An optimization approach to find the thermodynamic limit on convective mass transfer enhancement for a given viscous dissipation

Shengkun Jia, Chao Zhang, Xigang Yuan, Kuo-Tsong Yu

Chemical Engineering Science

www.elsevier.com/locate/ces

PII: S0009-2509(16)30068-9
DOI: http://dx.doi.org/10.1016/j.ces.2016.01.059
Reference: CES12815

To appear in: *Chemical Engineering Science*

Received date: 27 August 2015
Revised date: 22 January 2016
Accepted date: 25 January 2016

Cite this article as: Shengkun Jia, Chao Zhang, Xigang Yuan and Kuo-Tsong Yu, An optimization approach to find the thermodynamic limit on convective mas transfer enhancement for a given viscous dissipation, *Chemical Engineerin Science,* http://dx.doi.org/10.1016/j.ces.2016.01.059

An optimization approach to find the thermodynamic limit on convective mass transfer enhancement for a given viscous dissipation

Shengkun Jia, Chao Zhang, Xigang Yuan[*]*, Kuo-Tsong Yu*
School of Chemical Engineering and Technology, State Key Laboratory of Chemical Engineering, Chemical Engineering Research Center, Collaborative Innovation Center of Chemical Science and Engineering (Tianjin), Tianjin University, Tianjin, China

Abstract

An optimization method to find the thermodynamic limits of convective mass transfer for fixed viscous dissipation is developed. The method applies the principle of extremum entropy generation to the mass transfer problem. The mass transfer-induced entropy generation in the fluid flow is defined as the criterion. By maximizing or minimizing the criterion under the constraint of fixed viscous dissipation, a velocity field and associated body force field can be obtained, which can enhance the mass transfer process to the thermodynamic limit. By applying the optimization method, the dependence of the maximum convective mass transfer enhancement on viscous dissipation can be found. Such a mass transfer limit is shown to be useful for setting a target for mass transfer enhancement in practical applications. The analysis is demonstrated using three examples.

Keywords: enhancement of convective mass transfer; mass transfer-induced entropy generation; optimal velocity field; thermodynamic limit of mass transfer

Nomenclature

A,B,C_0	Lagrange multiplier
c_i	Mass concentration, $\mathrm{kg/kg}$
C	Total molar concentration, $\mathrm{mol/m^3}$
D	Diffusion coefficient, $\mathrm{m^2/s}$
$\boldsymbol{F}$	Additional volume force per unit volume, $\mathrm{N/m^3}$
J	Total entropy generation due to mass transfer, $\mathrm{W/K}$
J_q	Heat flux, $\mathrm{J/(s\cdot m^2)}$
J_n	Mass flux, $\mathrm{kg/(s\cdot m^2)}$
J_s	Entropy flux
k	Thermal conductivity, $\mathrm{J/(s\cdot K\cdot m)}$

[*] To whom correspondence should be addressed. Tel: +86 022 27402786. Email: yuanxg@tju.edu.cn