COMPUTATIONS OF CO_2 GASDYNAMIC LASER POWER PERFORMED UNDER DIFFERENT STATIONARY GENERATION CONDITIONS

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Computations of the carbon dioxide gasdynamic laser power P are performed in the geometric-optics approximation, as a rule, by using the stationary generation condition in local or integral form [1]. These computation methods were compared in [2] where the flow was computed of the combustion products of a stoichiometric fuel combination of acetylene and nitrogen-enriched air through a nozzle and a Fabry–Perot resonator 20 cm long in the stream direction. It turns out that the magnitudes of the radiation power obtained when using the integral form of the stationary generation condition are somewhat higher than when using the local form (the difference did not exceed 25%). At present, the CO_2 gasdynamic laser using combustion products is used extensively. Since the working media obtained as a result of combustion have a sufficiently diverse composition [1], a similar comparison in a broader domain of compositions is of interest in connection with estimates of the energy possibilities of these media. This is done in this paper for five distinct media including almost all the limiting cases, and in contrast to [2], the transmission coefficient of the output mirror t and the resonator length along the stream were optimized.

1. The energy W derived from a Fabry–Perot resonator in the form of radiation per unit mass of the working medium was computed numerically in the geometric-optics approximation with interaction between vibrational kinetics, radiation, and gasdynamics of the stream taken into account. The computation method using the local stationary generation condition is described in [3]. In contrast to [3], constancy of the radiation intensity I in the resonator was assumed in the case of using the integral condition, where the magnitude was selected so as to comply with the total equality of the radiation gain and loss during reflection from the mirrors:

$$\int_{x^0}^{x'} k_* dx = \frac{x' - x^0}{L}\left(\frac{1 - r_1}{1 + r_1} + \frac{1 - r_2}{1 + r_2}\right).$$

Here x^0 and x' are values of the coordinate along the stream at the resonator input and output, respectively, L is the distance between the resonator mirrors, r_1 and r_2 are the mirror reflection coefficients, and k_* is the saturated gain coefficient. In this case the specific energy output was computed by means of the formula

$$\overline{W} = P/G = (x' - x^0)HIt/G(1 + r_1),$$

where G is the mass flow rate and H is the height of the resonator mirror. (Here it is assumed that the radiation was derived only from the mirror with the reflection coefficient r_1.)

2. Computations were performed for a 1600°K stagnation temperature and 20-atm stagnation pressure. The flow of the media through a planar minimal-length profiled nozzle (with an angular point) with a $2 \cdot 10^{-4}$-m throat height and degree of broadening 30 was computed by the method in [4, 5]. The input to the resonator was taken at the point where the unsaturated gain coefficient reaches the maximum along the stream. In order to take account of the radiation losses in the resonator cavity indirectly, the absorption coefficient of each mirror is assumed sufficiently high and equal to 0.06, and L = 2 m. The compositions of the working media under consideration were substantially distinct. The passage from the composition 1, %: N_2 69.0; CO_2 27.6; H_2O 2.3; O_2 1.1 (here and henceforth everything is in vol. %) to the compositions 2 (N_2 64.5; CO_2 12.9; H_2O 2.2; O_2 20.4), 3 (N_2 65.4; CO_2 9.3; H_2O 3.8; CO 21.2; H_2 0.3), 4 (N_2 69.7; CO_2 9.3; H_2O 20.9; O_2 0.1) and 5 (N_2 84.8; CO_2 10.7; H_2O 2.4; CO 2.0; H_2 0.1) was characterized by a diminution in the CO_2 concentration and a corresponding increase in the O_2, CO, H_2O, N_2 concentrations in the media. The magnitudes of the specific energy output obtained in the computations, the optimal transmission coefficient t_{opt} and the coordinates along the stream at the resonator output x'_{opt} are presented in Table 1. The computations using the local stationary generation condition were terminated at a point of the stream at which selection of a magnitude of I assuring the value of

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TABLE 1

Compound no.	X^0, cm	Use of local condition			Use of integral condition		
		$\overline{W}$, kJ/kg	t_{opt}	x'_{opt}, cm	$\overline{W}$, kJ/kg	t_{opt}	x'_{opt}, cm
1	3,0	6,5	0,24	7,8	8,0	0,34	8±0,5
2	3,0	11,4	0,29	15,0	12,6	0,39	15±2,5
3	1,6	9,1	0,24	15,0	9,8	0,29	20±2,5
4	1,6	4,6	0,19	10,2	4,9	0,24	10±1,5
5	4,7	17,0	0,34	23,6	19,0	0,34	35±2,5

k_* given by this condition is already impossible, and the quantity x'_{opt} was found in this manner. The quantity x' varied during application of the integral condition since it turned out that maximum values of $\overline{W}$ were not achieved for a resonator at whose output $k_* = 0$. In this case they were obtained even less for compositions 3 and 4 than when using the local condition, and they equaled 8.3 and 4.0 kJ/kg for the optimal values of t equal to 0.19 and 0.14, respectively. The quantities $\overline{W}$ were usually higher when obtained using the integral condition, but the computed values are even better for optimal x' (see Table 1).

The difference in the magnitudes of the specific energy output calculated by using the local and integral forms of the stationary generation conditions for multicomponent working media of diverse compositions with optimal values of t and x' is just 6-18% and diminishes with the drop in CO_2 concentration. Hence, any of these forms can be used to estimate the energy possibilities of the working media of CO_2 gasdynamic lasers. The optimal resonator lengths obtained in both cases had not only an identical qualitative but also quantitative dependence on the composition; however, they differed by more than the magnitude of the specific energy output (up to 30%). The values of t_{opt} here had a somewhat distinct qualitative dependence on the composition.

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