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A Collaborative Effort Towards the Accurate Prediction of Flow and Heat transfer in Low-Prandtl Fluids

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Abstract

Turbulent heat transfer is an extremely complex phenomenon that has challenged turbulence modellers over various decades. In the recent past, several attempts have been made for the assessment and further development/calibration of the available turbulent heat flux modelling approaches. One of the main hampering factors with respect to the further assessment of these modelling approaches is the lack of reference data, i.e. experimental or numerical via the use of Direct Numerical Simulations (DNS). Within the framework of the EU SESAME and MYRTE projects, an extensive and collaborative effort has been put forward to generate a wide range of reference data, both experimental and numerical, to fill this gap. In parallel, this data has been used to validate and/or improve the classical and sophisticated turbulent heat flux modelling approaches.

This article reports the experimental and DNS database that has been generated within these projects for various low-Prandtl flow configurations in different flow regimes. This includes three experiments: confined and unconfined backward facing steps with low-Prandtl fluids, and a forced convection planar jet case with two different Prandtl fluids. In terms of numerical data, seven different flow configurations are considered: a wall-bounded mixed convection flow at low-Prandtl number with varying Richardson number (Ri) values; a wall-bounded mixed convection flow in a bare rod bundle configuration for two different Reynolds numbers; a forced convection in a confined backward facing step (BFS) for two different Prandtl fluids; a forced convection impinging jet for three different Prandtl fluids corresponding to two different Reynolds numbers of the fully developed planar turbulent jet; a mixed-convection cold-hot-cold triple jet configuration corresponding to Ri=0.25; an unconfined free shear layer for three different Prandtl fluids; and a forced convection infinite wire-wrapped fuel assembly.

This wide range of reference data is used to evaluate, validate and/or further develop different turbulent heat flux modelling approaches, namely simple gradient diffusion hypothesis based on constant and variable turbulent Prandtl number; explicit and implicit algebraic heat flux models; and a second order turbulent heat flux model. Lastly, this article will highlight the current challenges and perspectives of the available turbulence models, in different codes, for the accurate prediction of flow and heat transfer in low-Prandtl fluids.

Keywords: Heat transfer, low-Prandtl, experiment, DNS, turbulence models