Process Intensification and Green Chemistry – Notation and Symbology

Chapter 3 (process intensification)

Roman symbol	Definition	Units	Comments
a	surface area per unit volume	m^2/m^3	
A	area	m^2	
A	amplitude	m	
A/V	surface area of heat transfer to reaction volume	1/m	
ATU	area of a transfer unit	m^2	ATU takes the form of A_G, A_L, A_{OG}, or A_{OL} depending on which film is controlling
B^o	nuclei formed per unit volume per unit time	$1/m^3/s$	
Bo	Bodenstein number	-	
c	molar concentration of solute in solution	mol/m^3	
c^*	molar equilibrium concentration (solubility)	mol/m^3	
C_D	discharge coefficient of baffle	-	
C_W	flow rate coefficient	-	
d	diameter of disk	m	
d	inner tube diameter	m	
d_e	effective diameter of multi-orifice COBRs	m	if number of orifices $n_o = 1$, $d_e = d$
d_o	orifice diameter	m	
$D\ or\ D_m$	diffusion coefficient	m^2/s	
E_{ML}	Murphree efficiency based on liquid phase	-	
E_{MV}	Murphree efficiency based on vapor phase	-	
f	frequency	Hz	
F	F-factor	$Pa^{0.5}$	
$F_V\ or\ F$	feed flow rate	m^3/s	
G	molar flow rate of gaseous/vapor phase	mol/s	
G	crystal growth rate	m/s	
G	Gap ratio (RS-SDR)	-	
h	convective heat transfer coefficient	$W/m^2/K$	
$HETP$	height equivalent of a theoretical plate	m	
k	mass transfer coefficient	m/s	

k	thermal conductivity	W/m/K	
k_G	crystal growth rate constant	various units	function of temperature, agitation speed, impurities and system
k_L	mass transfer coefficient	m/s	
$k_L a$	volumetric mass transfer coefficient	1/s	
k_N	nucleation rate constant	various units	function of temperature
l	characteristic crystal length	m	
l_e	mixing length for eddy enhancement model	m	
L	molar flow rate of liquid phase	mol/s	
L	Baffle spacing (COBR)	m	
L/d	length to internal tube diameter ratio	-	
M_T	slurry density	various units	
n_o	number of orifices	-	
N	agitation speed	rpm	
N_b	number of baffles per unit length		
N_{CSTR}	number of CSTRs in series for the tank-in-series model		parameter used to characterize the non-ideality of real reactors
Nu	Nusselt number		
NTP	number of equilibrium plates		
NTS	number of equilibrium stages		
NTU	number of transfer units		NTU takes the form of N_G, N_L, N_{OG}, or N_{OL} depending on which film is controlling
p	pressure	Pa	
P	power	W	
Pr	Prandtl number		
Pe_{ax}	axial Peclet number		
Q	volumetric flow rate	m^3/s	
$\dot{Q}$	heat flow	W	
r	radial distance	m	
R	disk radius (TF-SDR)	m	
r_d	disk radius (RS-SDR)	m	
r_i	inner radius	m	
r_o	outer radius	m	
Re	Reynolds number		
Re_n	net flow Reynolds number		equivalent to Re
Re_o	oscillatory Reynolds number		
s	gap between rotor and stator (RS-SDR)	m	

s	supersaturation	mol/m^3	
S	saturation ratio		
$Str\ or\ Sr\ or\ St$	Strouhal number		
t	time	s	
t_{mx}	mixing time	s	
T	oscillation period	s	
T	temperature	°C or K	
u	velocity	m/s	
u_G	velocity of gas phase	m/s	
U	overall heat transfer coefficient	W/m^2/K	
v	velocity	m/s	
v_r	radial velocity	m/s	
v_θ	tangential velocity	rad/s	
V	volume	m^3	
V_r	volume of reactor	m^3	
V_{PFR}	plug flow volume	m^3	
V_{PFR}^*	volume fraction of plug flow to total reactor volume		
W	electrical power	W	
x	mole fraction of solute in bulk liquid phase		
x_i	mole fraction of solute in liquid phase at vapor/liquid interface		
x_j	mole fraction of solute in liquid phase at position j		j can refer to F feed, B bottoms, D distillate, or positions 1 or 2 of RPB
x_0	center-to-peak amplitude	m	
X	molar conversion		
y	mole fraction of solute in bulk vapor phase		
y_i	mole fraction of solute in vapor phase at vapor/liquid interface		
y_j	mole fraction of solute in vapor phase at position j		j can refer to F feed, B bottoms, D distillate, or positions 1 or 2 of RPB
z	position	m	
Greek symbols	**Definition**	**Units**	**Comments**
α	open cross-sectional area	m^2	
$\dot{\gamma}(r,z)$	shear rate	1/s	
$\delta(r)$	film thickness	m	
$\bar{\delta}$	mean film thickness	m	
ε	specific power dissipation or energy dissipation rate	W/m^3 or W/kg	
η	internal effectiveness factor		
λ	thermal conductivity	W/m/K	
μ	dynamic viscosity	Pa s	

ν	kinematic viscosity	m^2/s
$\nu_{i,j}$	stoichiometric coefficient of species i in reaction j	
ρ_G	density of the gas phase	kg/m^3
$\overline{\rho_m}$	mean density	kg/m^3
σ^2	variance	
$\sigma^2(\dot{\gamma})$	variance in the shear rate	$1/s^2$
$\sigma^2(\varepsilon)$	variance in the specific power dissipation	W^2/m^6
τ	mean residence time	s
τ_c	contact time (penetration theory)	s
τ_{mx}	(micro)mixing time	s
τ_{rx}	reaction time	s
ϕ	Thiele modulus	
Ψ	velocity ratio	
ω	angular velocity	rad/s
Ω	overall effectiveness factor	
Abbreviation	**Definition**	
CAPEX	capital expenditure	
CFD	computational fluid dynamics	
COBC	continuous oscillatory baffled crystallizer	
COBR	continuous oscillatory baffled reactor	
CSD	crystal size distribution	
CSTR	continuous stirred tank reactor	
HETP	height equivalent to a theoretical plate	
HEX	heat exchanger reactor	
HGAP	high-gravity anti-solvent precipitation	
HTF	heat transfer fluid	
MSMPR	mixed suspension mixed product removal	
MSZW	metastable zone width	
OPEX	operating expenditure	
PI	process intensification	
RPB	rotating packed bed	
RSR or RS-SDR	rotor-stator spinning disk reactor	
RTD	residence time distribution	
RZB	rotating zigzag bed	
SDR	spinning disk reactor	
SS	stainless steel	

TF-SDR	thin-film spinning disk reactor
TSCC-RPB	two-stage counter-current rotating packed bed