SHOCK WAVE PROPAGATION IN GASES UNDER SUBATMOSPHERIC PRESSURE

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Abstract

In the present paper the results of the experiments on the investigation of the shock wave dynamics under subatmospheric pressure in neutral gases are presented. The characteristics of spherical and plane configuration shock wave excitation and propagation are studied in the pressure region 1 Torr$< p <$760 Torr. It is shown that when p = 3 Torr it is still possible to fix successfully the shock wave appearance and propagation in various neutral gases. The pressure dependence of the shock wave propagation velocity and amplitude is determined experimentally. It is shown that when the pressure decreases the shock wave amplitude decrease and the increase of the Mach number take place. In the case of plane shock wave Mach number reaches the value M = 5.2 under the pressure p = 3 Torr.

1. Introduction

The study of the shock wave propagation in gases in the wide range of pressure is one of the interesting problems of nonlinear gasodynamics. Shock wave dynamics in the case of atmospheric pressure of the medium is studied quite well. There exists also a number of investigations which deal with the study of gas flows when the pressure of the medium is low ($p <$1 Torr). The study of the nonlinear gasodynamocal events in ionised gas and plasma is the separate problem. In this case the pressure of the medium $p <$1 Torr. On the other hand the study of the nonlinear gasodynamical events when the pressure is medium (1 Torr$< p <$100 Torr), is of great interest. In this case the medium is quite dense and the shock wave dynamics can be described by the classical theory [1,2], and, on the other hand, in this region of pressure it is possible to get the stable diffusive electric or ultra high frequency discharge. In this case it becomes also possible to compare the shock wave dynamics in ionised and nonionised medium under the same pressure. The investigation of the shock wave dynamics is of great interest during the study of a number of processes which take place in the various plasma devices. Shock wave interaction with plasma at the atmospheric pressure has been described in the paper [3]. It must be mentioned that the laser discharge plasma discussed in this experimental work is quite difficult object for the study of the shock wave because of its strong turbulence. Still there is no answer on the question about the reason of the shock wave strong dissipation, which was already described in [4].

The present work is the preliminary experimental investigation for the study of the shock wave dynamics under those pressure, when it is possible to get the stable gaseous discharge. The aim of the work is the experimental study of the shock wave dynamics in the pressure region 1 Torr$< p <$100 Torr, in various gases. Shock wave excitation takes place by means of electric discharge, which gives the possibility to imitate the single point explosion. Two configuration of the shock waves are studied: spherical, then the shock wave propagates in the unlimited medium, and plane, when the shock wave propagates along the cylindrical waveguide.

In the case of the spherical shock wave, the wave dynamics can be described as a single point explosion with the opposite pressure [5]. In this case the shock wave velocity sharp decreases and goes to the constant magnitude [6]. On the other hand during the pressure decrease the factor of the opposite pressure also decreases and in the case of the single point explosion under low pressure one must use the theory of the strong explosion.

2. Experimental set-up and results

Scheme of the experiment is presented in Fig. 1. In the vacuum camera **1**, which is equipped with the systems of gas pumping **3** and gas puffing **2**, the shock wave generator **4** and movable piezosensor **5** are situated to the opposite of each other. It is possible to place the waveguide **6** between them. The waveguide is the glass tube with the diameter 1.5 cm. The shock wave is excited by electric spark discharge, when the capacitor C, charged on the given voltage is discharged by switching the trigatron D. It is possible to create the atmosphere of various gases in the camera within the pressure region 760$\div$1 Torr. The capacity of the shock wave generator capacitor is 0.1 μF, the working voltage U = 20 kV. R resistor is used for the concordance wit the coaxial line. In such scheme 50% of the energy kept by the capacitor is released in the spark. The structure of the piezosensor gives the possibility to move it along the waveguide and place it on any distance from the shock wave generator.

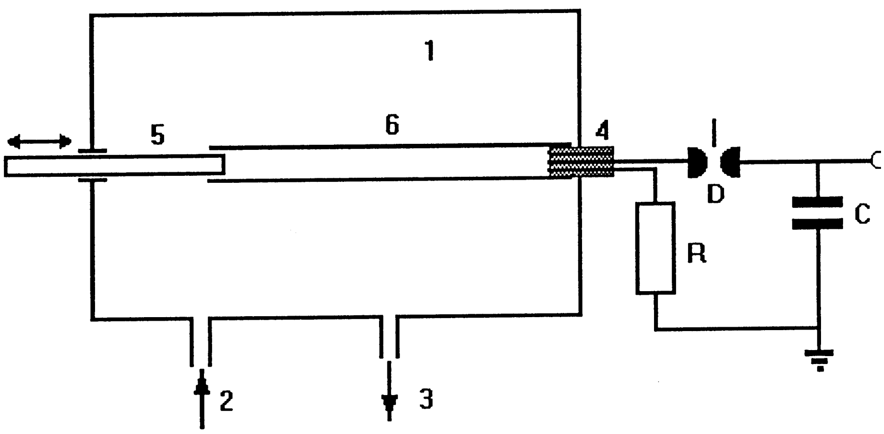

Figure 1. Experimental setup

In the experiments it was measured the time, which is necessary for the shock wave to reach the piezosensor from the discharger under various pressure. In one case the gas pressure was changed under the fixed position of the piezosensor and in another case the distance from the sensor to the discharger was varied under the fixed pressure. The experiments were performed for both - spherical and plane shock waves.

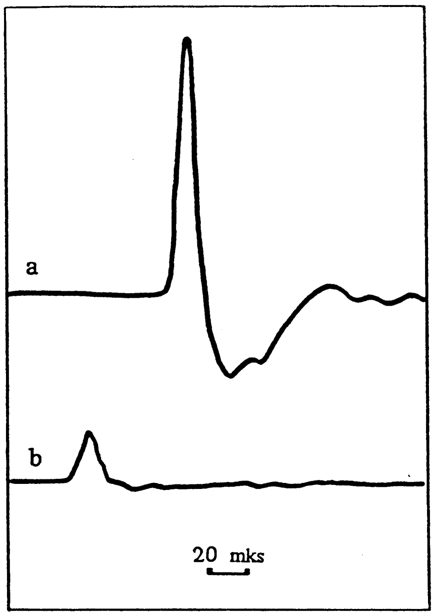

Figure 2. Spherical shock waves for (a) p = 300 Torr and (b) p = 10 Torr

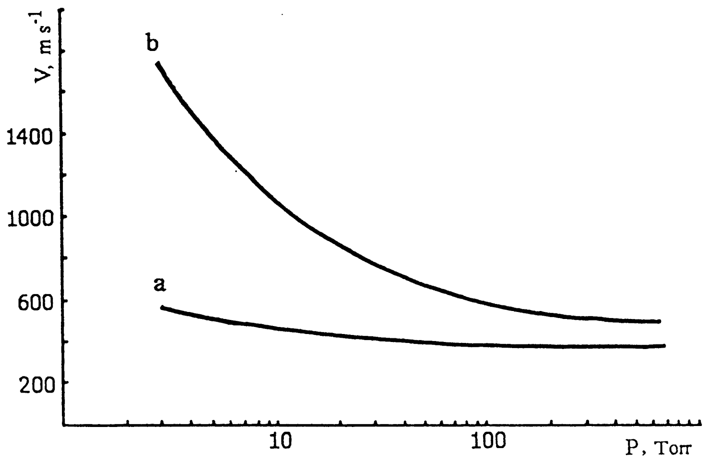

Figure 3. Velocity vs. pressure for (a) spherical and (b) planar shock waves

In Fig. 2 are presented the pictures of spherical shock waves registered by the piezosensor under p = 300 Torr (a) and p = 10 Torr (b) pressures in the air, on the 5 cm distance from the discharger. Under the constant pressure the spherical shock wave velocity decreases during the distance increase [6]. On the other hand when the pressure decreases, the wave velocity increases. In Fig. 3, the pressure dependence of the average velocities of (a) spherical and (b) plane shock waves in the case of air are presented. If we assume that in the considered region of pressure the sound velocity is given by the classical formula $c = \sqrt{\kappa RT}$, where $\kappa = C_p/C_v$ and R is the gas constant, then we can estimate the main characteristic of the shock wave - Mach number. As the measurements show, the increase of the Mach number takes place when the pressure decreases. At the same time for the spherical shock wave the Mach number magnitude increases from M = 1.2 (p = 720 Torr), up to M = 1.6 (p = 3 Torr), and for the plane shock wave in the waveguide - from M = 1.5 (p = 720 Torr), up to the value M = 5.2 (p = 3 Torr).

As one can see from the Fig. 2, the shock wave amplitude on the same distance decreases while the pressure goes down. In Fig. 4, the dependence of the shock wave amplitude (in relative units) on the pressure is presented. We must mention that the pressure dependence of the amplitude is the same for the air and Helium.

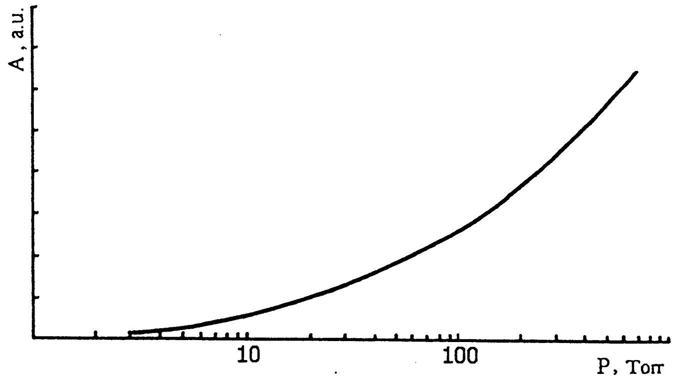

Figure 4. Shock wave amplitudes vs. pressure

3. Conclusion

We can conclude from all the above mentioned things the following:

a) the shock wave can be clearly fixed in gas by means of the piezosensor in the wide range of pressure and in the case, when the pressure $p = 1 \div 10$ Torr it is possible to study the form of the shock wave by means of this method

b) in the given region of pressure the plane shock wave is formed by the above described method and its velocity in the wide region ($\sim$30 cm) is practically constant.

The performed work will give, in the future, the possibility to study the shock wave propagation in the ionised medium under the pressure $p = 1 \div 10$ Torr, in the atmosphere of various gases. At the same time, because it follows from the experiments, that the shock wave is quite stable on a large distances in the waveguide and propagates with the constant velocity, one can presume that it will be possible to study in the future the shock wave dissipation mechanisms in the ionised medium.

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