SOME GENERATION PARAMETERS OF CO_2 GASDYNAMIC LASERS WITH HIGH-TEMPERATURE REGENERATIVE HEAT-EXCHANGER HEATER FOR THE WORKING GAS

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The results of a complete investigation of the generated power of a CO_2 GDL for mixtures with different H_2O content (1-6)% are presented. Alternate switching on of resonators was tested.

There is now a considerable amount of computational-theoretical information in the literature on the characteristics of GDL operating on mixtures of CO_2, N_2, and H_2O or He [1-3]. The inadequate amount of published experimental results makes it difficult to make comparisons with computational models and does not permit selecting the most reliable of these models. Taking into account the uncertainties in the calculations, related with the choice of interaction constants, it is of practical interest to accumulate experimental information.

In this work, we measured the generated power of CO_2 GDL as a function of the H_2O content in the mixture while maintaining constant the concentration of CO_2 (10%), the stagnation temperature $T_0 = 1400°K$ and the stagnation pressure $P_0 = 1$ MPa. All the experiments discussed were performed using a continuous CO_2 GDL with a generation duration up to 1 min. To heat the laser mixture, we used a high-temperature regenerative heat-exchanger heater with spherical packing [3].

The mixture was accelerated in a wedge nozzle, whose critical section was $h_{cr} = 1$ mm high; the degree of expansion was 30; the flare half-angle of the supersonic part of the nozzle was $\alpha = 13°$; and, the mach number at cutoff was $M = 5$. Two working sections were connected in series to the nozzle apparatus: $30 \times 378 \times 200$ mm boxes with constant cross section, into which single-pass stable optical resonators with fast acting (0.5 sec) pneumatic slides, which made it possible to switch in the mirrors independently, were placed. The axis of the first (downstream) resonator was postioned at a distance 100 mm from the nozzle cutoff and that of the second was positioned at a distance of 300 mm. Each resonator was formed by mirrors with a diameter of up to 150 mm: The output mirror was a flat disk and the nontransmitting mirror was a concave copper disk with a radius of curvature of 10 m. The flat output disks were made of single-crystalline germanium with an interference coating, which guaranteed a transmission factor of (8-10)%.

The stagnation parameters of the flow were measured with screened PPR thermocouples and MD-type pressure gauges. The carbon dioxide content was monitored with a GKhP-3M CO_2 analyzer, and the water content was monitored with a fast-acting IR analyzer. The generated power was recorded with a water-cooled conical calorimeter. Water was introduced in the vapor phase (temperature 700°K) into the lower layers of the spherical packing of the regenerator, which guaranteed reliable mixing of the components of the mixture.

Figure 1 shows the results of the measurements of the generated power P, scaled to the size of the mirror along the flow L, for both resonators. The curves were constructed from data obtained from calculations based on a mathematical model of CO_2 GDL [4] for several values of the losses. Comparison of the computational and experimental results makes it possible to estimate the losses in the resonators. In this case, they varied in the range 0.06-0.12, which is related with the degradation of the equality of the mirrors from shot to shot. It is evident from the figure that such an increase in losses decreases P approximately twofold.

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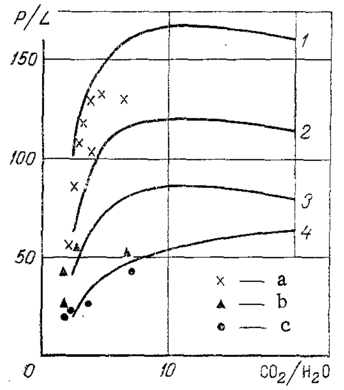

Fig. 1

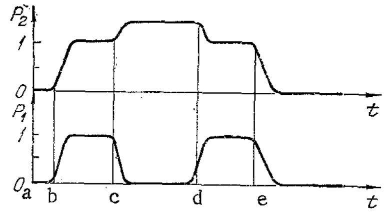

Fig. 2

Fig. 1. Dependence of P/L (W/cm) on the ratio of the volume percentage content of CO_2/H_2O: 1-3) results of calculations for the first (upstream) resonator with losses of 0.04, 0.08, and 0.12, respectively; 4) for the second (downstream) resonator with losses of 0.12 under the condition of generation in the first resonator; a) experimental points for the first resonator in a series of shots with new mirrors; b, c) for the first and second resonators, respectively, in shots with lower quality mirrors.

Fig. 2. Chronogram of the generated power of the first P_1 and of the second P_2 resonators along the flow (in relative units) for a single shot.

The generally satisfactory agreement between the experimental results and the calculations, which indicates the reliability of the chosen mathematical model of the GDL, should be noted.

It is interesting to investigate the generated power using two resonators switched-on simultaneously over the time of a single shot. A typical chronogram for this case is shown in Fig. 2. The shot was conducted for a mixture of $CO_2|N_2|H_2O = 13.0|82.6|4.4$ at $P_0 = 1.14$ MPa, $T_0 = 1240$°K, and G = 0.41 kg/sec. After gasdynamic triggering of the setup, output of power began from both resonators (section b-c) and then, the first (upstream) resonator was switched off (c-d) and again switched on (d-e); injection of working mixture stopped at time e. All of the shots analyzed exhibited an increase of about 50% in the generated power of the second resonator (section c-d) with the first resonator switched off with subsequent regeneration of the power to values characteristic for the section d-e.

The experimental results presented indicate the existence of a long active zone (not less than 375 mm) with admissible inversion characteristics, making possible the use of large-scale optical elements to extract power in subsequent investigations. This circumstance permits decreasing the fraction of the energy carried away by the flow and, therefore, increasing the efficiency of the resonator and the efficiency of the GDL as a whole.

NOTATION

GDL, gasdynamic laser; IR, infrared; M, Mach number; G, total flow rate of the working mixture; h_{cr}, height of the critical section; L, size of the mirror along the flow; P, generated power; P_1 and P_2, generated powers of the first and second resonators along the flow; P_0 and T_0, stagnation pressure and temperature; t, time; and α, half flare angle of the nozzle.

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