Thus, in the case $Pr \ll 1$, the value of Pr_T, in the greater part of the thermal sublayer, varies proportionally to the distance to the wall. In this case there is no analogy between the turbulent transfers of heat and momentum.

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WAVE FORMATION WITH THE COMBUSTION OF CONDENSED SUBSTANCES IN A TURBULENT FLOW

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The surface of samples of powder burning in a flow in the presence of erosion is spotted with roughnesses of almost-periodic structure [1]. Such roughnesses are also observed with the combustion of some ablating materials in a flow [2]. It has been observed that, with the unstable (resonance) combustion of powders, different acoustical modes correspond to the structure of the roughnesses [3]. One of the possible mechanisms of the formation of waves on the surface, developed in [4, 5], has still not received sufficient experimental confirmation. The present article discusses the laws governing the formation of a wave structure on the surface of various condensed substances, burning in a turbulent flow of the combustion products of ballistic powder N.

The experiments were made in a unit, analogous to that described in [6], and consisting of a gas generator with an erosion nozzle, a device for letting down the pressure, and a counterpressure block. A charge of ballistic powder N was put into the combustion chamber. The erosion nozzle ensured the possibility of blowing the sample under investigation with powder gases. The velocity of the gas flow and the level of the pressure were regulated by a change in the parameters of the gas generator. Extinction was effected by letting down the pressure with the sudden opening of an opening on the side of the combustion chamber. The starting parameters (the combustion surface, the critical cross section, etc.) were so selected as to exclude the appearance of instability or resonance combustion. Thus, in all the experiments, the combustion took place under steady-state conditions.

The investigations were made on samples made of Capron, vinyl plastic, ebonite, Plexiglas, fluorine plastic, polyethylene, textolite, and graphite, with a constant pressure of $75 \cdot 10^5$ N/m^2 and velocities of the blowing of 10-600 m/sec. The samples were cylindrical, with a diameter of $1.7 \cdot 10^{-2}$ m and a length of 0.1 m.

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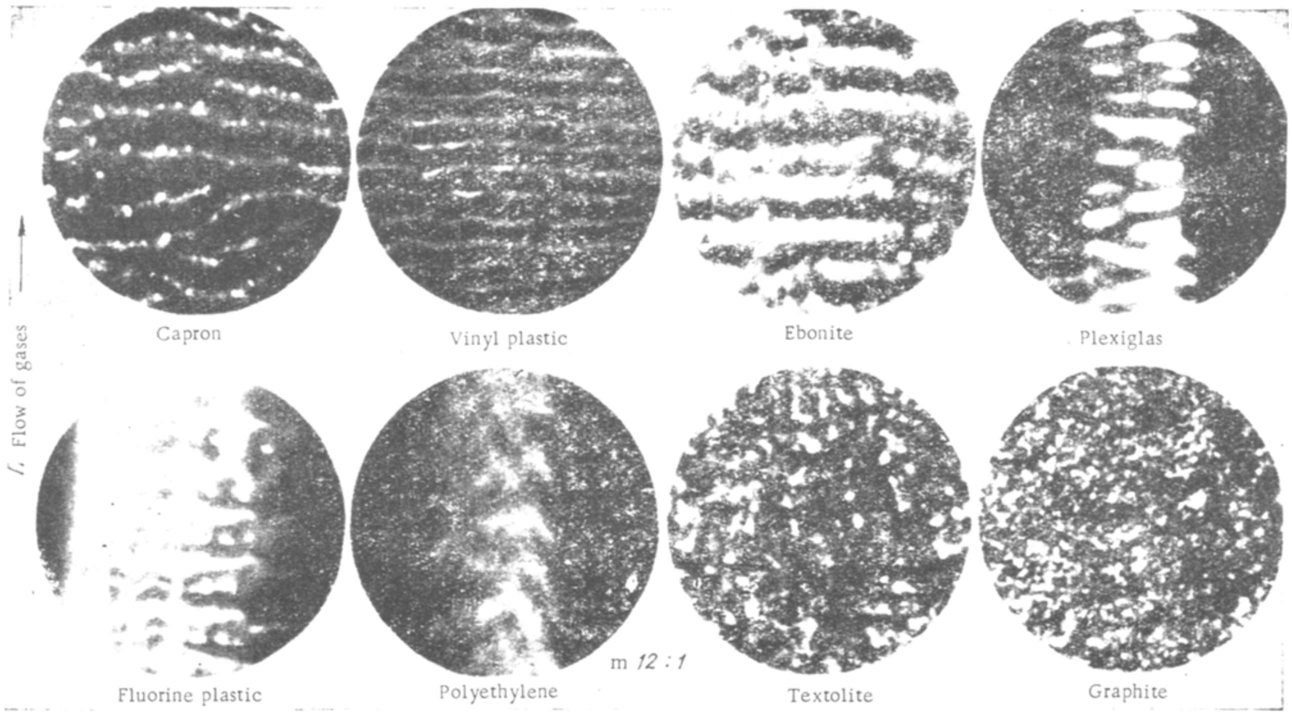

Fig. 1

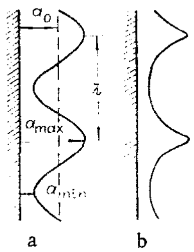

Fig. 2

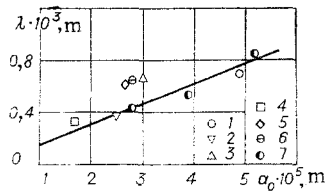

Fig. 3

Figure 1 gives photos of the surfaces of samples burning in a blown flow of gases with a velocity of 500 m/sec and a pressure of 70 atm. On the first six samples, ripples can be clearly seen, whose character depends on the physicochemical properties of the system under investigation.

The surface of textolite is covered with carbon fibers, covering the tissue paths. When the fibers are removed, no ripples are observed on the surface. On the surface of graphite, small structural cracks are observed; however, on the whole, the surface is practically even.

The observed ripples have a more or less periodic character. In their structure, they recall waves, whose length and amplitude, other conditions being equal, depend on the material under investigation. With a change in the velocity of the blown flow, there are regular changes in the kind of surface formations. Several regions can be isolated. With flow velocities of 50-100 m/sec (region I) the surface of the samples is even and smooth. With an increase in the velocity of the flow, waves are formed, whose profile is close to sinusoidal. A large single wave sometimes separates out against the background of the wavy structure.

With flow velocities of 200-500 m/sec (region II) a continuous periodic structure can be observed on all the samples (Fig. 2a), which, with a rise in the velocity of the flow, is characterized by a decrease in the wavelength and the amplitude. The boundaries of this region, with respect to the value of the velocity of the flow, are unique for each condensed substance.

With a further increase in the velocity of the flow (region III), the crests of the waves become sharp. Now, a rise in the velocity of the flow leads to an increase in the amplitude of the wave, although, as before, the wavelength decreases. The profile of the wave becomes close to trochoidal (Fig. 2b). At all velocities, the surfaces of the samples of textolite and graphite remain identical.

The decrease in the wavelength with a rise in the velocity of the flow and the appearance of waves only on the surface of materials for which there is no doubt of the existence of a liquid-viscous layer with combustion constitute evidence of the participation of the forces of surface tension in the wave formation. In actuality, in the case of the combustion of textolite and graphite, for which a dry surface can be postulated in advance, in a flow of gases, waves are not observed. Waves obviously constitute evidence of the presence of a liquid phase on the surface of the burning substances.

It is interesting to compare some of the dependences obtained experimentally and theoretically by a number of investigators for waves on the surface of thin films of water or alcohol, for the case of film-type flow through tubes in the presence of a flow of cold gases.

In accordance with the formula of Kapitsa [7]

$$\alpha = \frac{a_{max} - a_{min}}{a_{max} + a_{min}} = 0.46, \tag{1}$$

confirmed experimentally in [8], in region II the amplitude of the wave can be calculated over to the thickness of the liquid film a_0. The meaning of the notation is clear from Fig. 2a. The doubled amplitude of the wave and the wavelengths are determined experimentally by direct repeated measurements under a microscope.

Figure 3 gives points for various materials [1) Capron; 2) vinyl plastic; 3) ebonite; 4) Plexiglas; 5) fluorine plastic; 6) polyethylene; 7) ballistic powders], showing the dependence of the wavelength λ on the thickness of the liquid film a_0. The measurements of the values of λ and $(a_{max} - a_{min})$ were made in wave region II, where formula (1) holds.

In accordance with the expression obtained in [8],

$$\frac{\Delta\lambda}{\lambda} = \frac{1}{2}\left(\frac{\lambda}{\pi d}\right)^2,$$

the diameter of the samples investigated cannot have any significant effect on the length of the waves forming $(\Delta\lambda/\lambda \leq 0.02\%)$.

We note that the experimental points are grouped around a limiting dependence (the straight line), obtained for liquids in [9] and described by the expression

$$\frac{a_0}{\lambda} = 2\pi\left(\sqrt{2} - 1\right). \tag{2}$$

With an analogous test of ballistic powder, the experimental points practically lie on the theoretical curve (2). Figure 3 plots three points, corresponding to pressures of $75 \cdot 10^5$, $150 \cdot 10^5$, $300 \cdot 10^5$ N/m^2, and flow velocities of 100-150 m/sec. A rise in the pressure leads to a decrease in the wavelength. The waves on the surface of the powder are very clear and start to appear with a velocity of the flow equal to approximately 100 m/sec; the higher the pressure, the lower the value of the velocity. Region II for powder occupies a small interval of flow velocities (a few tens of m/sec). In this region, the number of cells formed with the dispersion of particles from the combustion surface is considerably less than with the combustion of a powder without a flow; a large part of the cells are deformed, particularly at the crests and troughs of the waves, and have an elongated form along the wave.

With a rise in the velocity of the flow, the amplitude of the wave in region III starts to decrease before attaining a maximal value, which is accompanied by a more appreciable splitting of the crest of the wave into individual parts. With a flow velocity greater than 500 m/sec, the wave becomes practically three-dimensional. It is obvious that here there starts the following region (region IV), characterized by a large percentage of three-dimensional formations, having an inclination along the flow of the gas.

Calculations show that the product of the thickness of the liquid film by the rate of combustion of a powder $(a_0 u)$ in region II at pressure of $(75\text{-}300) \cdot 10^5$ N/m^2, with a variance not exceeding 12-15%, remains constant. This means that a_0 is proportional to the thickness of the heated layer of powder. According to Fig. 3, the wavelength λ is also proportional to the thickness of the heated layer.

In contrast to the effect, following from [4], of an increase in the wavelength with a rise in the velocity of the blowing flow, the experiments show that, as for the condensed substances discussed above, a rise in the velocity of the flow leads to a decrease in the length of the waves at the surface of a burning powder.

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CALCULATION OF THE EXPLOSION OF A GASEOUS SPHERICAL CHARGE IN AIR

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INTRODUCTION

The problem of the explosion of a spherical charge in air has been solved by numerical methods in one approximation or another [1-4]. The original calculations were made within the framework of the theory of a point explosion [1, 2]. A further refinement of the problem was discussed in [3], where, in calculations of the explosion of a spherical charge of Trotyl, account was taken of the dimensions of the charge and the behavior of the detonation products. With such a statement of the problem, the basic characteristics of the flow behind the front of a blast wave were obtained, reflecting the experimental results more exactly. An investigation of the effect of the initial pressure of the air and the specific energy of the charge on the parameters of the flow behind the front of a blast wave was made in [4]. In [5, 6] it was shown experimentally that, with the explosion of a spherical charge of explosive consisting of a detonating gaseous mixture, a shock wave is propagated in the air, analogous to the wave arising by the explosion of condensed explosives. On the basis of the results of [5] there appears, in principle, the possibility of a numerical solution of the problem of the explosion of a gas mixture. Since the radius of a gaseous charge is an order of magnitude greater than the radius of a charge of condensed explosive, equivalent with respect to the amount of energy evolved, then in the statement of the problem its dimensions cannot be neglected. In the present work, the Neumann—Richtmyer pseudoviscosity method [7] is used to solve the problem of the propagation of shock waves in air, arising with the explosion of a spherical charge of an explosive gaseous mixture. Quantitative information is obtained on the flow of air and detonation products behind the front of a blast wave for gaseous mixtures of acetylene and propane with air. In these mixtures, the combustible was taken in a stoichiometric ratio with oxygen: 1) $C_2H_2 + 2.5O_2 + 9.4N_2$; 2) $C_3H_8 + 5O_2 + 18.8N_2$. The results of the calculations are compared with the experiments of [5].

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