The effect of rotation on heat and momentum transport and structures in plane Couette and Taylor-Couette flow

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Rotation strongly affects the physical transport phenomena and flow structures in shear flows. The influence of rotation on momentum transport in plane Couette flow (PCF) and Taylor-Couette flow (TCF) has been extensively studied[1]. However, much less is known about the effect of rotation on heat and scalar transport in PCF and TCF. Here, we present an investigation of the effect of rotation on both heat and momentum transfer and flow and thermal structures in PCF and TCF using DNS. The PCF and TCF systems are subject to rotation about the spanwise and axial directions, respectively. Buoyancy effects are neglected, and both the Reynolds number Re and rotation number R_Ω are varied in the DNS.

We observe that both momentum transport and heat transport are enhanced in PCF and TCF subject to anticyclonic rotation, as shown in e.g. Fig. 1(a). However, heat transport is more enhanced than momentum transport, especially at high anticyclonic rotation rates (positive R_Ω). Important implications are that the Reynolds analogy between heat and momentum transport fails and that heat transport can become much faster than momentum transport in anticyclonic rotating PCF and TCF. Another consequence is that the turbulent Prandtl number is approximately unity in nonrotating PCF and TCF, but becomes much less than unity in the cases with anticyclonic rotation, as shown in e.g. Fig. 1(b). The turbulent Prandtl number even becomes slightly negative for moderate R_Ω due to counter-gradient fluxes. Further results are shown in[2,3]. In the presentation, we also discuss the influence of rotation on the flow and thermal structures.

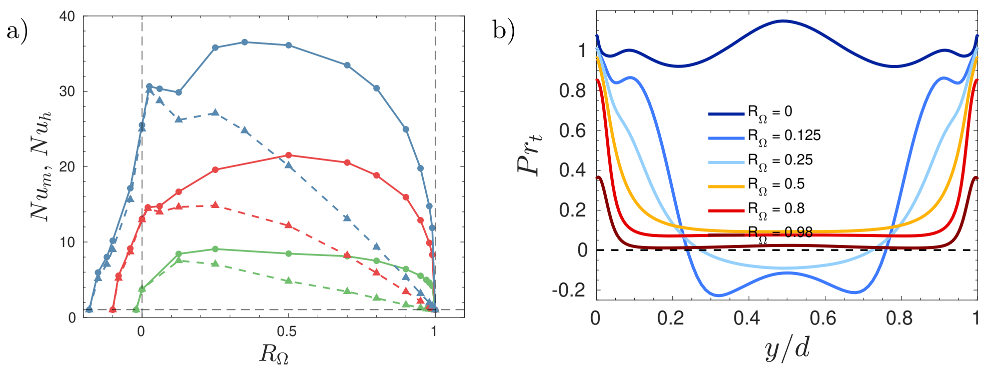

Figure 1: (a) Nusselt number for momentum transfer (dashed lines) and heat transfer (solid lines) as a function of R_Ω in PCF at $Re = 3200$ (green), $Re = 17\,200$ (red) and $Re = 40\,000$ (blue). (b) Turbulent Prandtl number Pr_t in PCF at $Re = 17\,200$ at varying R_Ω.

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[1] Brauckmann et al., *J. Fluid Mech.* **790**, 419 (2016).

[2] Brethouwer, *J. Fluid Mech.* **912**, A31 (2021).

[3] Brethouwer, *Int. J. Heat Mass Transfer* **205**, 123920 (2023).