EUROMECH COLLOQUIUM 651
International Colloquium on Films, bubbles, droplets and phase change

August 25th-29th 2025, Metz, France
https://euromech.org/colloquia/colloquia-2025/651

EUROPEAN MECHANICS SOCIETY

Forced convection in two-phase core-annular flows

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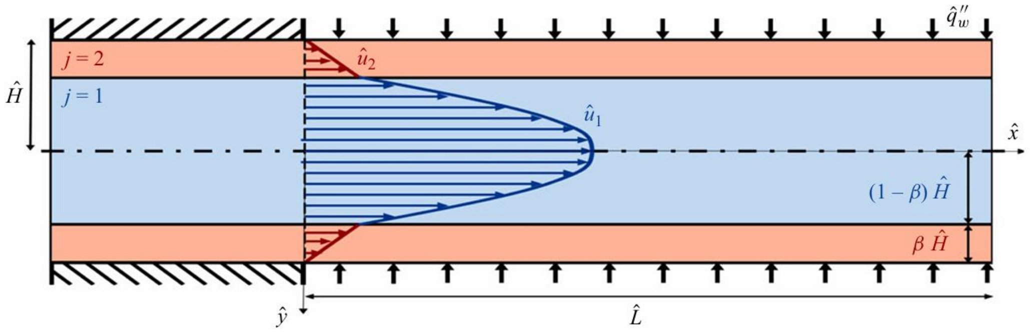
Predicting the temperature distribution in laminar two-phase flows is essential in a wide range of engineering applications, like heat dissipation of electronic equipment and thermal design of biological reactors. Motivated by this, we extend the classical Graetz problem, studying the heat transfer between two flowing phases in a core-annular flow configuration. Using a rigorous two-scale asymptotic analysis, we derived two coupled one-dimensional advection-diffusion heat-transfer equations (one for each phase) embedding the effects of advection, diffusion (both axial and transverse) and viscous dissipation. Specifically, the heat-transfer mechanisms are described through effective velocity and effective diffusion coefficients, while the interaction between the phases is accounted for via *ad hoc* coupling and source terms, respectively. The dynamics of the problem is controlled by seven dimensionless groups: the Péclet and Brinkman numbers, the heat flux, the viscosity, thermal diffusivity and thermal conductivity ratios, and the volume fraction. Our analysis reveals the existence of two main regimes, depending on the disparity in thermal conductivity between the phases. When the conductivity ratio is of order one, the problem is strongly coupled; otherwise, the phases are thermally decoupled. Interestingly, we investigate the evolution of the heat-transfer coefficient in the thin-film limit, shedding light on the most common assumptions underlying extensively used models in the context of film flows. Finally, we derived closed-form scaling laws for the Nusselt number clarifying the impact of the phases topology on heat-transfer dynamics. Since our model has been derived by first principles, we hope that it will improve the understanding of two-phase forced convection.



Schematic diagram of the extended Graetz-Brinkman problem for a laminar two-phase core-annular flow in a plane slender channel with a semi-infinite heating section.

Keywords: core-annular flow, multiphase flow, reduced-order modelling

Reference:

Botticini, P., Picchi, D., & Poesio, P., 2025, Forced convection in two-phase core-annular flows, *Journal of Fluid Mechanics*, 1011, A41, https://doi.org/10.1017/jfm.2025.360.

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