Proceedings of the 9th World Congress on Momentum, Heat and Mass Transfer (MHMT'23)
London, United Kingdom – April, 2024
DOI: 10.11159/enfht24.001

Fundamental Differences between Developing Internal Forced Convection Flow for a Uniform Heat Flux and a Uniform Wall Temperature on the Wall of a Circular Tube

Josua P Meyer
Department of Mechanical and Mechatronic Engineering
Stellenbosch University
South Africa

Extended Abstract

In the majority of prior studies pertaining to internal forced convection within circular tubes, either a uniform heat flux or a uniform wall temperature was employed. Measurements of temperatures and pressure drops were predominantly conducted on the tube walls to minimize disruptions within the flow field. Furthermore, fundamental analytical equations were employed, incorporating various simplifying assumptions, to describe the flow field, heat transfer coefficients, and friction factors. However, these equations primarily accounted for fully developed flow in nearly all cases. Additionally, it was assumed that the inlet velocity profile was fully developed, which has limited practical applicability. In most industrial applications, a square-edged inlet configuration is utilized, resulting in the simultaneous development of hydrodynamic and thermal boundary layers. Consequently, the objective of this paper was to generate computational fluid dynamics (CFD) data and employ it in conjunction with experimental measurements to compare the outcomes for both developing and fully developed flow. To achieve this, experimental data was contrasted with CFD data for water flowing through a 4 mm circular tube with a square-edged inlet, while varying the Reynolds numbers and heat fluxes. Through the acquisition of this comprehensive dataset, several significant flow phenomena were successfully identified and quantified for the first time. These include: (1) the distribution of wall temperature within the co-evolving hydrodynamic and thermal boundary layers, (2) the presence of a recirculation region at the tube inlet, (3) a non-linear fluid temperature gradient during the development of flow for a uniform heat flux, and (4) an unexpected and distinct map of flow regimes for a uniform wall temperature, contrasting with the previously published map for a uniform heat flux.