2D Regimes of Non-Fourier Convection in a Rectangular Cavity

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In this work, we investigate the 2D flow in a rectangular cavity subject to both vertical and horizontal temperature gradients. The linearized model is studied and the effect of the relaxation of the heat flux in the law of heat conduction is examined. Two different implementations of the relaxation term are considered: a local time derivative (the so-called Maxwell-Cattaneo law), and a frame indifferent (Oldroyd) objective time rate. To this end, two spectral numerical models are created based on a Galerkin expansion. The basis is the cartesian product of systems of beam functions and trigonometric functions. Beam functions are used in the direction across the slot so that four boundary conditions are satisfied. Respectively, trigonometric functions are used in the vertical direction satisfying the periodic conditions.

The natural modes of the system are derived for both the Fourier and Non-Fourier models. The results are compared to the works of Bergholz and Elder for the plain Fourier law. The inclusion of an additional time derivative brings one more family of eigen-values. Our computations show that for the plain Maxwell-Cattaneo law, some of the modes of the new family have positive real parts, which means that the convective flow is unstable. For the same set of parameters, the frame-indifferent law exhibits only stable modes which are quantitatively different from the Fourier. The modes of heat conduction with relaxation of the flux decay slower than their purely Fourier counterparts, but their frequencies are higher. The new family of eigenvalues are strictly negative and correspond to rapidly decaying transients.

The present results seem to confirm the assertion that for fluids, the Maxwell-Cattaneo law without frame indifferent additions, leads to paradoxical results.

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