VISUALIZATION OF 3D NON-STATIONARY TRANSONIC FLOW IN SHOCK TUBE USING NANOSECOND VOLUME DISCHARGE

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Non-stable flow, high - speed gas dynamics processes and microsecond interactions can be visualized with pulse (nanosecond-lasting) volume discharge [1, 2]. Special type of discharge was involved for original method for visualizing supersonic flows: pulse volume discharge with ultraviolet preionization by radiation from the sliding surface discharges. The exposure time during discharge glow (200 ns) is much shorter than gas dynamics time intervals. It is possible to use the total discharge glow recording for the non-stationary flow visualizing method. During a short exposure time discharge does not influence the flow structure. Ionization of non-homogeneous flow results in spatial redistribution of discharge plasma. Electron concentration (Ne) depends on local gas density (ρ). Shock waves, vortexes, weak disturbances in the gas flow are visualized as far as the local plasma glow intensity depends on the local gas flow density.

Various configurations of 2D, axis-symmetrical non-stationary flows were visualized in shock tube test chamber using pulse volume discharge with ultraviolet pre-ionization [1-4]. Instant discharge images of different supersonic flows after shock wave diffraction on obstacles were obtained. Numerically computed gas density fields had been compared to the images of ionized flow [3].

Experimental investigations of 3D transonic flow over model of payload shrouds were conducted in wind tunnel (4) and in a shock tube. Surface pressure pulsations were mated with transition from the developed separation of a boundary layer to a local one. Shadow technique cannot be used successfully to study 3D non-stable flow over model: optical path in the central flow area is not transparent for sounding light beam – the model blocks it.
Pulse electrical discharge visualization method allowed obtaining images of local low-density areas from two different views – upwind and downwind the model. Instant 3D images of transonic flow around complex cone model were obtained using pulse volume discharge technique.

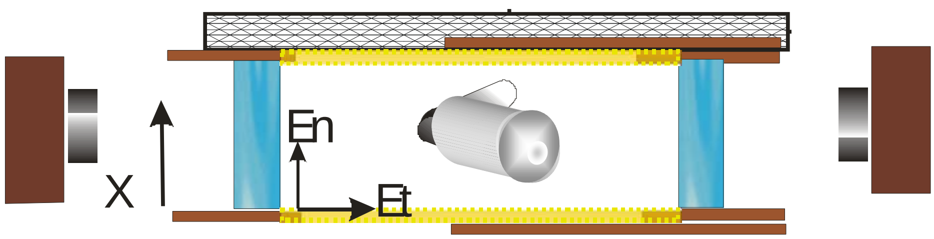

Fig.1. Pulse discharge visualization: scheme of experiment

Complex model (2 cylinders, 2 cones) was mounted in a discharge gap in the shock tube channel at the angle of attack 9°. The upwind and downwind sides were oriented on the windows of a shock tube test chamber (Fig. 1). The distance between opposite shock tube windows was 48 mms. The incident shock Mach number M=1,9-2,3, the flow Mach number 0.8 ÷ 1.1. Low pressure values – 10-30 torr. The model diameter– 9 mm, Re = $10^4 \div 10^5$. The fFlow duration was 300-350µs. Discharge pulse was synchronized with a pressure sensors signal: discharge was initiated in different stages of gas dynamics process.

The simultaneous instant images from two windows were taken on 2 cameras, scanned and analyzed. Images of different stages of shock wave diffraction on the complex model were obtained. Fig. 2 presents the pairs of instant (200ns-exposure) images of 2 different stages of shock diffraction. In Fig.2a shock wave (1) had passed over the complex model. The discharge glow was in front of the shock - in the low-density area. In Fig.2b the shock had passed away from the discharge gap. The redistribution of plasma glow in the complex 3D gas flow over the model was visualized in the shock tube flows. Glow reflections in windows glass spoil images. Shock waves (1), separation zones (2), vortexes (3) positions and configurations are seen in Fig.2a. 2 images of the same flow from the opposite sides allow reconstructing the spatial flow structure. The instant image of the pulsating 3D separation zone in the cone rear side is of special interest: 2-3 vortexes were recorded (2 in Fig.2b) with nanosecond volume discharge visualization. Boundary layer instabilities on glass windows surface are also visualized with nanosecond discharge plasma.

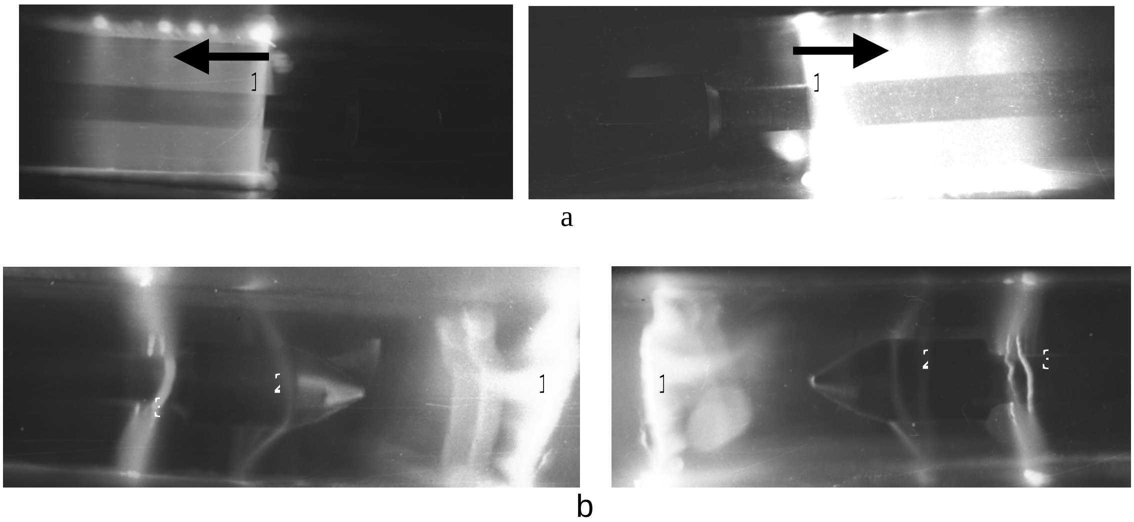

Fig.2. Pulse discharge visualization: flow images (200 ns exposure)

References

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