SHOCK WAVES UNDER NANOSECOND IONIZATION

I. V. Mursenkova, N. N Sysoev, I. A. Znamenskaya

Moscow State University, Leninskie Gory 1, Moscow, 119992 Russia

Shock wave interaction with the zone of instant (nanosecond-lasting) ionization is a complicated non-stationary process. The research of the quick energy release influence on the parameters of gas flow is a very actual problem. This problem is closely linked with applied problems of laser physics, plasma chemistry, plasma aerodynamics [1]. The purpose of the work is to investigate pulse volume and surface discharges in the test camera of a shock tube in the presence of different shock configurations and discharge glow analysis.

The experimental setup consists of the special discharge chamber mounted with a shock tube. The tube and discharge chamber have a rectangular profile of 48×24 mm. Experiments were made in the air at the pressure from 20 to 600 Torr. Mach numbers of a shock wave were M = 2-6; flow velocities from subsonic to 1600 m/s. Two side walls of the discharge chamber were the quarts plane glasses of 170 mm length.

Surface discharges (plasma sheets) were organized in the discharge chamber. Plasma sheets were the system of channels sliding on a dielectric surface. They were initiated on two opposite walls of discharge chamber size of 35×100 mm at a distance of 24 mm from each other [2-4].

Pulse volume discharge was realized after UV pre-ionization from plasma sheets. The pulse discharge time was about 200 ns, the voltage was 30-40 kV, the discharge current was about 1000 A. Integral glow of discharge was registered by photo camera through the windows of the discharge section. So, the setup allows experimental modeling of the process of instant creating of the plasma area in the supersonic flow with the different shock wave configurations.

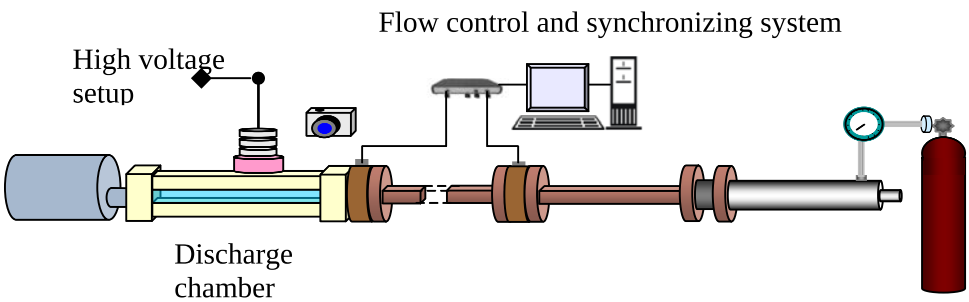

Fig. 1. Experimental setup

Quick processes in the gas flow are determined by non-stationary interactions of discontinuities and inhomogeneities moving with subsonic (~10^2 m/s) up to hypersonic (~ 10^4 m/s) velocities. The range of characteristic gasdynamic time interval is ~ 10^{-5}-10^{-7} s. The energy input process realized in the time interval t_e much smaller than the characteristic time can be considered as “instant”. At the shock wave velocity in the gas-plasma medium ~10^3 m/s, (Mach numbers of a shock wave in a gas are M = 2-6) the times should be of nanosecond scale – no more than $0{,}5\cdot10^{-6}$ seconds. At the time $t_e > 10^{-6}$ s the shock wave shift is comparable with characteristic scales of the gas flow. In that case it is necessary to take into account gas flow configuration changes and thermal heating during the time of energy input t_e. Thus, for adequate experimental simulation of impulse energy input in a segment of non-stationary gas flow with shock waves it is necessary to realize homogenous ionization with nanosecond duration. Pulse volume discharge with pre-ionization should be considered as instant energy input in the gas flow with shock waves. Pulse surface discharge realizes instant energy deposition in the gas near a boundary layer.

In the homogeneous gas, volume discharge forms the homogeneous plasma background in the area between plasma electrodes. In the presence of shocks the discharge is redistributed in a non-uniform gas flow according to its structure. Integrated recording of the discharge luminescence in a flow represents the image with an exposure of the discharge flash. Fig. 2 is the luminescence image of the discharge gap crossed by a shock wave (M = 2.3), which has passed about 50 % of the electrodes length. Both discharges (surface and volume) burn in the zone of the low gas' density – in front of the shock wave. Thus, at initiation of the discharge in the channel with a shock wave, the gas-plasma plane border is created instantly (during 200 nanoseconds) at the shock wave front. Gas flow ionization by the volume impulse discharge leads to volume discharge current redistribution in the low-density area due to the local medium conductivity dependence on the value of Taunsend parameter E/N (E – electric field, N – molecules concentration). The discharge concentrates in the low-density area which becomes a source of the increased intensity of luminescence. Discharge was self-concentrated in the low-density areas, which became the source of advanced intensity of lighting. Experiments revealed that the discharge plasma glow intensity increases near the front of the shock (Fig. 2).

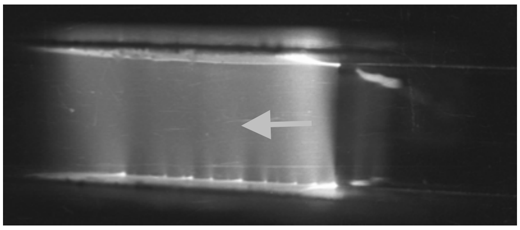

Fig. 2. Discharge image with plane shock

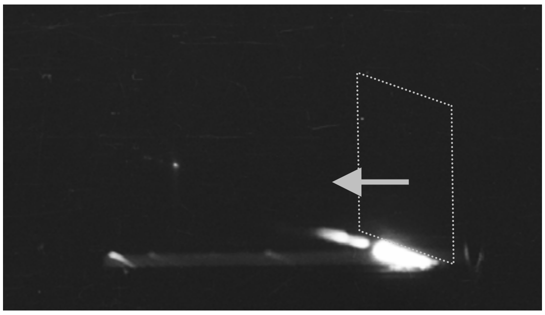

Fig. 3. Surface discharge image with plane shock

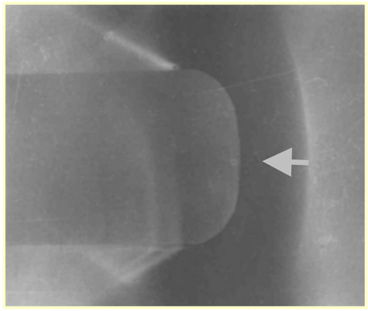

Fig. 4. Discharge image with bow shock configuration

Fig. 3 is the photo of the surface discharge area with a plane shock wave M=2.3. Experiments showed that surface discharge concentrated in the low-pressure area in front of the shock wave. Also we can see that glow is not homogeneous. It is more intensive near the shock surface. Fig. 4 is the photo of the discharge area with a bow shock wave M=1.5. Also, the glow intensity increases near fronts of shocks.

2 types of discharges in non-stationary gas flow with shock waves were used for investigating nanosecond flow ionization. The effect of the glow intensity increase towards the shocks fronts in nanosecond ionization was revealed.

Acknowledgements

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References

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