

**TWO-PHASE FLOW IN VERTICAL TUBES
AND FLOODING IN PACKED COLUMNS**



Ms. Jareerat Puengpatipan

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By : Ms. Jareerat Puengpatipan
Program : Petrochemical Technology
Thesis Advisors : Dr. Kitipat Siemanond
Prof. James O. Wilkes

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K. Bunyakiat
..... College Director
(Assoc. Prof. Kunchana Bunyakiat)

Thesis Committee:

Kitipat Siemanond
.....
(Dr. Kitipat Siemanond)

James O. Wilkes
.....
(Prof. James O. Wilkes)

Pomthong Malakul
.....
(Dr. Pomthong Malakul)

Boonyarach Kitiyanan
.....
(Dr. Boonyarach Kitiyanan)

ABSTRACT

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Keywords : Flow regime/ Bubble flow/ Slug flow/ Air-lift pump/ Vertical tube/ Flooding/ Packed column/ Eckert chart

Systems involving gas-liquid phase concurrent vertical flows are found important in evaporators and in the simultaneous transport of oil and gas in wells. For the two-phase flow study, flow regimes and the hydrodynamics of slug were determined. Experimental measurements were carried out in a vertical tube with 1.9 cm in diameter and 300 cm in length using an air-water system. The superficial air velocities used were in the range of 0 to 14.67 cm/s, whereas the superficial velocities of water were 2.93 to 70.42 cm/s. Bubble to slug flow pattern map was generated. In addition, the relation between rise velocity of single slug and the slug length, rise velocity of continuously generated slug, void fraction and air-lift pump operation within slug flow were investigated. All results conformed to the Nicklin's models.

Flooding, an important physical phenomenon in two-phase countercurrent packed towers, was studied experimentally by varying the type (ceramic ball and plastic raschig ring) and the heights (60 and 80 cm) of packing material in column with a diameter of 8.4 cm and 128 cm long. The range of water mass velocities studied was 0.15 to 0.60 g/cm².s and the air mass velocities between 0 to 11.66 g/cm².s. The Eckert type charts of different packing materials were studied to find the scope of flooding. The results showed that ceramic balls gave lower scope of flooding than plastic raschig rings did and at different heights of the same packing, they gave the same transition between normal and flooding operation. For the pressure drop study, an increase in gas mass velocities and water mass velocities at constant air mass velocity caused an increase in pressure drop.

บทคัดย่อ

จารีรัตน์ พึ่งปฏิภาณ : การไหลของของไหลสองสถานะในท่อแนวตั้งและการท่วมของของเหลวในท่อบรรจุตัวกลาง (Two-Phase Flow in Vertical Tubes and Flooding in Packed Columns) อ. ที่ปรึกษา : ศ. เจมส์ โอ วิลส์ และ ดร. กิติพัฒน์ สีมานนท์ 95 หน้า ISBN 974-03-1588-7

ระบบที่ประกอบด้วยแก๊สและของเหลวที่ไหลแบบขนานกันภายในท่อแนวตั้งมีความสำคัญในเครื่องทำระเหย และในท่อส่งน้ำมันและแก๊สจากบ่อน้ำมัน ในการศึกษาี้ รูปแบบการไหลและการเคลื่อนที่ของกระสุนอากาศในระบบอากาศและน้ำถูกวิเคราะห์ในท่อพลาสติกใส ขนาด 1.9 เซนติเมตร \times 300 เซนติเมตร (เส้นผ่านศูนย์กลางภายใน \times ความสูง) ความเร็วอากาศที่ศึกษาอยู่ในช่วง 0 ถึง 14.67 เซนติเมตรต่อวินาที ในขณะที่ความเร็วของน้ำอยู่ในช่วง 2.93 ถึง 70.42 เซนติเมตรต่อวินาที ผังการไหลแบบฟองและกระสุนอากาศได้ถูกสร้างขึ้น นอกจากนี้ยังได้มีการศึกษาความสัมพันธ์ระหว่างความเร็วพุ่งขึ้นของกระสุนอากาศในน้ำแบบเดี่ยว กับความยาวกระสุน, ความเร็วพุ่งขึ้นของกระสุนอากาศแบบต่อเนื่อง, อัตราส่วนว่างของอากาศ และการปฏิบัติการของเครื่องสูบอาศัยแรงดันอากาศภายในการไหลแบบกระสุน ผลการทดลองทั้งหมดสอดคล้องกับผลที่ได้จากแบบจำลองของนิกลิน

ของเหลวท่วมท่อเป็นปรากฏการณ์ที่เกิดขึ้นในระบบการไหลสองสถานะแบบสวนทางกันในหอปฏิบัติการ โดยได้ทำการศึกษาในท่อพลาสติกใสขนาด 8.4 เซนติเมตร \times 128 เซนติเมตร และเปลี่ยนชนิดของวัสดุตัวกลางคือ ลูกบอลเซรามิกและวงแหวนพลาสติกที่ความสูงของวัสดุตัวกลาง 60 และ 80 เซนติเมตร ความเร็วมวลน้ำที่ศึกษาจาก 0.15 ถึง 0.60 กรัมต่อตารางเซนติเมตร.วินาที และความเร็วมวลอากาศจาก 0 ถึง 11.66 กรัมต่อตารางเซนติเมตร.วินาที ผังรูปแบบของเอ็กเคิร์กได้ถูกนำมาใช้เพื่อศึกษาช่วงของการเกิดของเหลวท่วม ผลการทดลองพบว่าผังกเอ็กเคิร์กของลูกบอลเซรามิกให้ช่วงของของเหลวท่วมต่ำกว่าวงแหวนพลาสติกในทั้งสองความสูง ในขณะที่ผังกเอ็กเคิร์กของตัวกลางชนิดเดียวกันพบว่าการเปลี่ยนจากช่วงปฏิบัติการไปสู่ช่วงของเหลวท่วมไม่แตกต่างกันมาก ส่วนการศึกษาความดันลดพบว่าความดันลดจะเพิ่มขึ้นเมื่อเพิ่มความเร็วมวลอากาศ หรือเพิ่มความเร็วมวลน้ำในขณะที่ความเร็วมวลอากาศคงที่

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LIST OF SYMBOLS

A	Cross-sectional area of a tube, cm^2
a	Surface area of the packing per cubic centimeter of packed volume cm^{-1}
c	Constant value for equation (5)
D	Tube inner diameter, cm
F	Packing factor
G	Volumetric flowrate of gas, LPM
G_g	Gas mass velocity, $\text{g cm}^{-1}.\text{s}^{-1}$
G_l	Liquid mass velocity, $\text{g cm}^{-1}.\text{s}^{-1}$
g	Acceleration due to gravity, cm.s^{-2}
g_c	Conversion factor
H	Height of liquid in the main column, cm
H_0, h	Height of liquid in the reservoir column, cm
L	Volumetric flowrate of liquid, ccm
p_1	Pressure at point 1
p_2	Pressure at point 2
U_b	Rise velocity of bubble in stagnant liquid, cm.s^{-1}
U_l	Mean upward liquid velocity, cm.s^{-1}
U_s	Rise velocity of slug, cm.s^{-1}
u_a	Axial velocity component of liquid around slug, cm.s^{-1}
u_r	Radial velocity component of liquid around slug, cm.s^{-1}
ε	Void fraction
ρ_g	Density of gas, g cm^{-3}
ρ_l	Density of liquid, g cm^{-3}
ψ	Ratio of density of water and density of liquid
μ_l	Viscosity of liquid, cp
ϕ	Potential function