Heat transport and flow-state transition as Rayleigh-Bénard convection interacts with a self-proposed rigid rotor

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Abstract

Thermal boundary layers (BLs) are prominent fluid structures in turbulent Rayleigh-Bénard convection (RBC) that contribute the main resistance for the heat flows through the fluid domain and determine the global heat transport (Nu). An effective approach to control the heat transport in turbulent convection is thus to perturb fluid motions within the thermal BLs and modify the heat-transfer mechanism. Here we investigate the close interaction between a self-proposed rigid rotor and the turbulent flows of RBC in a horizontal cylindrical cell. The rotor consists of eight fan blades, spoked to a horizontal shaft that is allowed to rotate about the central axis of the cylinder with negligible friction. When driven to spin by the convective flows, the tips of the rotor's blades invade and sweep the BLs, leading to a significant enhancement of Nu. Flow visualization confirms that as the blades pass by, fluid parcels are forced to leave the thermal BLs, before they could become unstable and emit thermal plumes as seen in the classical situations. We further demonstrate that such fluid-structure interactions rectify effectively the convective flows, promoting the flow-state transition from chaotic plumes to large-scale coherent circulations.

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