AN EXPERIMENTAL STUDY OF THE PRESSURE BEHIND REFLECTED SHOCK WAVES IN HYDROGEN

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The spectral properties of hydrogen at high temperatures are of interest for the theory of continuous spectra, the broadening of spectral lines in a plasma, and for numerous astrophysical applications. For a correct explanation it is necessary to exactly determine the temperature and pressure of the high-temperature gas. Therefore, in the present report we raised the problem of directly measuring the pressure behind powerful reflected shock waves.

A piezoelectric pickup was used to measure the pressure behind shock waves. The procedure for preparing the pickup and measuring the pressure behind powerful shock waves is given in [1, 2]. To obtain powerful shock waves we used a two-diaphragm shock tube [3], the high-pressure chamber of which has a length of 2.5 m, the intermediate-pressure chamber 3 m, and the low-pressure chamber 8 m, while the inner diameters of all the chambers are 0.1 m. The leakage into the low-pressure chamber is $1.33 \cdot 10^{-1}$ N/m^2 per minute.

Hydrogen of high purity was used for the investigation. The measurements were made at initial pressures of $1.33 \cdot 10^2$ and $1.33 \cdot 10^3$ N/m^2 at a distance of 0.005 ± 0.001 m from the end of the shock tube (80 calibers from the second diaphragm). The Mach number of the incident wave varied from 6 to 15, which corresponds to a velocity of $(3-10) \cdot 10^3$ m/sec for the incident wave.

The molecular weight of hydrogen is low, so that slight air leakage into the low-pressure chamber can significantly alter the molecular weight of the test gas, which leads to a pronounced change in the Mach number of the incident shock wave. So that the molecular weight of the test gas would not change significantly owing to air leakage, we added to the hydrogen 20% argon, which is hardly ionized under such conditions since its ionization potential is higher than the ionization potential of hydrogen.

The dependence of the pressure behind a reflected shock wave on the velocity of the incident shock wave for this gas mixture ($0.8H_2+0.2Ar$) is presented in Fig. 1. The experimental values of the pressure are given by points, while the continuous curve gives the calculated values obtained in [4] in accordance with the gasdynamic theory of a shock tube with allowance for the change in the enthalpy of the mixture due to the dissociation and ionization of the hydrogen.

From a comparison of the experimental and calculated values it is seen that there is satisfactory agreement between them within the limits of the experimental errors.

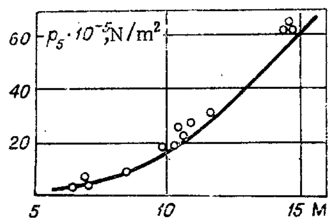

Fig. 1

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A NONSTATIONARY AXISYMMETRIC MOTION OF GAS

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Axisymmetric nonstationary and irrotational motions of gas can be described by the system of equations [1],

$$r\frac{\partial a}{\partial t}+Nr\frac{\partial a}{\partial r}+T\frac{\partial a}{\partial\theta}+(\gamma-1)a\left[\frac{\partial(Nr)}{\partial r}+\frac{\partial T}{\partial\theta}+N+T\operatorname{ctg}\theta\right]=0,\quad(1)$$
$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial r}[(N^2+T^2)/2+a/(\gamma-1)]=0,$$
$$\frac{\partial N}{\partial\theta}-\frac{\partial}{\partial r}(Tr)=0,\ a=\frac{dp}{d\rho},\ p=A\rho^{\gamma},$$

where N and T are the radial and the tangential components, respectively, of the gas velocity; a is the square of sound velocity; r, θ are the spherical coordinates.

A class of solutions will be found for system (1) assuming that the velocity components N, T depend on the angle θ and the time t only. It follows from the third equation in (1) that

$$N=f(\theta,t),\ T=f'_{\theta}(\theta,t).\quad(2)$$

By inserting N and T as given by (2) into the second equation of (1), an expression is obtained for the square of sound velocity in terms of the function $f(\theta, t)$

$$a=-(\gamma-1)[rf'_t+\psi(\theta,t)],\quad(3)$$

where $\psi(\theta, t)$ is an arbitrary function. The use of (2) and (3) reduces the first equation in (1) to the following system:

$$f=t\varphi(\theta)+x(\theta),\ \psi+A(\theta)t^2/2+B(\theta)t+\mu(\theta)=0,\quad(4)$$
$$(\gamma-1)\psi(2f+f'_{\theta}\operatorname{ctg}\theta+f''_{\theta\theta})+f'_{\theta}\psi'_{\theta}=0,$$

where

$$A(\theta)=(2\gamma-1)\varphi^2+(\gamma-1)\varphi''_{\theta\theta}\varphi+\varphi'^2+(\gamma-1)\varphi\varphi'_{\theta}\operatorname{ctg}\theta;\ B(\theta)=(2\gamma-1)x\varphi+(\gamma-1)x''_{\theta\theta}\varphi+x'_{\theta}\varphi'_{\theta}+(\gamma-1)\varphi x'_{\theta}\operatorname{ctg}\theta;$$

$\mu(\theta)$ is an arbitrary function. Since θ and t are independent variables, therefore (4) implies an overdetermined system of equations for finding $\varphi(\theta)$, $x(\theta)$, $\mu(\theta)$

$$(\gamma-1)(2\varphi+\varphi'_{\theta}\operatorname{ctg}\theta+\varphi''_{\theta\theta})A+\varphi'_{\theta}A'_{\theta}=0,\quad(5)$$
$$(\gamma-1)(2x+x'_{\theta}\operatorname{ctg}\theta+x''_{\theta\theta})A+x'_{\theta}A'_{\theta}+2B(\gamma-1)(2\varphi+\varphi'_{\theta}\operatorname{ctg}\theta+\varphi''_{\theta\theta})+2\varphi'_{\theta}B'_{\theta}=0,$$
$$(\gamma-1)(2\varphi+\varphi'_{\theta}\operatorname{ctg}\theta+\varphi''_{\theta\theta})\mu+\varphi'_{\theta}\mu'_{\theta}+B(\gamma-1)(2x+x'_{\theta}\operatorname{ctg}\theta+$$
$$+x''_{\theta\theta})+x'_{\theta}B'_{\theta}=0.$$
$$(\gamma-1)(2x+x'_{\theta}\operatorname{ctg}\theta+x''_{\theta\theta})\mu+x'_{\theta}\mu'_{\theta}=0.$$

The consistency of (5) is now analyzed. By assuming that $\varphi'_{\theta}\neq 0$, $x'_{\theta}\neq 0$, one can eliminate from (5) A'_{θ}, B'_{θ}, μ'_{θ}. As a result, one arrives at a relation between x and φ,

$$[Ax'_{\theta}/\varphi'_{\theta}+2\mu\varphi'_{\theta}/x'_{\theta}-2B][\Phi/\varphi'_{\theta}-X/x'_{\theta}]=0,\quad(6)$$

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