Synchronization between two Hele-Shaw cells

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The Hele-Shaw cell consists of two transparent plates separated by a small gap, so one dimension is much smaller than the other two. It is an interesting geometry because it reduces the complicated three dimensional fluid flow into a two dimensional flow. It is also a good model for the flow in a porous media.

The phenomenon of convection is the answer of a fluid layer to an instability due, for example, to a vertical gradient of temperature. By heating a fluid from below, we can observe a large number of different dynamical states: starting from stationary convection, oscillating convection, thermal plumes and turbulent flow. The richness of behavior in a rather simple geometry is a good candidate to study possible synchronization mechanisms between two convective cells.

The minimal critical Rayleigh number for the onset of convection is $4\pi^2$ and the corresponding flow pattern just above onset is a single convective roll. Above onset, the flow is steady and the convective motion increases in intensity with the Rayleigh number. As the convection becomes the dominant mechanism of heat transport, the evolution of the flow is characterized by an oscillatory flow. When $Ra > 400$ the key element is the formation of thermal plumes, as fluctuations born in the boundary layer eventually move out of the boundary layer. As an operational definition, we say that a plume has formed when an isotherm in the boundary layer has buckled to the extent that some portion of it becomes nearly vertical. At the onset of this oscillation at $Ra = 410$, the fluctuations are infinitesimal, by $Ra = 600$ the plumes form far from the turning region in the corner, whereas at $Ra = 900$ the plumes form at about the center of the layer. For $Ra > 1100$ no single period clearly prevails, this suggests that convection is already in the chaotic regime.

We have obtained synchronization in the region near and far from the threshold. The cells in each case are prepared with different initial conditions and the thermal coupling are applied between all points.

Finally, the difficulty to realize an experiment that will show synchronization between two systems using all points brought us to investigate about the minimal number of points that are needed to get synchronization.

Figura 1. One period of oscillation at $Ra = 900$, $\tau_p = 0.00273$, in dimensionless units. This sequence of temperature through the entire plume formation process. Time proceeds from top-left to bottom-right.