MODELLING OF A CONTINUOUS OPTICAL DISCHARGE STABILIZED BY A GAS FLOW IN QUASI OPTICAL APPROXIMATION

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We consider a continuous optical discharge (COD), which is also known as 'laser-supported combustion wave') [1], sustained by a weakly focused CO_2 laser beam. We also introduce a cold gas flow incident in the direction of laser radiation propagation in order to stabilize the COD (Figure 1). Furthermore, the gas flow is assumed to be subsonic and laminar at atmospheric pressure.

We have developed a two-dimensional radiative gas-dynamic model for COD, which uses realistic quasi optics and takes into account all of important factors that are of influence, including the effect of the laser radiation refraction in the plasma, which is essentially capable of changing the light channel geometry and space distribution of the beam intensity.

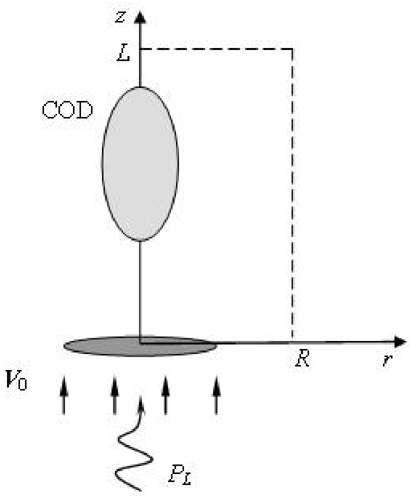

Fig. 1 Schematic of the computational region for a COD in a gas flow.

We determine the thermal and gas-dynamic structure of COD by solving the set of equations, which includes

- the continuity equation,
- compressible Navier-Stokes equations,
- equation of energy balance, which is determined by the processes of convection, heat conduction, laser radiation absorption and selective thermal radiation transport,
- equation for thermal radiation transport in multigroup diffusion approximation, and finally
- equation for laser beam propagation in parabolic approximation of quasi-optics.

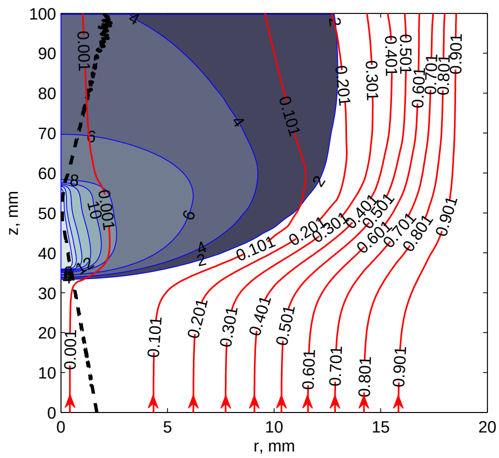

Fig. 2 Temperature field and gas streamlines G\G$_{max}$ in COD for inflow gas velocity U_0=1.0 m/s (G_{max}=0.73 g/s) and laser power P_L= 3 kW. The dashed curve corresponds to the laser beam boundary.

The model is applied to calculate the parameters of COD in a converging CO_2 laser beam in air flow as a function of the laser power and inlet velocity of the incident flow.

Our calculations show that the discharge is stable in air flows along the laser beam. We see that cold air incident to the created plasma flows primarily around it. Then, a small fraction of the gas flow is found penetrating the highly heated region as shown in Figure 2.

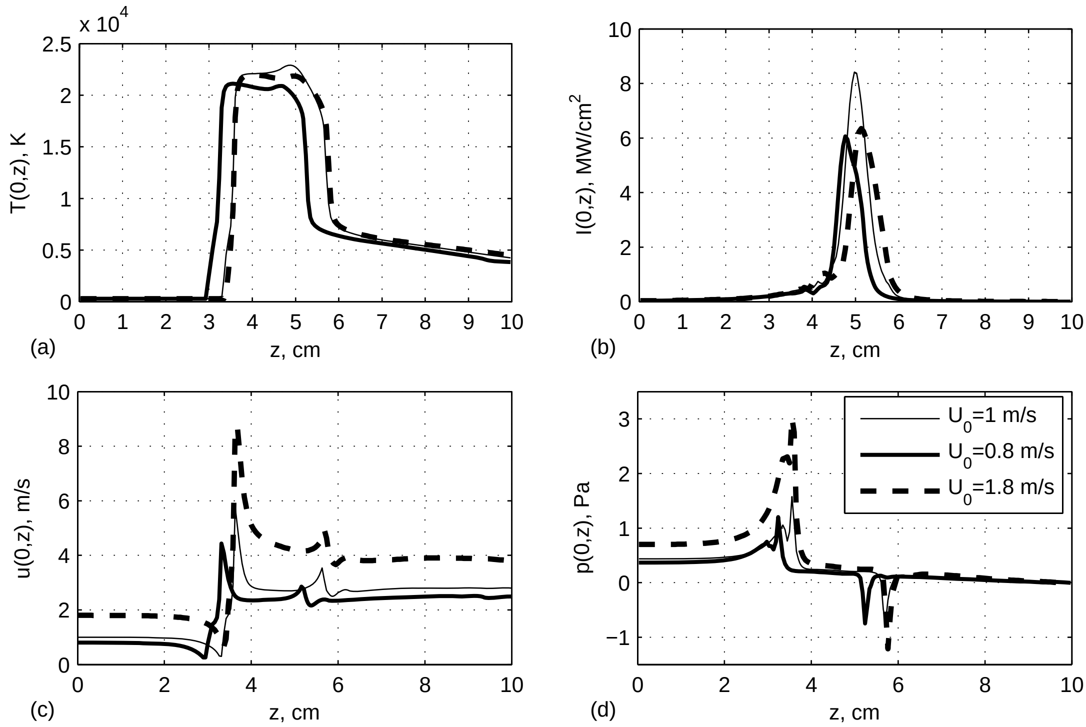

Fig. 3 Plasma temperature *T* (a), laser radiation intensity *I* (b), axial component of velocity *u* (c), and pressure *p* (d) along the z-axis in a COD in a air for *p*=1 atm and inlet gas-flow velocities U_0=0.8, 1, and 1.8 m/s, which provide a steady-state plasma. Geometrical focal point is at z=5 cm. Laser power is P_L=3 kW.

Calculations confirm the experimental and theoretical evidence [2-7] that because of refraction of the laser beam in a nonuniform plasma, the plasma initiated in a 'geometrical' focal region is shifted from this region toward the laser radiation source (Figure 3). It shifts together with the focus itself, and is localized in a region of the maximal laser radiation intensity. If the COD progresses to a point in the beam where the intensity is no longer sufficient to maintain, it vanishes. Incident cold gas flow directed opposite to the direction of beam propagation can stabilize the COD. In calculations (Figure 3) the velocity is chosen such that it is sufficient to stop the 'laser-supported combustion wave'. Hence, the quasistationary COD becomes stationary.

Reference

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