$$\bar{n} = 1{,}02501 \cos\left(\frac{\pi}{2} r\right) - 0{,}02501 \cos\left(\frac{3\pi}{2} r\right). \quad (25)$$

Comparison of the calculations based on formulas (20) and (25) demonstrates that up to values of r = 0.5 there is virtually no divergence (<1%), while it increases in the range $0.5 < r \leq 1$, not exceeding 6%. In this case the values of $\bar{n}$ are more readily found from formula (20). Let us note that in comparison with [6] the approximate solution of Eq. (2) has also been found for the region with a negative value for the parameter ν.

NOTATION

n, electron concentration; n_0, electron concentration at the axis of symmetry; $\bar{n} = n/n_0$, dimensionless electron concentration; x, coordinate; R, characteristic dimension of discharge zone; r = x/R, dimensionless coordinate; D_a, coefficient of ambipolar diffusion; ν, effective coefficient of direct ionization ($\nu > 0$) or adhesion ($\nu < 0$); β, effective coefficient of stepwise ionization ($\beta > 0$) or recombination ($\beta < 0$).

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POSSIBILITIES OF ELEVATING SPECIFIC CHARACTERISTICS OF ACTIVE MEDIA WITH HEAT PUMPING AT LOW CO_2 CONCENTRATIONS

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We present the calculational results, as well as those of our experimental study, with respect to the specific characteristics of active media with a low carbon-dioxide content.

In the works of numerous authors, including [1, 2], reference is unavoidably made to the influence exerted by the composition, temperature, and pressure of the gas on the characteristics of carbon-dioxide-based molecular lasers. The expansion of heated mixtures of CO_2 and H_2O with nitrogen in a supersonic nozzle is a well-known method of achieving markedly nonequilibrium media. The drawback of this method is its comparatively high relaxation losses, generally amounting to 50-60% at a carbon-dioxide gas concentration of Ψ_C = 10-20% and a water vapor concentration of Ψ_H = 0.5-3%. The utilization of nozzles in which the components are mixed eliminates this shortcoming, but some of the positive characteristics of the homogeneous method are lost. There exists an alternative possibility for reducing the relaxation losses, namely to utilize gas mixtures with a limited CO_2 content at a level of 1-3%. Heat-exchange heaters made on a base of aluminum or zirconium ceramics [3-5] allow us to heat the working mixture to a temperature of 2300-2500 K. The calculations and experiments carried out by the authors demonstrate that under the above-described conditions the relaxation losses do not exceed 15-25%, while the specific disposable energy (the energy stored in the oscillations of the nitrogen molecules and the antisymmetric oscillation mode of the CO_2, multiplied by the quantum efficiency) amounts to 50-100 J/g at a deceleration pressure of 2.5-6 MPa.

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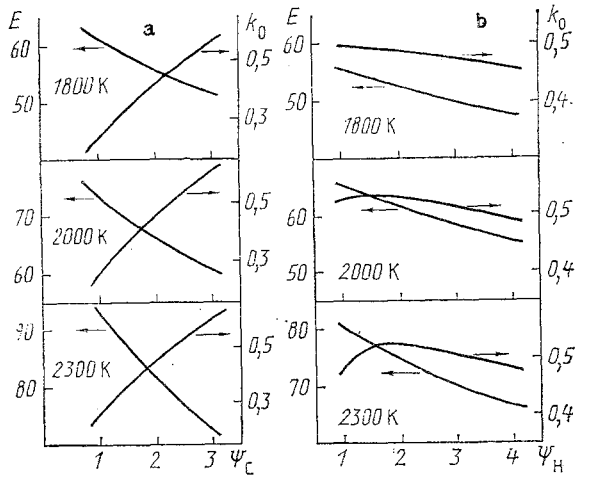

Fig. 1. Specific disposable energy and amplification factor as functions of carbon dioxide concentration (a) and the concentration of water vapor (b). E, J/g; k_0, m^{-1}; Ψ_C, Ψ_H, %.

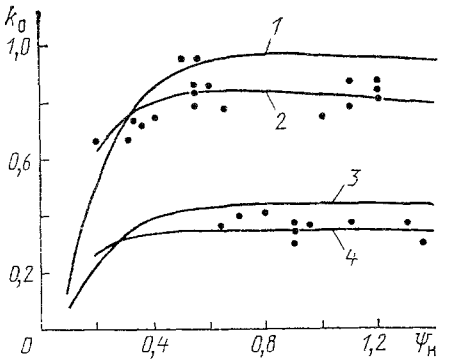

Fig. 2. Amplification factor as a function of water-vapor concentration. Solid lines represent theoretical data: 1, 3) T_0 = 1500 K; 2, 4) 1300; 1, 2) Ψ_C = 10 ± 1%; 3, 4) 3 ± 0.5%. The dots represent experimental data.

The method used to calculate the amplification factors and the specific disposable energy is described in detail in [6, 7]. The calculations were carried out for the following temperatures and deceleration pressures T_0 and P_0, as well as for a nozzle-flare angle A: 1) T_0 = 1800 K, P_0 = 4 MPa, A = 40; 2) T_0 = 2000 K, P_0 = 5 MPa, A = 50; 3) T_0 = 2300 K, P_0 = 6 MPa, A = 60. Based on the deceleration temperature the first variant corresponds to the operating conditions for the heat-exchange heater fashioned out of an aluminum-oxide ceramic, while the second is the limit case, but one that can easily be achieved with zirconium ceramics; the third variant is very near to the limit of the latter. The flare angle has been chosen so that the static temperature of the gas in the supersonic flow is at 270-300 K, and the magnitude of the deceleration pressure must ensure exhaust of the gas to the atmosphere at a pressure recovery factor of 25-30 in the supersonic diffuser portion of the nozzle. We made the assumption that the expansion of the mixture takes place in the flat supersonic nozzle whose critical cross section exhibits a height of 0.3-0.5 mm. In most of the calculations, if we impose no particular limitations, we make the assumption that this height is 0.4 mm.

Figure 1a shows the amplification factor and the specific disposable energy as functions of the CO_2 content at a water concentration of Ψ_H = 1.5%. The amplification factor under the adopted conditions is virtually independent of the deceleration temperature and in the range Ψ_C = 1-3% amounts to 0.25-0.50 m^{-1}. The efficiency of the nozzle in all of the cases falls within a range of 0.70-0.85, and the specific disposable energy therefore increases significantly with the deceleration temperature and amounts to 50-60 J/g when T_0 = 1800 K, 60-80 J/g when T_0 = 2000 K, and 70-100 J/g when T_0 = 2300 K.

These same quantities, depending on the H_2O concentration, are shown in Fig. 1b for a carbon dioxide content of 2.5%. In this case, as is the case when dependent on the deceleration temperature, the amplification factor changes only slightly. With an increase in H_2O, the specific disposable energy diminishes slowly and monotonically.

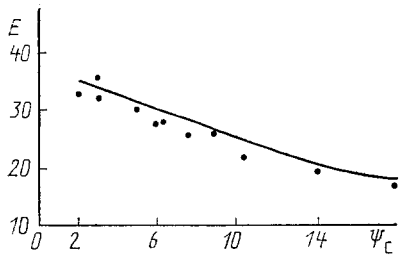

Fig. 3. Specific disposable energy as a function of carbon dioxide concentration. Solid line represents theoretical data for T_0 = 1450 K, and the dots represent experimental data.

Calculation has shown that a change in the height of the critical cross section from 0.3 to 0.5 mm reduces the specific energy approximately by 10%.

The experiments were conducted with nozzles whose flare angle was equal to 30, and the pressure and deceleration temperatures of the gas flow were, respectively, P_0 = 25 MPa, T_0 = 1300-1500 K, with the height of the critical section 0.5 mm. A highly stable electric-discharge CO_2 laser served as the probe, and it was tuned by means of a diffraction grid according to the 00G1-10°0 oscillation-rotation junctions of the CO_2 radiation band. A pyrodetector whose signal was automatically recorded by a synchronous amplifier served as the radiation receiver. The radiation wavelength was controlled by means of CO_2 spectral analyzer. Amplification of the weak signal was measured at a distance of 70 mm from the outlet of the nozzle grid, a unit comprised of 33 individual nozzles.

Figure 2 shows the measurement results for the amplification factor (junction P22) for the mixtures with Ψ_C = 10 ± 1% and mixtures with a small carbon-dioxide content Ψ_C = 3 ± 0.5% for T_0 = 1450 ± 50 K, conventionally used in the homogeneous regime. The experimental values of k_0 are close to the theoretical values. We can see from the figure that the amplification factor for mixtures with a carbon-dioxide concentration of approximately 3% is not large, and in this range of temperatures it is k_0 = 0.3-0.4 m^{-1}. Over a broad range of variations in H_2O the values of k_0 are virtually constant for the given deceleration temperature. For mixtures with Ψ_C = 10 ± 1% the amplification factor attains its maximum value at a water content of 0.5-1% and diminishes with subsequent increase in Ψ_H.

The specific disposable energy was determined from the results obtained in the measurement of the amplification factor on several CO_2 emission lines for the molecule P, i.e., the branches of the 00°1-10°0 band, based on the method familiar from [8]. Since the temperature and pressure of the active medium were, respectively, approximately 300 K and less than 0.01 MPa, then according to an analysis of the errors contained in the method described in [9], the utilization of this method is proper. The experimentally derived distribution of k_0 over the rotational quantum numbers corresponds satisfactorily to theory.

The specific energy measured as a function of the CO_2 content is shown in Fig. 3 for T_0 = 1450 ± 50 K and Ψ_H = 1.2 ± 0.1%. With an increase in the carbon-dioxide concentration from 2 to 18%, the energy falls by a factor of virtually two as a consequence of the increase in the relaxation losses in the expansion of the gas. The efficiency of the nozzle varies from 0.82 (Ψ_C = 2%) to 0.37 (Ψ_C = 18%).

Thus, it has been demonstrated theoretically and experimentally that reduction in the concentration of the carbon-dioxide gas in mixtures with H_2O and nitrogen of up to 1-3% makes it possible to elevate the specific stored energy without any additional expenditure. This measure is particularly effective in the case of high pressures and deceleration temperatures corresponding to 4-6 MPa and 2000-2300 K. However, converting the stored energy to radiation in the case of comparatively low values for the amplification factor is possible, for example, through use of multipass resonators.

NOTATION

Ψ_C, Ψ_H, volumetric concentration of carbon-dioxide gas and water vapor; T_0, P_0, the deceleration temperature and pressure for the gas flow; A, nozzle flare angle; k_0, weak-signal amplification factor; E, specific disposable energy.

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CHANGE IN THE STRUCTURE OF THE ALLOY KhN57KVYu UNDER THE ACTION OF SHOCK WAVES GENERATED BY THE ACTION OF POWERFUL NANOSECOND LASER PULSES

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We have calculated and experimentally measured the amplitudes of shock waves generated in the monocrystals of the nickel alloy KhN57KVYu under the action of powerful nanosecond laser pulses. We employed an electron-microscope method to study the defect structure formed at various depths of the layers deformed by the shock waves.

When powerful laser pulses interact for brief periods of time with a metal surface, extremely high pressures may be generated within the metal [1, 2, etc.]. The energy absorbed in this case is transferred by the shock waves into the volume of the metal. In this case, if the amplitude of the shock wave exceeds the maximum yield stress of the material, the shock wave will result in plastic deformation at depths considerably greater than that of the thermal heating layer for so long as the action of the pulse is maintained.

It has been established that the direct action of a powerful laser pulse on the surface of a solid cannot produce a high pressure level within the test material, and this is associated with the high rate of vaporization product expansion. Therefore, in order to increase the pressure pulse we resort to treatment beneath a layer of dielectric materials or fluids transparent to laser radiation and this is done in conjunction with a layer of materials which are strong absorbers of laser radiation. Thus, in the capacity of these experimental materials capable of absorbing the laser pulse we used metal foils equal in thickness to the depth of heat-wave penetration during the effective action of the pulse, defined as $\sqrt{\alpha\tau}$, where α is the coefficient of thermal diffusivity; τ is the duration of the light pulse. Utilization of such absorbing layers, given relatively low levels of radiation intensity ($\sim 10^9$ W/cm^2), makes it possible to achieve pressures on the order of 10 GPa [7].

The amplitude of the pressure pulse which arises as a consequence of the brief laser pulses can be calculated [3].

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