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Effects of microscale inertia on heat or mass transfer from a drop

DEEPAK KRISHNAMURTHY, GANESH SUBRAMANIAN, Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore — Heat or mass transport from suspensions of solid particles or drops is ubiquitous in many industrial processes. In the zero inertia limit the transport is diffusion limited owing to the presence of closed streamlines around each particle. A small but finite amount of inertia though, results in a vastly different picture, greatly enhancing transport by destroying the closed streamline configuration. We develop a theoretical formulation to study the effects of weak inertia on transport from a density-matched drop in a 2D linear flow. It is shown that, unlike a solid particle, the near-surface streamlines are closed only when the viscosity ratio (λ) exceeds a critical value $\lambda_c=2\alpha/(1-\alpha)$, where α is the linear flow parameter measuring relative magnitudes of extension and vorticity. The velocity field on the drop surface can be characterized using a complex-valued analogue of the (C,τ) coordinate system used to describe Jeffrey orbits of an axisymmetric particle. In the open-streamline case $(\lambda < \lambda_c)$, convective transport occurs even with zero inertia, and for large Peclet number (Pe) (the relative magnitude of convective to diffusive transport), the Nusselt number (dimensionless rate of heat transfer) is expected to scale as $F(\alpha,\lambda)Pe^{1/2}$ and is determined via a boundary layer analysis in the (C,τ) coordinate system. In the closed streamline case $(\lambda > \lambda_c)$, similar to the solid particle, inertia plays a crucial role, and the Nusselt number must scale as $G(\alpha,\lambda Re^{1/2}Pe^{1/2}$. A methodology is developed to analyze the convection along spiraling streamlines using a physically motivated choice of coordinate system on the drop surface.

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