

INTERACTION OF SMALL HYDRODYNAMIC PERTURBATIONS WITH INHOMOGENEOUS NONEQUILIBRIUM GAS FLOW

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The problem of the hydrodynamic stability of laser systems is frequently discussed in literature. But when analyzing a flowing system one should take into account, those small perturbations, for example, thermal inhomogeneous perturbations drift away with the gas flow and exceed the bounds of the active area of a laser. Analyzing the stability of a flowing nonequilibrium system is possible only when solving the full problem including a feedback. This feedback may arise due to perturbations reflection from the bounds in the case of taking into account finite set-up parameters. However, there exists also the reflection from the profile of hydrodynamic parameters. This profile is concerned with relaxation processes in the gas flow. Here the interaction of small hydrodynamic perturbations with a nonequilibrium inhomogeneous gas flow is considered and the stability of such a gas flow is investigated.

Steady flow

The steady solution represents a one-dimensional gas flow with energy pumping into vibrational degrees of freedom and relaxation into translational and rotational degrees of freedom. Two types of pump are considered – instantaneous (the pump zone width is much smaller than the proper magnitude of perturbations) and extensive.

Calculation algorithm

Calculation of interaction with small hydrodynamic perturbations is related with taking into account the properties of a linear system for perturbations. Arbitrary perturbation is a combination of acoustic, vortex and thermal waves, which can be calculated in equilibrium areas. However in the nonequilibrium gas in the presence of gradients of hydrodynamic parameters the problem of modes decomposition has no analytical solution. These modes can be calculated numerically by integrating the equations for perturbations in the nonequilibrium area with the initial conditions corresponding to the modes in the equilibrium area.

Interaction with small hydrodynamic perturbations

The incidence of acoustic, vortex and thermal waves from the area of an equilibrium cold gas is considered (Fig. 1). Fig. 3 presents the calculation results of amplitudes of generated thermal perturbations when falling vortex wave on the nonequilibrium area. As can be seen from the figure, there exist regimes, at which the generation of thermal waves is maximum. This result can explain the experimental data, which are related with an attempt of improving heat removal using additional turbulization of the gas flow. This turbulization was achieved by grating placement in the cold gas, which led to the vortex formation. It appears however that vortex waves result in thermal perturbation generation – the most dangerous for the system stability. We have considered also the reflection and transmittance for acoustic and thermal waves.

Stability investigations

The system becomes unstable if there exists an opportunity of waves generation by the nonequilibrium area and such perturbations increase in time. It is necessary to determine the conditions of the beginning of perturbation generation when the imaginary part of the frequency of generated perturbations equals zero. Such parameters correspond to the neutral stability zone, which separates the stable zone from the unstable one. In Fig. 2 the neutral stability curve is presented for the instantaneous pump in terms of vibrational temperature versus the flow speed.

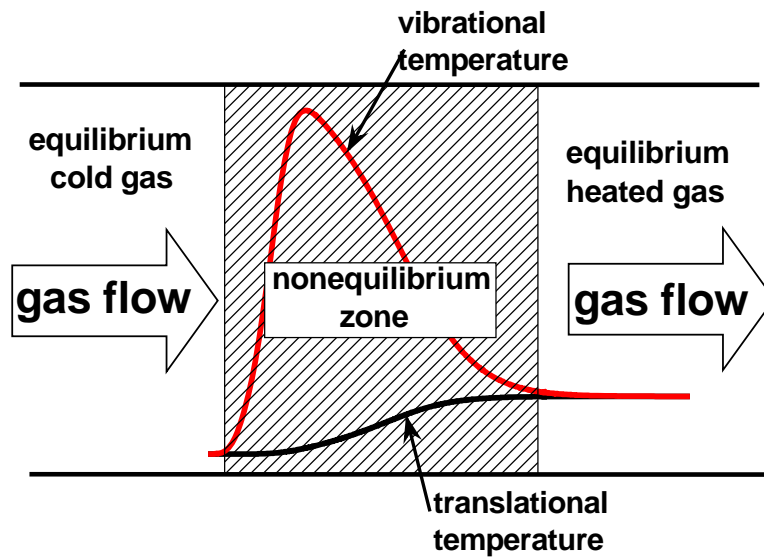


Fig. 1. Scheme of flowing nonequilibrium system

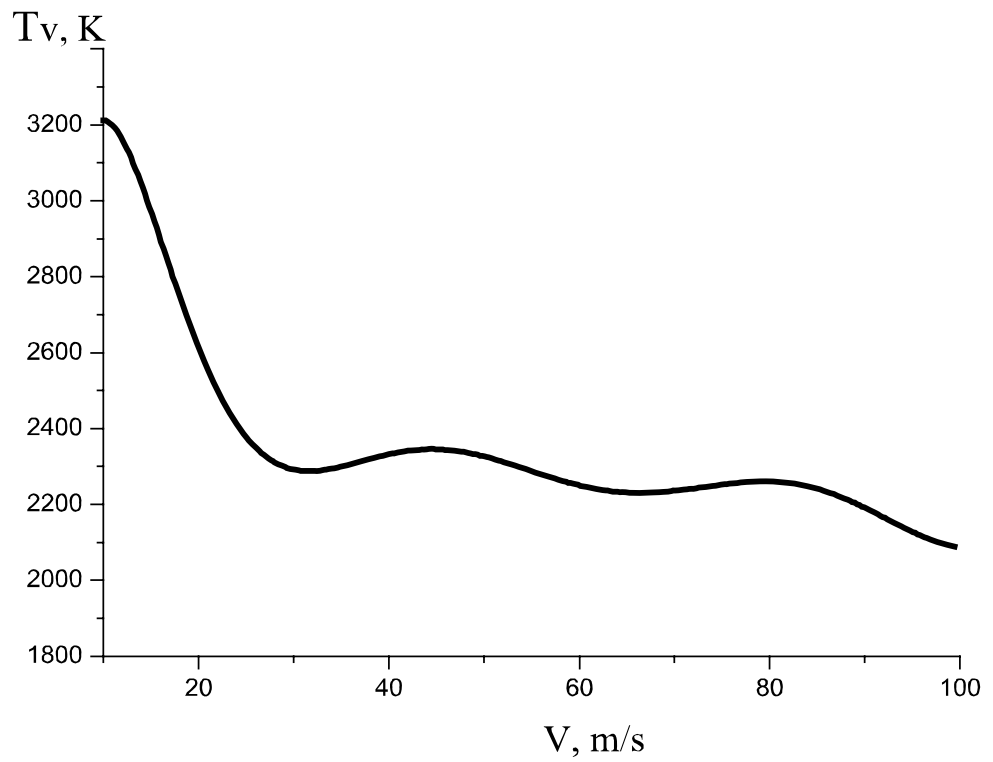


Fig. 2. Neutral stability curve for a nonequilibrium flowing system with local pump

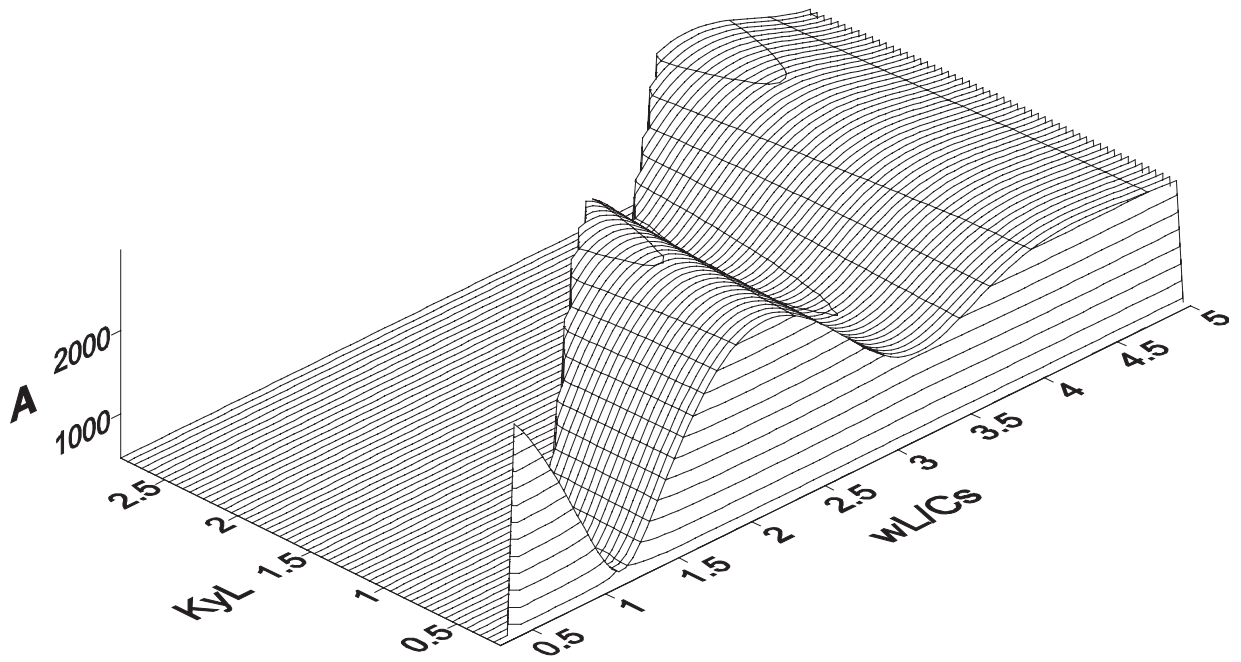


Fig. 3. Dependence of amplitudes of generated thermal perturbations A on the non-dimensional frequency wL/Cs and the non-dimensional wave vector $k_y L$ at the flow velocity of 50 m/s and the initial vibrational temperature of 2000 K