Competition between vertical and Rayleigh-Benard convection in a thin cylinder.

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When an accident occurs in a nuclear power plant, a fluid called "corium" composed of the radioactive fuel and the reactor metallic components is formed. To deal with this event, one of the strategies consists in submerging the reactor in water in order to cool the wall reactor and try to keep the corium inside. However, few minutes after the accident, the corium splits in 2 phases : an oxide layer, highly radioactive, which heats from below a thin liquid metal layer at the surface. It has been shown[1] that the heat flux across the thin metal layer can lead to the complete melting of the side wall, hence to the failure of this retention strategy.

Motivated by those nuclear safety issues, we study heat flux exchanges in the liquid metal layer, modeled by a thin cylinder with an imposed flux at the bottom and top (not necessarily equal) and a fixed temperature on the side. We combine Direct Numerical Simulations and a theoretical approach to derive scaling laws for the temperature difference between top and bottom and for the mean temperature of the system. We find two scaling laws depending on the heat flux ratio. The first one is controlled by heat exchanges on the side, for which we recover classical laws of vertical convection[2]. The second one is driven by top-bottom heat transfers analogous to Rayleigh-Bénard convection[3]. Furthermore, we show that the system is inherently inhomogeneous, with a superposition of both mechanisms identified. In addition to averaged quantities, we show that heat flux fluctuations at the side wall are large and highly intermittent, which might impact safety protocols.

Références

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