22d Heat Transfer in Plane Couette Flow Using Coupled Direct Simulations and Lagrangian Methods

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Heat transfer in fully developed plane Couette flow was studied by direct numerical simulation (DNS) in conjunction with the Lagrangian methods (Lagrangian scalar tracking, LST). Plane Couette flow is defined as the flow that is driven by the shear motion of the two walls of the channel moving in opposite directions. The transport of a passive scalar was simulated with LST, which involves the tracking of the trajectories of scalar markers in the flow field generated by the DNS. Statistical analysis can be used to synthesize the mean temperature profile from the behavior of heat sources at the walls. This methodology has been used previously to determine the dependence of the heat transfer coefficient of plane channel flow and turbulent dispersion of elevated sources of plane channel and plane Couette flow on Prandtl number [1, 2]. The focus of the present work is to explore heat transfer in plane Couette flow, its differences from heat transfer in plane Poiseuille flow, and the effects of the velocity field on the mechanism of heat transfer fro the wall. Heat markers were released from continuous line sources of heat at the channel wall for fluids with Prandtl numbers between 0.1 and 15000 (e.g., liquid metals, gases, liquids, refrigerants, oils, electrochemical fluids). Temperature profiles and heat transfer coefficients were calculated for the plane Couette flow and were compared to Poiseuille flow.

The paper will also discuss second-order scaling for turbulent heat transfer from the wall. This type of scaling has been suggested by Churchill [3, 4] and has been found to be superior in several respects when compared with the conventional scaling that is based on the viscous wall units. The unique range of results from the DNS/LST has been used to explore the Churchill scaling. According to this new scaling, fully developed flow and convection can be expressed as local fractions of the shear stress and the heat flux density due to turbulent fluctuations; and the fully developed temperature can be predicted if the velocity field and the turbulent Prandtl number are known [5]. Temperature profiles for Pr from 0.1 to 50000 have been calculated theoretically and with DNS/LST data for both plane channel flow and plane Couette flow and will be presented to validate this method. Improved formulas will be suggested (based on our empirical findings) for better precision for the prediction of temperature using second-order scaling.

References

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