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Solving the population balance equation with the high-order least-squares method: Implementation issues

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Abstract

The high-order least-squares method is associated with complex linear algebra and thus complicated implementation issues. In this study, a population balance problem describing bubbly flows is solved using the least-squares technique within the spectral framework. The aim of this paper is to outline the numerical solution algorithm.

Keywords: Population balance; least-squares method; bubbly flow; implementation issues

1. Introduction

In gas–liquid systems such as bubble column reactors [1] the dispersed phase plays a major role in determining the hydrodynamic behavior of the system. The complex dynamics of the dispersed phase and its influence in the hydrodynamics of the system is a challenging problem which is still not sufficiently understood. In bubble columns, the complexity of the hydrodynamics relates to evolution of phenomena such as breakage, coalescence, growth and advective transport of the bubbles. Such events affect the bubble size distribution in the bubble columns; and consequently, set the interfacial momentum, heat, and mass transfer fluxes through the contact area. Thus, the bubble size distribution is important for the operation of the bubble columns in order to obtain optimal process performance. Both experimental studies and modeling work are needed to achieve extended understanding of the important mechanisms of

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Nomenclature

Latin Letters

$\mathcal{B}$	Boundary operator
b	Breakage frequency (1/s)
c	Coalescence frequency (1/s)
f	Unknown function
$f_{d,V}$	Volume density function (1/m)
$f_{d,M}$	Mass density function (kg/m/m^3)
$f_{d,N}$	Number density function (#/m^3/m)
f_{pdf}	Probability density function (-)
$\mathcal{J}$	Functional
g	Gravitational acceleration (m/s^2)
g	Source term
h_0	Initial film thickness (m)
h_f	Critical film thickness for rapture (m)
h_b	Daughter size redistribution (1/m)
k_1	Breakage kernel parameter (s)
k_2	Breakage kernel parameter (-)
$\mathcal{L}$	Linear operater
L	Problem matrix
N	Number of bubbles (1/m^3)
N	Number of collocation points
p	Pressure (Pa)
P_z	Polynomial order, z-coordinate
P_ξ	Polynomial order, ξ-coordinate
R	Gas constant (J/kmol/K)
r	Coordinate in physical space (m)
r_c	Equivalent radius (m)