ME Seminar

A dimensionless heat transfer coefficient better than Nusselt number for natural convection

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ABSTRACT

Natural convection refers to buoyancy driven flows, for example, as that created by a heated sphere in still air. In non-dimensional terms the buoyancy forcing is given in terms of Rayleigh number Ra, which is proportional to the density difference and L^3, L being the reference length, for example diameter of the sphere. The heat flux (W/m^2) is standardly given in terms of Nusselt number (*Nu*), which is proportional to L, and given as correlations of the form, Nu ~ $Ra^n Pr^m$, where Pr is the Prandtl number, ratio of momentum to heat diffusivities. For turbulent natural convection across almost all geometrical configurations, $n \sim 1/3$ and m is small, implying the heat flux is nearly independent of the length scale and has weak Pr dependence: the heat flux values on 10 cm diameter and 1m diameter spheres heated to the same temperature above the ambient will be nearly identical, whereas the Nu value will be ten times for the larger sphere. A new non-dimensional heat transfer coefficient, C_q, which is independent of the length scale is proposed thus reflecting the fact that heat flux does not depend on L. It is observed, surprisingly, that the C_q values for natural convection over several geometries lie in a small range ~ 0.1 – 0.2; the same data in terms of Nu varies over orders of magnitude. Physically, a constant value of C_q implies a constant value of Rayleigh number based on the thermal boundary layer thickness, consistent with marginal stability hypothesis. It can be shown that C_q is akin to the non-dimensional representation of wall shear stress, skin friction coefficient C_f, which also shows small variation over a wide range of Reynolds numbers. We believe that C_q is a more meaningful representation of heat flux than Nusselt number, and will be as useful for natural convection flows as C_f is for forced flows.

ABOUT THE SPEAKER

Prof. Jaywant H Arakeri served in the faculty of the Mechanical Engineering department and the Centre for Product Design and Manufacture at the Indian Institute of Science, Bangalore till 2022. Currently he is a visiting professor at IIT, Jodhpur and an honorary professor at JNCASR, Bangalore. All his education has been in aeronautical engineering, BTech (IIT, Madras), ME (IISc) and PhD (Caltech). His research is primarily focused on the fundamental understanding of various phenomena in fluid mechanics and heat transfer, in particular related to turbulence, transition to turbulence, unsteady flows, bio-fluid mechanics and evaporation from porous media. Some of his recent research topics include the role of turbulence in condensation and droplet growth in clouds, flows around flexible surfaces like fish tails and heart valves, unsteady flows, like those found in arteries and related to pulsed propulsion, heat and moisture loss from soils and leaves, and precision agriculture.

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