



Review

Interfacial forces used in two-phase flow numerical simulation

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ABSTRACT

High fidelity 3D computational simulation for gas–liquid two-phase flow is getting important to simulate various thermal–hydraulic phenomena in nuclear related components. Single-phase computational simulation techniques have reached to a certain level of reasonable prediction accuracy for the purposes of designs and performance analyses of industrial equipment. However, two-phase computational simulation techniques have not reached to the level of reliable prediction due mainly to the difficulty in the modeling of interfacial transfer terms. Accurate modeling of the interfacial forces including the interfacial area modeling is one of the keys to predict the distribution of gas phase in various two-phase flow systems successfully. This paper is aiming at reviewing the interfacial force modeling including recent advance of the interfacial area transport equation. This paper discusses the frame-work of bubble-wall collision force which is potentially used in place of the wall lubrication force applicable for laminar flow. This paper also discusses the frame-work of the bubble collision force considering the effect of the bubble coalescence on the bubble collision frequency. The review of existing interfacial force models including newly developed bubble-wall collision force and recent advance of the interfacial area transport equation offers the most advanced knowledge of constitutive equations necessary for improving the predictive capability of the two-phase flow computational simulation codes.

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Nomenclature

A_{base}	base area of group-2 bubble radius	σ	surface tension
A_d	projection area of a bubble	η	volume generation rate per unit volume
a_i	interfacial area concentration	η_c	collision efficiency
B_g	bubble volume	ϕ	source term of interfacial are concentration
C_W	coefficient	ρ	density
D	hydraulic equivalent diameter of flow channel	$\Delta\rho$	density difference
D_b	bubble diameter	ν	kinematic viscosity
Eo	Eötvös number	ν_t	kinematic turbulent viscosity
F	interfacial force	ν_t^{BI}	bubble induced kinematic turbulent viscosity
G_S	dimensionless velocity gradient	μ	dynamic viscosity
g	gravitational acceleration	Σ	macroscopic bubble collision cross section
H_{gf}	curvature of gas phase	$\bar{\tau}$	shear stress
k	turbulent kinetic energy	ζ	modification factor due to bubble deformation
L_{wet}	perimeter		
M	interfacial momentum transfer term		
n_b	number density	Subscripts	
n_w	normal unit vector of wall	1	group-1
n_z	unit vector along flow direction	2	group-2
p	pressure	f	liquid phase
P	variable of exponential law	g	gas phase
P	momentum	i	value at interface
$Pr_{\alpha f}$	Prandtl number for volume fraction	j	j -th interface
Re	Reynolds number	ph	phase change
r_d	bubble radius	k	k -phase (gas or liquid)
S	source or sink term of bubble number per unit volume	q	bubble group q (group 1 or group 2)
St	Stokes number	W	wall
t	time	∞	single-bubble system
V	volume		
v	velocity	Superscripts	
v_r	relative velocity	BC	bubble collision force
v_t	turbulence velocity	BF	Basset force
y_w	distance between bubble and wall	BW	bubble/Wall collision force
		D	drag force
Greek symbol		IP	interfacial pressure force
α	void fraction	IS	interfacial shear force
α_{max}	maximum allowable void fraction	LF	lift force
Δm_{12}	inter-group mass transfer term	VM	virtual mass force
Γ	interfacial mass transfer term	SL	shear induced lift force
ε	turbulence dispersion rate	TD	turbulent dispersion force
χ	coefficient of inter-group transfer	WL	wall lubrication force

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