

**EXPERIMENTAL STUDY AND SIMULATION OF BUBBLE
FLUIDIZATION**



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ABSTRACT

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The objectives of this study were to measure the particle granular temperature in gas-solid fluidization using a CCD camera technique, to simulate the model for bubble fluidization, and to compare the experimental results with the simulation results. Granular temperatures and bubble properties were measured in a two-dimensional fluidized bed using 530 μm diameter glass beads and a uniform inlet gas velocity. At a low gas inlet velocity of 33.55 cm/sec, the bubble diameter was higher than that calculated by Davidson model due to an error by the measurement in the bubble burst region. Bubble rising velocity was near that calculated by Gidaspow model. At a high gas inlet velocity of 58.7 cm/sec, two granular temperatures; particle granular temperature and bubble-like granular temperature, were measured from experiment. The particle granular temperature was obtained from particle velocity oscillations per photograph of CCD camera. The bubble-like granular temperature was received from the bubble motion. It was found that the bubble-like granular temperature from the bubble motion was higher than that of particle velocity oscillation. The simulation calculated the axial and radial velocity in the bubble. The errors of the radial velocity between the experiment and simulation were from 1.49 – 48.87 % and that of the axial velocity were from 13.21 – 38.16 %.

บทคัดย่อ

สุทธิพงษ์ ทรงประวัตติ: การทดลองและการประมวลผลทางโปรแกรมของฟองอากาศในหอฟลูอิดไดซ์ (Experiment and Simulation of Bubble Fluidization) อ. ที่ปรึกษา : ศ. ดร. ดิmittรี จิตาสพาว, ดร. กิติพัฒน์ สีมานนท์, และ ดร. สุขญา นิตวิฒนานนท์ 137 หน้า ISBN 974-17-2306-7

วัตถุประสงค์ของการศึกษานี้คือการวัดอุณหภูมิระดับอนุภาค(Granular temperature) ของอนุภาคในการไหลของก๊าซโดยใช้เทคนิคกล้องถ่ายภาพวีดีโอซีซีดี, เพื่อแสดงผลของแบบจำลองสำหรับการไหลแบบมีฟองอากาศ, และเพื่อเปรียบเทียบผลจากการทดลองกับผลจากแบบจำลอง อุณหภูมิระดับอนุภาค และฟองอากาศได้จากการวัดในหอฟลูอิดไดซ์แบบสองมิติ โดยการใช้อุณหภูมิของอนุภาค 530 ไมครอน และความเร็วของก๊าซขาเข้าที่ความเร็วต่ำซึ่งมีค่าเท่ากับ 33.55 เซนติเมตรต่อวินาที, ขนาดของฟองอากาศมีค่าสูงกว่าค่าที่คำนวณจากเดวิดสัน เนื่องจากค่าความคาดเคลื่อนของการวัดซึ่งเกิดจากฟองอากาศเกิดการแตกตัวที่บริเวณผิว และความเร็วของฟองอากาศ มีค่าใกล้เคียงกับค่าที่ได้จากสูตรของดิmittรี สำหรับการทดลองที่ใช้ความเร็วของก๊าซขาเข้าเป็น 58.7 เซนติเมตรต่อวินาที อุณหภูมิระดับอนุภาคมี 2 ค่า คือ อุณหภูมิระดับอนุภาคของอนุภาคกับ อุณหภูมิระดับอนุภาคของฟองอากาศ อุณหภูมิระดับอนุภาคของอนุภาคได้จากการวัดแกว่งของอนุภาค ซึ่งได้จากการเฉลี่ยค่าของความเร็วของอนุภาคในแต่ละรูปภาพ อุณหภูมิระดับอนุภาคของฟองอากาศหาได้จากการเคลื่อนที่ของฟองอากาศ จากการทดลองพบว่าอุณหภูมิระดับอนุภาคของฟองอากาศสูงกว่าอุณหภูมิระดับอนุภาคของอนุภาค แบบจำลองคำนวณค่าของความเร็วในแนวตั้งกับความเร็วในแนวนอน ค่าความคาดเคลื่อนของความเร็วในแนวนอนระหว่างการทดลองกับแบบจำลองมีค่าตั้งแต่ .49 – 48.87 % ค่าความคาดเคลื่อนของความเร็วในแนวตั้งระหว่างการทดลองกับแบบจำลองมีค่าตั้งแต่ 13.21 – 38.16 %.

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LIST OF SYMBOLS

A_o	Catchment area, m^2
C_D	Drag coefficient
c_0	Average particle velocity of the system, cm/sec
C_o	Orifice coefficient
$c_{x_{i,j}}$	Radial velocity of the i th particle on the j th frame, cm/sec
$c_{y_{i,j}}$	Axial velocity of the i th particle on the j th frame, cm/sec
$\langle C_x C_x \rangle_j$	Reynolds stress in x- direction on the j^{th} frame, cm^2/sec^2
$\langle \overline{C_x C_x} \rangle$	Average Reynolds stress in x- direction, cm^2/sec^2
$\langle C_x C_y \rangle_j$	Shear stress on the j^{th} frame, cm^2/sec^2
$\langle \overline{C_x C_y} \rangle$	Average Shear stress, cm^2/sec^2
$\langle C_y C_y \rangle_j$	Reynolds stress in y- direction on the j^{th} frame, cm^2/sec^2
$\langle \overline{C_y C_y} \rangle$	Average Reynolds stress in y- direction, cm^2/sec^2
D_B	Equivalent bubble diameter, m
ΔL	Length of stripped line on the snapped picture (cm)
ΔP	Different pressure, $g/(m*s^2)$
Δt	Time of shutter speed, second
G	Shear modulus
g	Gravitational acceleration = 980.6 cm/sec^2
h	Height above distributor, m
N	Total number of the frame
n_j	Total number of the particle in the j th frame
P_f	Fluid pressure
Q_o	Volumetric flow rate at orifice
R	Gas constant
Re	Reynolds Number
t	Time, second

T	Temperature, K
T_f	Shear stress of fluid
T_k	Shear stress of solid
\bar{u}	Average radial velocity of system, cm/sec
u_j	Average radial velocity of particle on the j th frame, cm/sec
U	Superficial velocity, m/sec
U_{mf}	Minimum fluidization, m/sec
\bar{v}	Average axial velocity of system, cm/sec
v_f	Velocity of fluid, cm/sec
v_j	Average axial velocity of particle on the j th frame, cm/sec
v_k	Velocity of solid
v_x	Velocity of particle in x - direction, cm/sec
v_y	Velocity of particle in y - direction, cm/sec
α	Angle between the direction of particle and the vertical line
θ	Granular temperature
ε_f	Volume fraction of fluid
ε_k	Volume fraction of solid
β	Ratio of orifice diameter to pipe diameter
β_{fk}	Inter-phase drag coefficient
ρ_f	Density of fluid, g/cm^3
ρ_k	Density of solid, g/cm^3
τ_f	Fluid stress, $dyne/cm^2$
τ_k	Solid stress, $dyne/cm^2$
μ_f	Viscosity of fluid
ψ_k	Sphericity of solid