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ระหว่างของเหลวกับของแข็งในถังกวนมาตรฐาน



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A STUDY OF GENERAL SOLID - LIQUID MASS TRANSFER CORRELATION
IN STANDARD AGITATED VESSEL



Miss Anchaleeporn Waritswat

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

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หัวข้อวิทยานิพนธ์	การศึกษาเพื่อหาสัมพัทธ์ทั่วไปของการถ่ายเทมวลระหว่างของเหลวกับของแข็งในถังกวนมาตรฐาน
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บทคัดย่อ

การศึกษาเพื่อหาสัมพัทธ์ทั่วไปของสัมประสิทธิ์การถ่ายเทมวลระหว่างของเหลวกับของแข็งในถังกวนมาตรฐาน โดยมีของแข็งที่มีความหนาแน่นค่าต่าง ๆ แขนงลอยอยู่ในของเหลวต่างชนิดกันคือน้ำ สารละลายน้ำตาลซูโครส 13, 20 และ 35.5 เปอร์เซ็นต์ โดยน้ำหนัก พบว่า ความแตกต่างระหว่างค่าความหนาแน่นของของแข็งกับของเหลว ซึ่งมีค่าไม่เกิน 0.4 กรัม/ลูกบาศก์เซนติเมตร จะไม่มีผลต่อค่าสัมประสิทธิ์การถ่ายเทมวล ทั้งนี้ได้ทำการศึกษาในช่วงอุณหภูมิ 25 °C ถึง 45 °C และความเร็วรอบของการปั่นกวน มีค่าระหว่าง 250 ถึง 550 รอบต่อนาที

ผลที่ได้แสดงอยู่ในรูปของกลุ่มตัวเลขไร้มิติ คือ

$$Sh_p = rRe_p^{1.21} Sc^{0.50}$$

ความสัมพัทธ์ดังกล่าวนี้ สามารถใช้งานได้ในช่วงตัวเลขเรย์โนลส์ระหว่าง 1.04×10^4 ถึง 7.7×10^4 และตัวเลขชมิติก์ระหว่าง 411 ถึง 14,318 สำหรับค่าคงที่ r ขึ้นอยู่กับระบบที่ใช้ในการทดลอง พบว่า ในระบบที่มีกรดเบนโซอิกเคลือบบนวัสดุต่าง ๆ คือ บนเม็ดลูกแก้ว เม็ดกลมของโพลิสไตรีน เม็ดพลาสติกชนิดที่ 1 และชนิดที่ 2 กับน้ำ หรือกับสารละลายน้ำตาลซูโครส 13, 20 และ 35.5 เปอร์เซ็นต์ โดยน้ำหนัก ค่าคงที่ r จะมีค่าเป็น 1.90×10^{-5} , 3.00×10^{-5} , 3.57×10^{-5} และ 6.48×10^{-5} ตามลำดับ ดังนั้นความสัมพัทธ์ที่ได้สำหรับระบบต่าง ๆ คือ

ระบบที่มีกรดเบนโซอิกเคลือบบนวัสดุต่าง ๆ - น้ำ

$$Sh_p = 1.90 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$4 \times 10^4 < Re_p < 7.7 \times 10^4$$

$$411 < Sc < 1,032$$

ระบบที่มีกรดเบนโซอิกเคลือบบนวัสดุต่าง ๆ - สารละลายน้ำตาล 13 เปอร์เซ็นต์
โดยน้ำหนัก

$$Sh_p = 3.00 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$3 \times 10^4 < Re_p < 5 \times 10^4$$

$$1,210 < Sc < 1,516$$

ระบบที่มีกรดเบนโซอิกเคลือบบนวัสดุต่าง ๆ - สารละลายน้ำตาล 20 เปอร์เซ็นต์
โดยน้ำหนัก

$$Sh_p = 3.57 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$2.2 \times 10^4 < Re_p < 4.5 \times 10^4$$

$$1,539 < Sc < 3,043$$

ระบบที่มีกรดเบนโซอิกเคลือบบนวัสดุต่าง ๆ - สารละลายน้ำตาล 35.5 เปอร์เซ็นต์
โดยน้ำหนัก

$$Sh_p = 6.48 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$1.04 \times 10^4 < Re_p < 2.2 \times 10^4$$

$$7,072 < Sc < 14,318$$

Thesis Title A Study of General Solid - Liquid Mass Transfer
 Correlation in Standard Agitated Vessel

Name Miss Anchaleeporn Waritswat

Thesis Advisor Assistant Professor Sasithorn Boon-Long, Dr. 3eme cycle

Department Chemical Engineering

Academic Year 1986



ABSTRACT

This work is a contribution to the study of general solid - liquid mass transfer coefficient correlation in standard agitated vessel. Solids of different densities are suspended in different liquids, water, 13 wt %, 20 wt % and 35.5 wt % sucrose solution respectively. It is found that density difference ($\Delta\rho$) not greater than 0.4 g/cm^3 had insignificant effect on the mass transfer coefficient. In this study the temperatures are between 25°C to 45°C and the speeds of rotation between 250 rpm to 550 rpm.

Results obtained are shown and correlated in terms of dimensionless number

$$Sh_P = r Re_P^{1.21} Sc^{0.50}$$

This correlation is valid for Reynolds number in the range of 1.04×10^4 to 7.7×10^4 and Schmidt number in the range of 411 to 14,318. The constant r depends on the systems in the experiment. In the system of benzoic acid coated on glass beads, polystyrene spheres, plastic particles type 1 and type 2 and water, 13 wt %, 20 wt % and 35.5 wt % sucrose solution, the constant r is

1.90×10^{-5} , 3.00×10^{-5} , 3.57×10^{-5} and 6.48×10^{-5} respectively. The correlations obtained for the systems are as follows

The system of benzoic acid coated on various materials -
water

$$Sh_p = 1.90 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$4 \times 10^4 < Re_p < 7.7 \times 10^4$$

$$411 < Sc < 1,032$$

The system of benzoic acid coated on various materials -
13 wt % sucrose solution

$$Sh_p = 3.00 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$3 \times 10^4 < Re_p < 5 \times 10^4$$

$$1,210 < Sc < 1,516$$

The system of benzoic acid coated on various materials -
20 wt % sucrose solution

$$Sh_p = 3.57 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$2.2 \times 10^4 < Re_p < 4.5 \times 10^4$$

$$1,539 < Sc < 3,043$$

The system of benzoic acid coated on various materials -
35.5 wt % sucrose solution

$$Sh_p = 6.48 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$$

$$1.04 \times 10^4 < Re_p < 2.2 \times 10^4$$

$$7,072 < Sc < 14,318$$



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NOMENCLATURE

Dimensions are given in terms of mass (M), length (L), time (t) and temperature (T).

A	=	Area (L^2)
c	=	Concentration (ML^{-3})
c_f	=	Final concentration (ML^{-3})
c_o	=	Initial concentration (ML^{-3})
c_s	=	Saturation concentration (ML^{-3})
Δc	=	Concentration difference (ML^{-3})
Δc_{ML}	=	Log mean of concentration difference (ML^{-3})
dA	=	Exchange area (L^2)
dm	=	Quantity of dissolved mass per unit time (Mt^{-1})
\bar{d}_p	=	Average particle diameter (L)
d_p	=	Particle diameter (L)
D_{AB}	=	Binary diffusivity for system A-B (L^2t^{-1})
D_i	=	Impeller diameter (L)
\bar{D}_v	=	Average Diffusion coefficient (L^2t^{-1})
D_v	=	Diffusion coefficient (L^2t^{-1})
g	=	Gravitational acceleration (Lt^{-2})
H_i	=	Impeller height from the tank bottom (L)
H_l	=	Liquid height (L)
k	=	Mass transfer coefficient (Lt^{-1})
L	=	Impeller blade length (L)
m	=	Quantity of mass dissolved per unit time (Mt^{-1})
N	=	Rotation speed (t^{-1})

N'	=	Mass flux across a phase boundary ($\text{mol L}^{-2}\text{t}^{-1}$)
N_A	=	Molar flux of species A ($\text{mol L}^{-2}\text{t}^{-1}$)
N_B	=	Molar flux of species B ($\text{mol L}^{-2}\text{t}^{-1}$)
p	=	Variable exponent
q	=	Variable exponent
r	=	Constant vary with impeller type and system geometry
S	=	Fractional rate of surface renewal (t^{-1})
t	=	Time (t)
T	=	Tank diameter (L)
V	=	Volume of liquid in the vessel (L^3)
W	=	Impeller blade width (L)
W_b	=	Baffle width (L)
x	=	Variable exponent
X_A	=	Mole fraction of A (dimensionless)
Z	=	Thickness of the diffusion film (L)
δ	=	Film thickness (L)
μ	=	Liquid viscosity ($\text{ML}^{-1}\text{t}^{-1}$)
ρ_s	=	Solid density (ML^{-3})
ρ, ρ_1	=	Liquid density (ML^{-3})
$\Delta\rho$	=	Density difference between solid and liquid = $\rho_s - \rho_1$ (ML^{-3})
ω	=	Angular velocity (t^{-1})
ϕ_s	=	Shape factor of particle

Commonly used Dimensionless Groups

M_v	=	Density group ($\rho_s - \rho_1 / \rho_1$)
Re_a	=	Reynolds number referred to agitator ($D_a^2 N \rho_1 / \mu$)
Re_p	=	Reynolds number referred to solid particle ($T d_p \rho_1 / \mu$)
Re_T	=	Reynolds number referred to tank ($T^2 N \rho_1 / \mu$)
Sc	=	Schmidt number ($\mu / \rho_1 D_v$)
Sh_p	=	Sherwood number referred to solid particle ($k d_p / D_v$)
Sh_T	=	Sherwood number referred to tank (kT / D_v)



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