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INSTABILITY OF A FLOW OF A REACTING FLUID IN A VERTICAL FLUID LAYER

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Linear stability of a flow of a viscous incompressible fluid in a vertical layer is considered. Chemical reaction takes place in the fluid. As a result, nonlinear heat sources generate a steady convective flow in the vertical direction. The walls of the channel are porous so that there is also a flow through permeable walls with constant velocity. The channel is assumed to be closed (the fluid flux through the cross-section of the channel is equal to zero). The flow is described by the system of the Navier-Stokes equations under the Boussinesq approximation [1].

Nonlinear boundary value problem for the base flow is analysed numerically. Bifurcation analysis shows that depending on the intensity of the chemical reaction described by the Frank-Kamenetskii parameter F and the Reynolds number Re based on the strength of the cross-flow through permeable walls the number of solutions is zero, one, or two. For each Re there exists a threshold value of $F^* = F^*(Re)$ such that there are no steady solutions in the interval $F > F^*$. Such a situation is referred to as the thermal explosion in the literature [2].

Linear stability analysis of the base flow in the range $0 < F < F^*$ is performed for different values of Re and Prandtl number Pr, where the correct form of the base flow is chosen in accordance with the bifurcation analysis conducted above. In addition, both positive and negative Re are considered.

Linear stability problem is solved by collocation method based on Chebyshev polynomials. Numerical results show that (a) both positive and negative Re have overall stabilizing influence on the flow; (b) increase in F destabilizes the flow; (c) instability for small Pr is of a hydrodynamical nature due to two fluid streams moving vertically in opposite directions; (d) instability for large Pr occurs in the form of thermal running waves that are propagating downstream with sufficiently high phase velocity.

REFERENCES

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