

**THEORY AND SIMULATION OF INCIPIENT INSTABILITY IN  
GAS-SOLID FLUIDIZATION**

**LOOK KAR YANG**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**THEORY AND SIMULATION OF INCIPIENT INSTABILITY IN  
GAS-SOLID FLUIDIZATION**

By

**LOOK KAR YANG**

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**Chairman: Associate Professor Thomas Choong Shean Yaw, PhD**

**Faculty: Engineering**

The mechanism of incipient instability in gas-solid fluidized bed was investigated by using Computational Fluid Dynamics (CFD) simulation – FLUENT version 6.1.18. The Finite Volume Method (FVM) is employed to simulate the complex flow behaviours and heterogeneous structure of the gas-solid fluidized bed. Fluidization of Geldart group A, B and C particles were simulated.

The formation and development of the plumes during incipient fluidization were studied. Different fluidization behaviours of Geldart group A, B and C particles were observed from the contours of gas volume fraction and velocity vector. The observations agreed well with characteristics and behaviours of particles in gas-solid fluidized bed as reported by [Geldart \(1973\)](#).

A theory of transient instability adopted with the principles advanced by Tan and Thorpe (1992 and 1996) was proposed to calculate the theoretical transient Rayleigh number ( $Ra_c$ ) for the onset of incipient instability. The mobilization of the particles occurred once a critical value of transient Rayleigh number was exceeded. Different type of particles exhibited different  $Ra_c$  values. However, the  $Ra_c$  is almost independent of the superficial velocity.

The incipient instability of gas-solid fluidized bed was first identified when the initial stable air diffusion became distorted and particles began to move chaotically. The fluidization parameters such as gas volume fraction, bubble rise velocity and bed pressure drop were used to determine the critical time for onset of incipient instability.

The simulated critical onset time ( $t_c$ ) and transient Rayleigh Number ( $Ra_c$ ) for the incipient instability of gas-solid fluidized bed were then investigated. A correlation between  $Ra_c$  and permeability was derived, which provides a convenient and simple way to estimate the  $Ra_c$ . The predicted values of  $Ra_c$  were found to agree fairly well with the literature data.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**TEORI DAN SIMULASI KETIDAKSTABILAN INSIPIEN DALAM  
PEMBENDALIRAN GAS-PEPEJAL**

Oleh

**LOOK KAR YANG**

**Disember 2006**

**Pengerusi: Profesor Madya Thomas Choong Shean Yaw, PhD**

**Fakulti: Kejuruteraan**

Mekanisme ketidakstabilan insipien dalam turus terbendalir gas-pepejal telah dikaji dengan menggunakan simulasi komputasi bendalir dinamik (CFD) – FLUENT version 6.1.18. Kaedah Isipadu Terhingga (FVM) telah diguna untuk mensimulasikan kelakuan aliran yang kompleks dan struktur heterogen dalam turus terbendalir gas-pepejal. Pembendaliran butiran kumpulan Geldart A, B dan C telah disimulasikan.

Pembentukan dan perkembangan ruang udara semasa pembendaliran insipien telah dikaji. Sifat pembendaliran yang berbeza untuk butiran dari kumpulan Geldart A, B dan C telah diperhatikan daripada kontur pecahan isipadu gas dan vektor halaju. Cerapan ini bersetuju dengan ciri dan sifat butiran dalam turus terbendalir gas-pepejal seperti yang dilaporkan oleh Geldart (1973).

Teori transien ketidakstabilan yang berdasarkan prinsip yang dimajukan oleh Tan dan Thorpe (1992 and 1996), Tan *et al.* (2003) dan Tan (2004) telah dicadangkan untuk menghitung nombor Rayleigh transien ( $Ra_c$ ) secara teori untuk permulaan ketidakstabilan insipien. Pergerakan butiran terjadi apabila nilai kritikal nombor Rayleigh transien telah dilebihi. Butiran yang berlainan akan mempamerkan nilai  $Ra_c$  yang berbeza. Walau bagaimanapun, nilai  $Ra_c$  adalah tidak tersandar kepada kelajuan gas.

Ketidakstabilan insipien turus terbendaliran gas-pepejal pertama dikenalpastikan apabila resapan awal gas stabil mula terherot dan butiran bergerak secara tidak tertib. Parameter seperti pecahan isipadu gas, halaju buih dan susutan tekanan telah diguna untuk menentu masa kritikal untuk permulaan ketidakstabilan insipien.

Simulasi masa kritikal permulaan ( $t_c$ ) dan nombor Rayleigh transien ( $Ra_c$ ) untuk ketidakstabilan insipien dalam turus terbendalir gas-pepejal telah dikaji. Satu hubungan di antara  $Ra_c$  dan ruangan butiran telah diterbitkan. Ini menyediakan kaedah yang mudah dan ringkas untuk meramalkan  $Ra_c$ . Nilai ramalan  $Ra_c$  didapati bersetuju dengan data dalam literatur.

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I certify that an Examination Committee met on **7<sup>th</sup> November 2006** to conduct the final examination of Look Kar Yang on his Master of Science thesis entitled "Theory and simulation of incipient instability in gas-solid fluidization" in accordance with

Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Sa'ari Mustapha, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Luqman Chuah Abdullah, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Siti Aslina Hussain, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Internal Examiner)

**Yinghe He, PhD**

Associate Professor  
Faculty of Engineering  
James Cook University, Australia  
(External Examiner)

---

**HASANAH MOHD. GHAZALI,**  
**PhD**  
Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

**Thomas Choong Shean Yaw, PhD**

Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Mohamad Amran, PhD**

Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**AINI IDERIS, PhD**

Professor/Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:



## **DECLARATION**

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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**LOOK KAR YANG**

Date:

## **TABLE OF CONTENTS**

**DEDICATION**

**Page**  
ii

<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	v
<b>ACKNOWLEDGEMENTS</b>	vii
<b>APPROVAL</b>	viii
<b>DECLARATION</b>	x
<b>LIST OF TABLES</b>	xiii
<b>LIST OF FIGURES</b>	xiv
<b>LIST OF NOMENCLATURE</b>	xvi
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	1.1
<b>2. LITERATURE REVIEW</b>	2.1
2.1 Introduction	2.1
2.2 Principle of Fluidization	2.1
2.2.1 Minimum fluidization velocity	2.6
2.2.2 Instabilities in Fluidized Bed	2.8
2.2.3 Flow pattern in Gas-solid Fluidized Bed	2.10
2.2.4 Fluidization Parameters	2.11
2.3 Theoretical Analysis of Incipient Fluidization	2.14
2.3.1 Theory of Transient Instability	2.16
2.4 Numerical Studies in Fluidized Bed	2.18
2.5 Overview	2.22
<b>3. DEVELOPMENT OF THE TRANSIENT INSTABILITY THEORY</b>	3.1
3.1 Introduction	3.1
3.2 Incipient Fluidization Induced by Transient Mass Diffusion	3.2
3.3 Overview	3.7
<b>4. MATERIALS AND METHODOLOGY</b>	4.1
4.1 Computational Fluid Dynamics (CFD) Simulations	4.1
4.2 Overall Solution Algorithm	4.2
4.3 Simulation of Eulerian Multiphase Model for Instability in Fluidized Bed	4.3
4.3.1 Conservation Equations in Eulerian Multiphase Model	4.4
4.3.2 Fluid-Solid Exchange Coefficient for Fluidized Bed	4.5
4.4 Numerical Considerations and Constrains in CFD Simulation	4.6
4.4.1 Computational Grid Size	4.6
4.4.2 Time-dependent Simulation and Simulation Time Step	4.7
4.4.3 Under-relaxation	4.8
4.4.4 Interpolation Scheme	4.8
4.4.5 Physical Properties	4.9

4.4.6	Residual and Convergence Criteria	4.9
4.5	Simulation Setup for the Incipient Instability in Gas-solid Fluidized Bed	4.10
4.6	Judging of Convergence and Data Output	4.12
4.7	Overview	4.13
<b>5.</b>	<b>RESULTS AND DISCUSSIONS</b>	<b>5.1</b>
5.1	Introduction	5.1
5.2	Validation of the Simulations	5.2
5.3	Geldart group C Particle	5.3
5.3.1	Flow Behaviour and Detection of the Onset of Incipient Fluidization	5.4
5.4	Geldart group A Particle	5.14
5.4.1	Flow Behaviour and Detection of the Onset of Incipient Fluidization	5.15
5.5	Geldart group B Particle	5.21
5.5.1	Flow Behaviour and Detection of the Onset of Incipient Fluidization	5.22
5.6	Critical Rayleigh Number and Critical Onset Time	5.28
5.7	Overview	5.32
<b>6.</b>	<b>CONCLUSIONS</b>	<b>6.1</b>
<b>7.</b>	<b>RECOMMENDATIONS</b>	<b>7.1</b>
	<b>REFERENCES</b>	<b>R.1</b>
	<b>APPENDICES</b>	<b>A.1</b>
	<b>BIODATA OF THE AUTHOR</b>	<b>V.1</b>

## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
2.1	Geldart's classification of solid in gas fluidization	2.3

2.2	Different contacting regimes at increasing superficial velocity (Grace, 1986)	2.4
2.3	The profile of voidage for increasing superficial velocity	2.12
2.4	Evolution and propagation of two-dimensional bubble. (a) 0.25 s; (b) 0.34 s; (c) 0.39 s; (d) 0.44 s; (e) 0.49 s; (f) 0.60 s. (Bouillard, 1991)	2.13
2.5	Calculated and experimental result in Yuu's (2000) simulation with air velocity of 0.4 m/s	2.19
2.6	Snapshot of the behavior of gas-solid fluidized bed. (Kenya and Masayuki, 2002)	2.20
2.7	Distribution of the void fraction for a simulated bubbling fluidized bed by Pain <i>et al.</i> (2002)	2.21
4.1	An overview of the segregated solution method	4.3
4.2	Comparison of the grid size effect on the velocity profile	4.7
4.3	The setting of the computational domain for the fluidized bed simulation (Group C particle)	4.11
5.1	Diffusion of air at superficial velocity less than the minimum fluidization velocity ( $U_c = 0.8 U_{mf}$ ). Convection is not observed	5.3
5.2	Onset of incipient instability of zeolite particle bed subjected to superficial velocity of 0.02 m/s (contours of gas volume fraction)	5.5
5.3	Onset of incipient instability of zeolite particle bed subjected to superficial velocity of 0.02 m/s (contours of air velocity)	5.8
5.4	Comparison of the velocity profiles at $z_{max}$ for Geldart group C particle (geothite) subjected to different superficial velocities	5.9
5.5	Comparison of the velocity profiles at $z_{max}$ for Geldart group C particle (zeolite) subjected to different superficial velocities	5.10
5.6	Comparison of the velocity profiles at $z_{max}$ for Geldart group C particle (alumina) subjected to different superficial velocities	5.10
5.7	Comparison of pressure drop profiles at $z_{max}$ for Geldart group C particle (geothite) subjected to different superficial velocities	5.11
5.8	Comparison of pressure drop profiles at $z_{max}$ for Geldart group C particle (zeolite) subjected to different superficial velocities	5.12

5.9	Comparison of pressure drop profiles at $z_{\max}$ for Geldart group C particle (alumina) subjected to different superficial velocities	5.12
5.10	Onset of incipient instability of zinc oxide particle bed subjected to superficial velocity of 0.1 m/s (contours of gas volume fraction)	5.15
5.11	Onset of incipient instability of zinc oxide particle bed subjected to superficial velocity of 0.1 m/s (contours of air velocity)	5.17
5.12	Comparison of the velocity profiles at $z_{\max}$ for Geldart group A particle (zinc oxide) subjected to different superficial velocities	5.19
5.13	Pressure drop profile at $z_{\max}$ for zinc oxide particle bed subjected to superficial velocity of 0.10 m/s	5.20
5.14	Onset of incipient instability of glass bead particle bed subjected to superficial velocity of 0.4 m/s (contours of gas volume fraction)	5.22
5.15	Onset of incipient instability of glass bead particle bed subjected to superficial velocity of 0.4 m/s (contours of air velocity)	5.25
5.16	Comparison of the velocity profiles at $z_{\max}$ for Geldart group B particle (glass bead, 310 $\mu\text{m}$ ) subjected to different superficial velocities	5.26
5.17	Pressure drop profile at $z_{\max}$ for glass bead subjected to various inlet superficial velocities.	5.27
5.18	Critical Rayleigh number for Geldart group C particles subjected to different superficial velocities	5.29
5.19	$Ra_c$ versus permeability	5.29
5.20	Comparison of predicted and literature $Ra_c$	5.31

## LIST OF TABLES

Table		Page
2.1	Characteristic and behavior of particle according to Geldart's classification	2.3

2.2	Some fluidization parameters studied in the literature	2.11
2.3	Comparison between the DEM and TFM method	2.22
4.1	Setting of the simulation cases for fluidized bed (Group C particles)	4.12
4.2	Dimension of simulated fluidized bed for group A and B particle	4.12
5.1	Properties of Geldart group C particles studied ( <i>Kwauk et al., 1997</i> )	5.4
5.2	Summary of critical onset time at different superficial velocity detected from three different fluidization profiles (Geldart group C particles)	5.13
5.3	Comparison of simulated and experimental critical onset time of incipient fluidization for an inlet air superficial velocity of 0.02 m/s	5.13
5.4	Properties of Geldart group A particle studied ( <i>Kenya and Masayuki, 2002</i> )	5.14
5.5	Summary of critical onset time at different superficial velocity detected from three different fluidization profiles (Geldart group A particles)	5.20
5.6	Comparison of simulated and experimental critical onset time of incipient fluidization for an inlet air superficial velocity of 0.1 m/s	5.21
5.7	Properties of Geldart group B particles studied ( <i>Yuu et al., 2000</i> )	5.21
5.8	Summary of critical onset time at different superficial velocity detected from three different fluidization profiles (Geldart group B particles)	5.27
5.9	Comparison of simulated and experimental critical onset time of incipient fluidization for an inlet air superficial velocity of 0.4 m/s	5.28