Design and Development of a Modified Spouted Bed Coater for the Micro-encapsulation of Powders

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Abstract

A modified spouted bed coater was designed and constructed for the micro-encapsulation of solid particles. The coating of small particles with a polymer film can alter physical factors such as taste and release rate. These properties are particularly important in the field of pharmacology as the nature of the coating can be changed to prolong or target drug release based on physiological conditions such as pH and time.

The spouted bed coater was modified to induce gas and particle recirculation through a draft tube containing a venturi to increase droplet and particle mixing, while a high velocity gas jet and large diameter draft tube promotes the recirculation of gas and solid within the apparatus. The effectiveness of the design was tested in terms of gas and solid mass flows through the draft tube using a venturi within the draft tube and an induction detector to measure the mass flow.

To determine the effectiveness of the coater design in terms of coalescence and the influence of operational variables, a factorial experiment was conducted. The result of this experiment showed that the coalescence of particles was dominated by the relative humidity in the apparatus which was unable to be directly related to the operational variables.

The capacity to micro-encapsulate particles was demonstrated by coating fine table salt with an acrylic polymer Eudragit NE 40D in combination with bentonite clay as a free flow agent or glident. The results of this trial showed the distribution of polymer/clay and the reduction in dissolution rate as a function of particle size.

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Nomenclature

a	particle radius, m
A	area of droplet, m^2
A_a	area of atomizer air nozzle, m^2
A_t	total area of atomizer air nozzle orifice, m^2
c	rupture energy constant
C_o	capillary pressure of touching spheres, Pa
C_D	coefficient of drag
d_p	particle diameter, m
$d_{p(max)}$	maximum particle diameter for coalescence, m
D_d	diameter of droplet, m
D_{dt}	diameter of draft tube, m
$D_{j(0)}$	diameter of inlet gas jet at z = 0, inlet gas nozzle diameter, m
D_{50}	50% of the mass of particles are less than this diameter, m
D_{90}	90% of the mass of particles are less than this diameter, m
D_{max}	maximum diameter of draft tube, m
dM/dt	rate of mass change, kg/s
e	coefficient of restitution
F_γ	surface tension force, N
F_{sp}	capillary suction force, N
F_{total}	total liquid bridge force, $F_\gamma + F_{sp}$, N
G	granule or particle growth rate , m/s
g	gravitational constant, m/s^2
h	half the separation distance between particle surfaces, m
h_c	convection heat transfer coefficient, W m^{-2} K^{-1}
h_0	initial height of liquid layer on particle surface, m
h_a	height of surface asperity on surface of core particle, m
H	height, m
H_{min}	minimum height of draft tube, m
k_d	thermal conductivity of droplet, W/mK
K_f	coefficient of resistance of fabric, kPa s/m
K_p	coefficient of resistance of powder, kPa m s/kg

M_p	individual particle mass, kg
M_s	total mass of solids in apparatus, kg
M_{sf}	mass of solids on filter fabric, kg
m	mass of particle, kg
N	number concentration, particles/m^3
N_{pixel}	number of pixels
P	pressure, Pa
Q_a	mass of atomizer air flow, kg/s
Q_l	mass of atomizer liquid flow, kg/s
Q_g	mass flow of gas, kg/s
$Q_{g(Z)}$	mass flow of gas at point z on the z axis, kg/s
Q_s	mass flow of solids, kg/s
Q_b	mass flow of binder, kg/s
r_1	minimum radius of liquid bridge, m
r_2	radius of curvature of liquid bridge, m
t	time, s
$t_{circ.}$	circulation time, s
t_r	gas retention time, s
u	velocity of particle, m/s
u_0	initial particle velocity, m/s
$u_{0(max)}$	initial maximum particle collision velocity for coalescence, m/s
U	velocity of gas, m/s
U_t	settling velocity of particle, m/s
v_r	radial particle velocity, m/s
V_d	volume of atomized droplet
v_{rel}	relative velocity, m/s
V_p	volume of particle, m^3
V_b	volume of liquid bond, m^3
v	velocity, m/s
W	work, J
x	particle separation distance, m
Z	distance from jet, m

Dimensionless Groups

b^* binder to solids volume ratio, V_b/V_p

b^*_c critical binder to solids ratio, $(1+h_a/a)^3-1$

C_a Capillary number, $\mu u/\gamma$

Nu Nusselt number, $h_c D_d / k_d$

Re Reynolds number, $U_g D \rho_g/\mu_g$

St_v Stoke's number, $2mu_o/3\pi\mu a^2$

V_b * dimensionless bridge volume, V_b/a^3

W^* dimensionless bond rupture energy, $W/\gamma a^2$

ε dimensionless particle separation distance, $2h/a$

Greek

α contact angle, degrees

β half-filling angle, degrees

ΔH_{vap} latent heat of vaporization, J/kg

ΔT_{lm} log mean temperature difference, K

μ viscosity, kg/ms

ρ density, kg/m^3

ρ_s density of solid, kg/m^3

γ surface tension, N/m

ε_z voidage of fluid bed at point z on the z axis

θ gas jet dispersion angle, degrees

φ the binder liquid contact angle

ω powder loading, kg/m^2