Convective Stability of a Chemically Reacting Fluid in an Annulus

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ABSTRACT

Analysis of processes of combustion and heat generation is aimed to develop a cleaner and more efficient energy production using different types of biomass. In order to enhance biomass thermo-chemical conversion different technical solutions are proposed [1]. Experimental investigation of the processes of biomass thermo chemical conversion is performed in [2]. Intensification of combustion processes can be achieved as a result of hydrodynamic instabilities. In the present paper we analyze one linear stability problem related to a convective flow of a chemically reacting fluid in an annulus.

Consider a tall vertical annulus filled with a viscous incompressible fluid. The annulus is closed so that the total fluid flux through the cross-section of the annulus is equal to zero. The internal heat sources are distributed within the annulus in accordance with the Arrhenius law [3] as a result of exothermic chemical reaction.

Under certain conditions there exists a steady one-dimensional convective flow in the vertical direction for small values of the Frank-Kamenetsky parameter. The steady-state solution is described by the system of nonlinear differential equations in the Boussinesq approximation. The system is solved numerically for different values of the parameters of the problem in order to obtain the base flow.

Linear stability analysis of the base flow is performed in the paper. Numerical solution of the linear stability problem is obtained by a collocation method based on Chebyshev polynomials. Stability is investigated with respect to asymmetric perturbations with the azimuthal wave number $n = 1$. Note that this mode is the most unstable for the case of uniformly distributed heat sources within the fluid. Marginal stability curves are obtained numerically. It is found that the increase of the Frank-Kamenetsky parameter destabilizes the flow. It is also found that the second branch of the marginal stability curve appears for the values of the Prandtl number of order one. This branch corresponds to lower critical Grasshof numbers and lower wavenumbers. Instability in this case is associated with thermal running waves moving in the vertical direction with sufficiently high phase speed.

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