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DISCRETE PARTICLE SIMULATION OF SPOUTED BED WITH HEAT TRANSFER

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อากาศพลศาสตร์ของอนุภาคและการไหลของแก๊สในสเปาเต็ดเบดแบบสองมิติที่มีแผ่นกั้น (draft plates) อยู่ภายใน ได้ถูกศึกษาโดยอาศัยวิธีการแบบดิสครีตอีลิเมนต์ (Discrete element method) รูปทรงของสเปาเต็ดเบดแบบสองมิติที่มีแผ่นกั้นถูกกำหนดให้ใกล้เคียงกับการทดลองของ Kudra, 1992 และ Kalwar, 1991 คุณสมบัติของอนุภาคกำหนดให้ใกล้เคียงกับข้าวโพด ผลการคำนวณความเร็วต่ำสุดในการเกิดสเปาและความดันลด สอดคล้องตามความสัมพันธ์ของ Kudra, 1992 และ Kalwar, 1991 ในบริเวณสเปาพบว่าความเร็วในแนวตั้งของอนุภาคลดลงตามความสูงของภาชนะที่เพิ่มขึ้น อัตราการไหลเวียนของอนุภาคเพิ่มขึ้นเมื่อสัมประสิทธิ์แรงเสียดทานลดลงหรือ ระยะห่างระหว่างแผ่นกั้นที่อยู่ในสเปากับฐานของภาชนะ (Separation height) เพิ่มขึ้น ที่จุดความเร็วต่ำสุดในการเกิดสเปา ความสูงของเบดไม่มีผลกระทบต่ออัตราการไหลเวียนของอนุภาคในสเปาเต็ดเบดแบบสองมิติที่มีแผ่นกั้นอยู่ภายใน แผ่นกั้นที่อยู่ในสเปา ไม่เพียง ช่วยลดความเร็วต่ำสุดในการเกิดสเปา และ ความดันลด แต่ ยังช่วยเพิ่มความสูงของเบดในการเกิดสเปา (Maximum spoutable bed height) ผลกระทบของการนำแผ่นกั้นภายในสเปาออกต่อปรากฏการณ์การเกิดสเปา และผลกระทบของแผ่นกั้นที่ด้านบนของสเปา (Deflector) ต่อการแตกหักของเมล็ด ได้ถูกศึกษาด้วย การถ่ายเทความร้อนระหว่างแก๊สไปยังอนุภาคในสเปาเต็ดเบดแบบสองมิติที่มีแผ่นกั้นอยู่ภายในได้ถูกศึกษาโดยใช้วิธีการแบบดิสครีตอีลิเมนต์ร่วมกับแบบจำลองทางความร้อนที่ได้พัฒนาขึ้นมา ผลการศึกษาพบว่าอัตราการถ่ายเทความร้อนระหว่างแก๊สไปยังอนุภาคเกิดขึ้นส่วนใหญ่ในบริเวณสเปา ซึ่งสอดคล้องกับรายงานของ Freitas and Freire (1998).

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สาขาวิชา...วิศวกรรมเคมี.....ลายมือชื่ออาจารย์ที่ปรึกษา.....
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KEY WORD:DEM SIMULATION/ TWO-DIMENSIONAL SPOUTED BED/ HEAT TRANSFER

THANIT SWASDISEVI: DISCRETE PARTICLE SIMULATION OF SPOUTED BED WITH HEAT TRANSFER. THESIS ADVISOR: PROF.WIWUT TANTHAPANICHAKOON, Ph.D., THESIS CO-ADVISOR : PROF. YUTAKA TSUJI, Ph.D., ASSOC.PROF: TAWATCHAI CHARINPANITKUL, D.Eng., 115 pp. ISBN 974-17-3950-8

The aerodynamics of particles and gas flow in a two-dimensional spouted bed (2DSB) with draft plates is investigated with the aid of the Discrete Element Method (DEM). The geometry of the 2DSB with draft plates is set as close as possible to the experimental apparatus of Kudra (1992) and Kalwar (1991). The physical properties of the coarse particles are similar to those of shelled corn. The calculated minimum spouting velocity and pressure drop agrees well with the correlations of Kudra (1992) and Kalwar (1991). In the spout region, the particle vertical velocities are found to decrease as the height increases. The fluid velocity in the downcomer region decreases as the superficial gas velocity increases. The particle circulation rate increases when the friction coefficient decreases or the separation height increases. At the minimum spouting velocity, the bed height does not affect the particle circulation rate in the 2DSB with draft plates. The draft plates not only reduce the minimum spouting velocity and pressure drop but also increase the maximum spoutable bed height. The effect of taking out the draft plates on the spouting phenomenon is investigated and the effect of putting in a deflector on the possible breakage of the particles are also estimated. The gas-to-particle heat transfer in 2DSB with draft plates is also investigated with the aid of the DEM and the developed thermal model. It is found that the gas-to-particle heat transfer occurs mainly in the central or spout region of the bed as reported by Freitas and Freire (1998).

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NOMENCLATURES

A_d	cross-sectional area of downcomer, m^2
A_p	external area of a particle, m^2
c_p	heat capacity, J/kg K
d	diameter, m
F	force, N
f_c	contact force, N
f_D	drag force, N
f_{pi}	interaction force between the fluid and particles, N
g	gravity acceleration, m/s^2
h	heat transfer coefficient between a particle and its external gas, $J/K/m^2/s$
H_b	bed height, m
H_d	spout height, m
H_e	entrance height or separation height, m
I	moment of inertia, $kg\ m^2$
k	thermal conductivity, W/m K
k_n	spring constant in normal direction, N/m
k_t	spring constant in tangential direction, N/m
L_b	bed length, m
m	mass of a particle, kg
Δn	relative displacement, m
n_{ij}	unit vector from the center of particle i to that of particle j , -
Nu	Nusselt number, -
p	gas pressure, Pa
ΔP	pressure drop, Pa
Pr	Prandtl number, -
Q_s	heat transfer between a particle and gas, $J/s/m^3$
R_d	distance from the spout central axis to the draft plate, m
Re	Reynolds number, -

NOMENCLATURE (Continued)

r	distance, m/s
s	slot width, m
t	time, second
t_0	initial time, second
T	temperature, K or torque,
Δt	time step, second
u	gas velocity, m/s
u_i	superficial gas velocity at inlet gas, m/s
u_{ms}	minimum spouting velocity, m/s
v	particle velocity or velocity vector or fluid velocity, m/s
v_{rij}	velocity vector of particle i relative to particle j , m/s
v_{sij}	the slip velocity of the contact point, m/s
v_p	particle velocity above slanting base, m/s
\bar{v}_{pi}	average particle velocity, m/s
V_p	volume of a particle, m^3
V	volume of a fluid cell ($\Delta x * \Delta y * \Delta z$)
W	vessel width, m
W_d	spout width, m
W_i	width of gas inlet, m
W_s	mass flow rate of particle, kg/s
x_1	displacement of particle 1 in x direction, m/s^2
y	distance from the central spout axis in y direction, m
y_1	displacement of particle 1 in y direction, m/s^2
z	distance from the bottom of the vessel in z direction, m

Greek letters

ϵ	void fraction, -
ρ_b	bulk density, $\rho_b = \rho_p(1-\epsilon)$, kg/m^3
ρ_g	gas density, kg/m^3

NOMENCLATURE (Continued)

ρ_p	particle density, kg/m ³
ϕ	sphericity or dependent variable, -
θ	slant angle, degree
ε	void fraction, -
ω	angular velocity,
η	damping coefficient
μ_r	friction coefficient, -
μ_g	gas viscosity of gas phase, Pa s
δ_{nij}	particle displacement caused by normal force
δ_{tij}	particle displacement caused by tangential force
α_R	relaxation factor
$(\dot{\cdot})$	time derivative
Superscript	
*	assumed value
'	modified value
Subscript	
N	North
S	South
E	East
W	West
n	north surface
s	south surface
e	east surface
w	west surface
p	particle
g	gas
d	disperse phase (particle)
c	continuous phase (gas)