Measured three-dimensional flow structure in aspect ratio 1/10 turbulent Rayleigh-Bénard convection

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Thermal convection is a phenomenon occurring widely in nature and in many industrial processes. A paradigm to study the generic convection phenomenon is the Rayleigh-Bénard (RB) system. The most typical geometry of the system is a cylindrical convection cell with an adiabatic sidewall. Recent experimental and simulation studies show an increasing interest on slender cell as it is experimentally economical to reach higher Rayleigh number. A natural question is how aspect ratio (Γ, the ratio of the lateral and the vertical size of the convection cell) affects the flow structure in the cell? Is the flow structure in the slender cell ($\Gamma = 1/10$) the same as that in the aspect ratio unity cell? Although there are several numerical simulations, direct three-dimensional velocity measurement in slender cell is still lacking.

In the present work, we have measured the whole field of the three-dimensional velocity in a cylindrical cell with $\Gamma = 1/10$ by using Tomo-PIV. The experiments were conducted with water and glycerol solution at Prandtl number 5.7 and 57 and moderate Rayleigh number. It is found when the flow state is slightly above the onset of convection, the flow can be approximated as a single roll structure. While when Rayleigh number increases, this single roll giant flow structures tend to breakup, and multi-roll structure is formed. The modal decomposition results show that the the multi-roll structure can be characterized by the variation of the energy of the modes with height.

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