric discharge is generated across a shock wave, the radiation intensity in the shock layer is different from that in the freestream according to the difference of each density, consequently the location of the shock wave can be easily found by taking a photograph of this discharge column. Since the location of the electrodes may be chosen arbitrarily and the discharge column can be observed from any direction, it will be expected to be able to observe cross-sectional shock shapes or the shock wave in a shaded region as stated above.

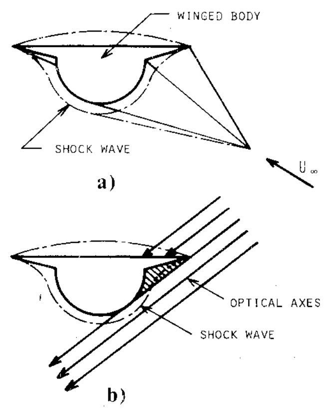

Fig. 1 a) Shock wave around a winged body. b) Cross-section and optical axes.

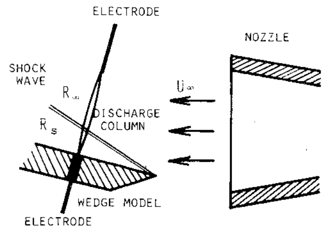

Fig. 2 Sketch in the test section.

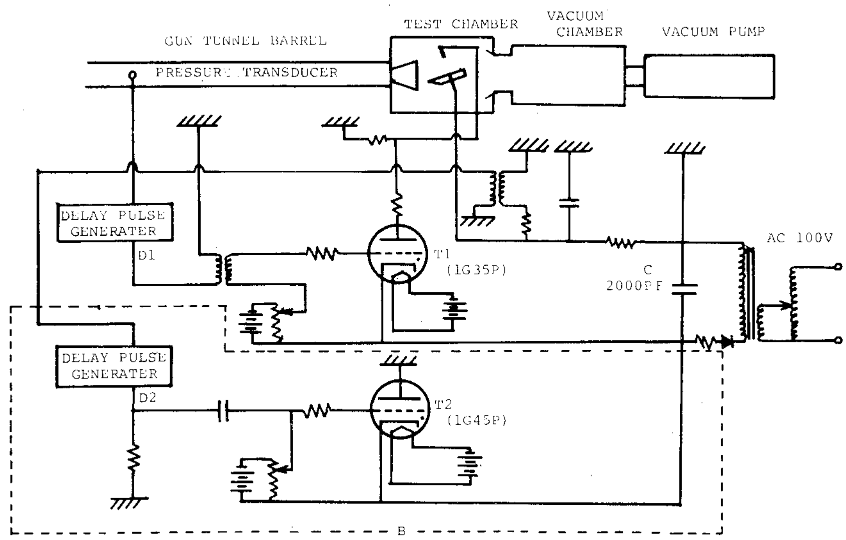

Fig. 3 Discharge circuit.

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Index categories: Shock Waves and Detonations; Supersonic and Hypersonic Flow.

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Contents

A sketch in the test section is shown in Fig. 2. One of the electrodes is inserted in a model and another one is settled in the freestream region apart enough not to make the shock wave disturb. An electric discharge is generated between these electrodes. In the electric discharge column, free electron velocities in the freestream region R_∞ are different from those in the shock layer R_s because there exists differences between gas densities in R_∞ and R_s. The radiation intensity depends on the excitation cross-section which is related to the gas density

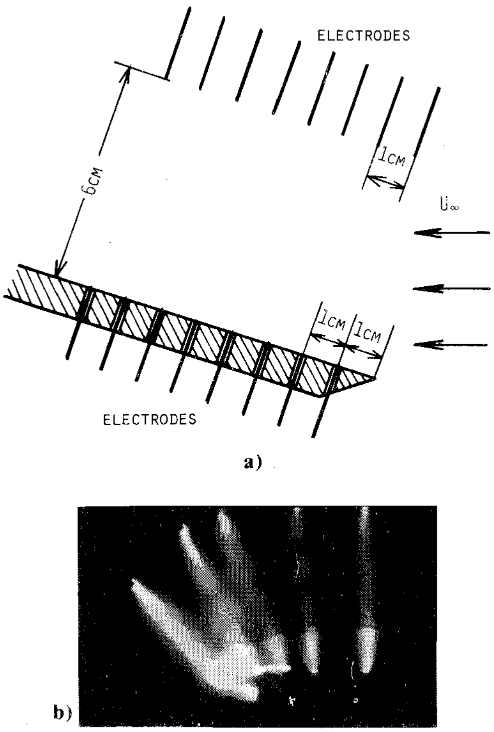

Fig. 4 a) Location of electrodes. b) Lateral shock shape.

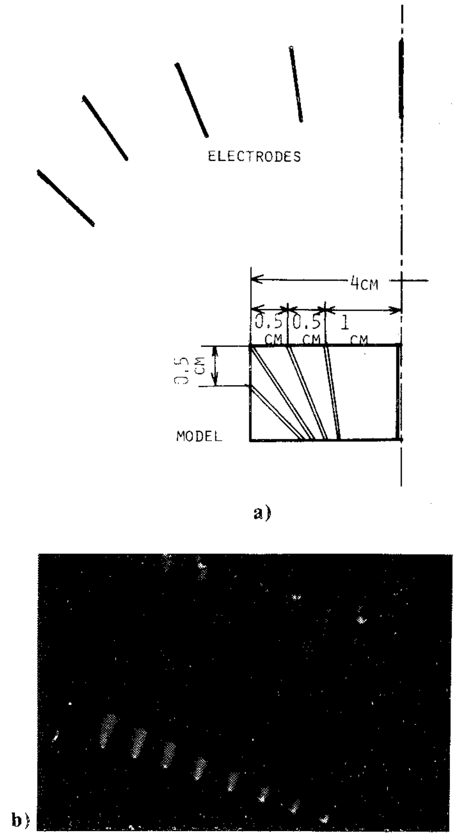

Fig. 5 a) Location of electrodes. b) Cross-sectional shock shape.

and the electron velocities,[2] therefore each radiation density of the region R_∞ and R_s differs from each other.

The supersonic freestream was obtained by a hypersonic gun tunnel[3]; Mach number $=10$, Reynolds number $=2\times10^4$ cm^{-1}, freestream velocity $U_\infty=10^3$m/sec, static pressure $=0.4$ mmHg, freestream density $\rho_\infty=4\times10^{-4}$ kg sec^2/m^4 and duration time $=10$ msec. The exit diameter of the nozzle is 15 cm. The electrode in a model is 0.1 cm in diameter and its surface is finished smoothly with the model surface. Another electrode, 0.1 cm in diameter, is set at distance of 3 cm and 6 cm from the model. Figure 3 shows the discharge circuit.

The location of the shock wave can be decided from photographs of the discharge column. Since one discharge column shows only one point of the shock location, a large number of discharges must be generated at several places along the shock wave. In this experiment, eight discharges were applied to observe the oblique shock wave over a wedge model as shown in Fig. 4a. The angle of attack was 20°, each electrode was arranged at 1 cm intervals from the leading edge and the gap of the electrodes was 6 cm. The strength of electric field was 3×10^4V/m. The experimental result shown in Fig. 4b agrees well with the shock shape determined by the schlieren method.

Figure 5a shows a schematic diagram for the measurement of a cross-sectional shock shape. The position of the cross-section was at 7 cm apart from the leading edge. The width of the wedge model was 4 cm, and five pairs of electrodes were used. Experimental conditions were the same as those in Fig. 4. This result is shown in Fig. 5b. The shock shape near the center of wedge shows the two-dimensional oblique shock wave and its thickness agrees with the result of Fig. 4. The shock shape near the wedge edge is no longer two-dimensional wedge flow due to cross flows.

References

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[2] Von Engel, A., *Ionized Gases,* 2nd ed., Oxford University Press, Amen House, London, 1965, pp. 217-221.

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