Optimized transition of buoyancy-suppressed turbulence in vertical pipe flow

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Many energy systems rely on fluids to transfer heat from one device to another to facilitate power generation, provision of heating or production of chemicals. Flows are often forced through channels or arrays of pipes taking heat away from the surfaces. In an isothermal flow, the volume flux is driven by an externally applied pressure gradient, which is referred to as forced flow. In a vertical configuration, however, buoyancy resulting from the lightening of the fluid close to the heated wall can provide a force that partially or fully drives the flow, referred to as mixed or natural convection, respectively. There is particularly interesting physics in mixed convection flow, where partial or full laminarization occurs in the presence of buoyancy, dependent on the flow rate and difference between the bulk and boundary temperatures[1]. Heat transfer is significantly destroyed due to the suppression of the turbulence. It is essential to figure out the mechanism behind this phenomenon to develop control strategies to avoid the disappearance of turbulence.

A new direct numerical simulation (DNS) model is established to better capture the flow features of the heated flow with buoyancy, which incorporates the axial temperature gradient of boundary conditions. The flow with different strengths of buoyancy at different Reynolds numbers was simulated, and results show good consistency with the experiment data. The flow is found to show three main regimes – shear-driven turbulence, laminarization and convective-driven turbulence, as reported by Marensi *et al.* [2] and others. We further calculate the minimal seed at Re=3000 with different buoyancy conditions. As the buoyancy increases, the amplitude of the minimal seed first rises, then reduces to a low value. This corresponds to the three flow patterns – enhanced nonlinear stability cause the laminarization of flow, and convective-driven turbulence is brought by inflectional instability. Work is ongoing towards heat transfer optimization, more directly, using the nonlinear variational method.

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[1] He, S., K. He, and M. Seddighi, *J. Fluid Mech.* **809**,31-71 (2016).

[2] Elena Marensi, Shuisheng He, and Ashley P. Willis, *J. Fluid Mech.* **919**,A17(2016).