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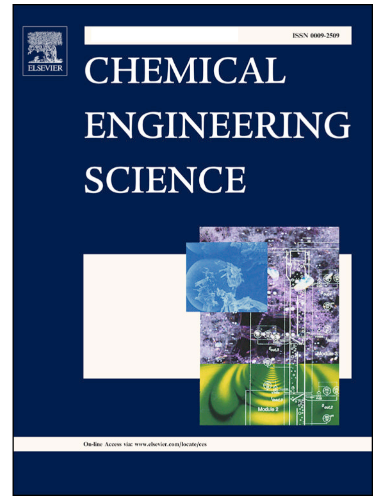

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Forced convection heat and mass transfer from a slender particle

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Abstract

We utilize slender body theory along with a reciprocal theorem to predict the convective enhancement in heat and mass transfer from an axisymmetric particle in a Stokes flow that approaches a uniform stream at large distances. The particle can be oriented at an arbitrary angle to the flow. The Péclet number, Pe, based on the particle length is considered to be $O(1)$, in which case the effect of convection is not small on this scale. Specifically, we calculate the ratio $Nu(Pe)/Nu(0)$ through $O(1/\ln(1/\epsilon))$, where Nu is the Nusselt number (i.e., the normalized heat flux from the particle) and ϵ is the (small) ratio of the characteristic thickness to length of the particle. At fixed Pe, the maximum value of Nu occurs for a body whose axis of symmetry is perpendicular to the imposed flow; the minimum value occurs when the axis of symmetry is aligned with the flow.

Keywords:
Forced convection, Slender body theory, Reciprocal theorem, Heat and mass transfer

1. Introduction

Calculation of the convective enhancement of heat and mass transfer from particles immersed in a flowing fluid is a classic problem in chemical engineering science. Here, we consider a single, rigid particle at a uniform temperature, T'_p, held fixed in an incompressible fluid whose velocity at large distances from the particle approaches a uniform stream. The temperature far from the particle, T'_f, is also uniform. We assume that the physical properties of the fluid do not vary with temperature. Therefore, the temperature field in the fluid, T', satisfies the convection-diffusion equation, which in dimensionless form reads

$$Pe\left(\frac{\partial T}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla} T\right) = \nabla^2 T, \tag{1}$$

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