A new perspective on internal forced and mixed convection heat transfer

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Abstract:

Heat transfer through a smooth circular tube remains one of the most important heat transfer problems in internal convetion. Depending on the method of heating/cooling (constant heat flux or constant wall temperature) the flow regimes might be forced convection or mixed convection. This will significantly influence parameters such as the development of the hydrodynamic and thermal boundary layers and entrance lengths, the local- and average heat transfer coefficients, as well as the local and average pressure drops.

Extensive theoretical work was done from which the above-mentioned parameters were estimated for forced convection conditions, but it was unfortunately not necessarily verified by rigorous experimental work. A little experimental and theoretical work has been done for mixed convection heat transfer; however, the focus was mainly on the laminar flow regime and very little work has been done for the transitional flow regime.

It was therefore the purpose of this study to give a new perspective on forced and mixed convection heat transfer in smooth circular tubes by conducting rigorous experiments and compiling an experimental database which were orders of magnitude larger than previous databases. Some of the main new perspectives that were developed from the results are:

1. A longer thermal entrance length is required if the flow is simultaneously hydrodynamically and thermally developing.
2. The fully developed forced convection laminar Nusselt number is not constant at 4.36, but is a function of Reynolds number for Reynolds numbers greater than 600.
3. Free convection effects were found to decrease the thermal entrance length.
4. The width of the transitional flow regime decreased and the transition gradient increased as the flow developed along the tube length. Once the flow was fully developed, both the width of the transitional flow regime and transition gradient remained constant.
5. Free convection effects caused the width of the transitional flow regime to decrease and the transition gradient to increase. At very high Grashof numbers, the transitional flow regime even became negligible and the flow regime changed from the laminar flow regime to the quasi-turbulent flow regime at the next Reynolds number increment.

Bio:

Prof Josua Meyer, was in 2002, appointed at the University of Pretoria as professor, and Head of Mechanical and Aeronautical Engineering (1900 students), and in 2004, Chair of the School of Engineering (7000 students). He is now serving his fourth terms for both Head of Department and School Chair.

He is leading the Clean Energy Research unit that he established with a broad focus on thermal sciences and fluid flow, but with a narrower focus on heat exchangers. His heat exchanger work focused on fundamental work of flow in the transitional flow regime, nanofluids, and condensation. On an applications level his work focuses on thermal-solar-, wind- and nuclear energy. He has grown this group to approximately 50 full-time graduate students and 10 staff members. During this time, he also established various labs with state-of-the-art instrumentation and designed and constructed (with his group members) more than 12 unique experimental set-ups.

He has received 11 different national teaching awards from three different universities, as well as an international award, in 2013, for “Best professor in mechanical and aeronautical engineering”. He has won more than 45 research awards including 23 awards for best article of the year or best conference paper. For his research he has won the following national and international awards: Thomas Price Award, Rand Coal Award, South African Institute of Mechanical Engineers Medal, LT Campbell-Pitt Award, Literati Award, Chairman’s Award of the South African Institute of Air-conditioning and Refrigeration and Will Stoecker award. He is a member or fellow of various professional institutes and societies such as ASME, ASHRAE, AIAA, and the Royal Aeronautical Society.

He has an A-rating from the NRF. His is a “highly cited researcher” according to the ISI and ranked among the top 1% in engineering. He is on the editorial board of 13 journals and is editor of 7 journals in his field of research. Recently, he was on the selection committee of the Franklin Institute Awards Programme (one of the world’s oldest (since 1824)) for the Benjamin Franklin Medal. To date, 117 awards of this institute have been honoured with Nobel prizes.

He has (co)authored more than 800 articles, conference papers, and book chapters, and has (co)supervised more than 100 research masters and PhD students. In 2016, he won the University of Pretoria “Exceptional Achiever Award” for the fifth time.