Several Hydrodynamic Instabilities Illustrated Using COMSOL Multiphysics®

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Abstract

COMSOL has proved itself an invaluable tool for teaching "Transport Phenomena" to graduate and undergraduate engineers. In particular, the software allows us to visualize and explore solutions well beyond what students could do with pencil and paper. For instance, COMSOL allows us to work with realistic (non-conformal) geometries, to include the nonlinear terms in the conservation equations in our models, and to easily incorporate multiple "physics" into our simulations. Generally, textbook style problems can be set up and solved in a single 50-minute class setting with additional assignments based on that day's model completed overnight.

One of the topics that had to be skipped in these classes due to the complexity of the math involved was transport-induced instabilities. While it had been possible with pen-and-paper to study hydrodynamic instabilities up to the point of "neutral stability," using COMSOL the class is able to locate the point of neutral stability, visualize the changes in the system as the instability emerges, amplifies and then progresses to a secondary (steady or unsteady) state and, in some cases, we have been able to provoke an instability in the secondary state.

In this poster, we will look at a number of different flow instabilities as predicted by COMSOL including Taylor vortices, Rayleigh-Bénard cells, thermogravitational vortices (Clusius-Dickel column) and a conductivity-gradient induced electrohydrodynamic instability.
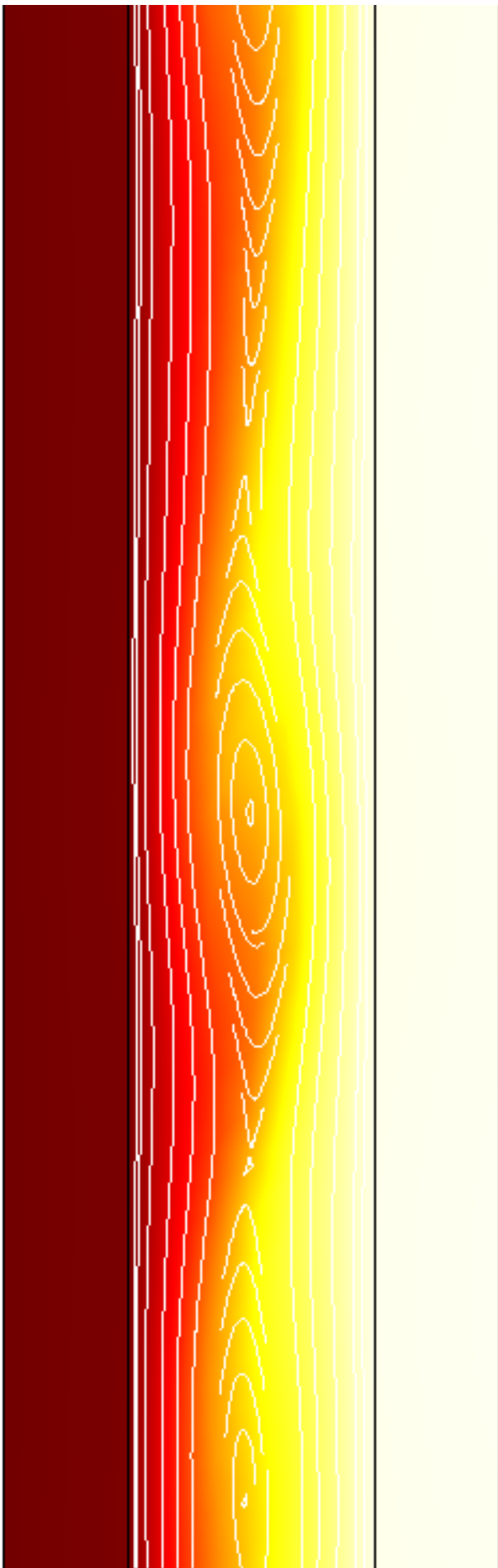
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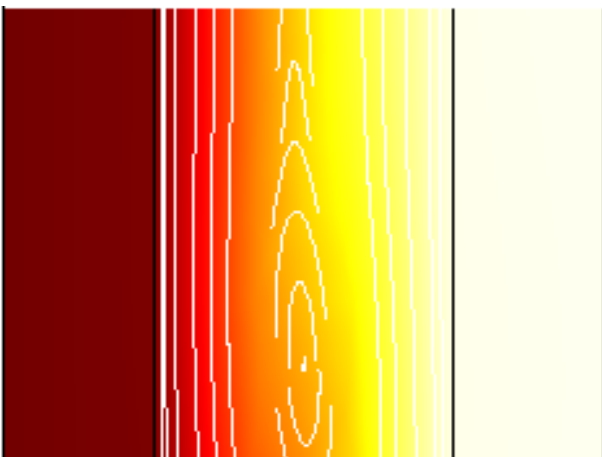
Figure 1: Vortices appear in the fluid contained between the hot (right) and cold (left) steel walls of a vertical Clusius-Dickel column as the Grashof number exceeds its first critical value.