

Accepted Manuscript

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PII: S0009-2509(17)30569-9

DOI: <http://dx.doi.org/10.1016/j.ces.2017.09.015>

Reference: CES 13792

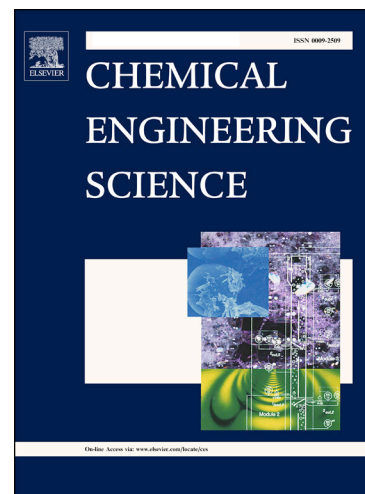
To appear in: *Chemical Engineering Science*

Received Date: 13 June 2017

Accepted Date: 7 September 2017

Please cite this article as: L.M. Relyea, A.S. Khair, Forced convection heat and mass transfer from a slender particle, *Chemical Engineering Science* (2017), doi: <http://dx.doi.org/10.1016/j.ces.2017.09.015>

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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

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

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