Mechanistic, Neural Network, and Intelligent Hybrid Models for a Three-Phase Fluidised-Bed Biofilm Reactor

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This thesis is dedicated to
my grandmother 이용녀.

너는 마음을 다하여 여호와를 의뢰하고
네 명철을 의뢰하지 말라.
너는 범사에 그를 인정하라
그리하면 네 길을 지도하시리라 (잠언 3장 5-6절)

Trust in the Lord with all your heart,
And do not lean on your own understanding.
In all our ways acknowledge Him,
And He will make your paths straight.
(Proverbs 3:5-6)

ABSTRACT

Over the past three decades, considerable amount of research efforts have been undertaken in order to develop a mathematical model for a three-phase fluidised-bed biofilm reactor (TPFBBR). Although biofilm properties such as biofilm thickness and its density are allowed to vary with biofilm growth in the model to simulate the real TPFBBR system, they are assumed to be constant in the majority of models developed for a TPFBBR. The main goal of this thesis is to develop mathematical models incorporating dynamic biofilm growth for a TPFBBR using three different modelling approaches such as a mechanistic model, a neural network model, and an intelligent hybrid model with a neurofuzzy model.

This thesis consists of three parts. Firstly, a dynamic biofilm growth model, which reflects the variation of biofilm thickness and its density in time, is developed. This model is derived from a biomass balance equation and is solved by the method of characteristics. The biofilm detachment model is proposed and incorporated within the dynamic biofilm growth model. The dynamic biofilm growth model with detachment is then combined with a reaction-diffusion model and reactor model to form an integrated model of a TPFBBR. Simulation method of integrated model incorporating the dynamic biofilm growth model is developed. It is observed that results predicted are in good agreement with experimental data and the integrated model proposed provides a valuable tool to predict performance of a TPFBBR.

Secondly, the sequential neural network model, which is composed of two parts, namely, the neural process estimator and the neural process predictor, is developed to describe the task of process estimation and prediction for a TPFBBR. In order to implement the sequential neural network model, multilayer feedforward neural network (MFNN) with cascaded-correlation (C-C) learning and extended Kalman filtering (EKF) learning, and generalized regression neural network (GRNN) are used. Results shows that the sequential neural network model has the feasibility as

intelligent estimators and dynamic predictors and gives considerably good results in process estimation and prediction for a TPFBBR.

Finally, this thesis shows how a combination of both mechanistic and empirical modelling approaches, called a hybrid model, can be implemented and utilised for modelling a TPFBBR. The neurofuzzy model as an empirical part of hybrid model is used to estimate the variation of the biofilm thickness and biofilm density, and is combined with mechanistic model-based reaction-diffusion and axial-dispersion models to predict the dynamic behavior and performance of a TPFBBR according to the variation of biofilm density and biofilm thickness. This hybrid modelling approach due to its flexibility shows a unified framework through incorporation of strong points of both mechanistic and empirical models, and provides a new modelling framework with a great potential to be applied to other types of biofilm reactors.

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CONTENTS

Abstract ii

Acknowledgements iv

Contents v

List of Figures x

List of Tables xv

List of Abbreviations xvii

1 Introduction **1**

1.1 Introduction 1

1.2 Thesis Overview 4

1.3 Contributions of This Thesis 6

2 Three-Phase Fluidised-Bed Biofilm Reactor-Background **8**

2.1 Three-Phase Fluidised-Bed Biofilm Reactor (TPFBBR) 8

2.2 Hydrodynamics of TPFBBR 13

2.2.1 Flow Regimes 13

2.2.2 Minimum Fluidisation Velocity 14

2.2.3 Pressure Drops and Phase Holdups 16

2.2.4 Gas-Liquid Mass Transfer 17

2.2.5 Liquid-Solid Mass Transfer 19

2.2.6 Mixing 24

2.3 Biofilm Characteristics in a TPFBBR 28

2.3.1 Biofilm Formation 28

2.3.2 Biofilm Characteristics 30

3 Experimental Methods **34**

3.1 Introduction 34

3.2 Experimental 34

3.2.1 Reactor 34

3.2.2 Startup and Operation of a TPFBBR 35

3.2.3 Microorganisms and Culture Medium 37

3.2.4 Analytical Methods 38

4 Mechanistic Model for a TPFBBR Incorporating Dynamic Biofilm Growth **40**

4.1 Introduction 40

4.2 Overview of Biofilm Growth Model 41

4.2.1 Steady-State Biofilm Growth Model 41

4.2.2 Dynamic Biofilm Growth Model 42

4.3 Dynamic Biofilm Growth Model 43

4.3.1 Detachment Model 46

4.3.1.1 Overview of Biofilm Detachment Model 46

4.3.1.2 Important Parameters Influencing Detachment in a TPFBBR 48

4.3.1.3 Detachment Model Formulation 50

4.3.2 Biofilm Growth Model Incorporating Detachment 53

4.4 Review of Mathematical Modelling of a TPFBBR 55

4.5 Integrated Model Development 56

4.5.1 Reaction-Diffusion Model 57

4.5.2 Reactor Model 58

4.5.3 Hydrodynamic Parameters 59

4.5.3.1 Axial Dispersion Coefficient 60

4.5.3.2 Liquid-Solid Mass Transfer Coefficient 60

4.5.3.3 Phase Holdups 62

4.6 Results and Discussion 64

4.6.1 Computer Program 64
4.6.2 Computer Simulation Scheme of Integrated Model 65
4.6.3 Model Simulation Results 68
4.7 Conclusions 82

5 Sequential Neural Network Model for a TPFBBR 83

5.1 Introduction 83
5.2 Basics of an Artificial Neural Networks 85
5.2.1 What is an Artificial Neural Network (ANN)? 85
5.2.2 An Artificial Neural Network as a Process Modelling Tool 87
5.2.3 Multilayer Feedforward Neural Networks (MFNN) 90
5.2.4 Backpropagation (BP) Training Algorithm 92
5.2.5 Cascade-Correlation (C-C) Algorithm 99
5.2.6 Extended Kalman Filtering (EKF) Learning Algorithm 101
5.2.7 Generalized Regression Neural Network (GRNN) 104
5.3 Sequential Neural Network Model 107
5.3.1 Criteria for Validation of Neural Network Mode 109
5.4 Results and Discussions 112
5.4.1 Data Sets 112
5.4.2 Data Transformation 112
5.4.3 Neural Process Estimator 119
5.4.4 Neural Process Predictor 124
5.5 Conclusions 127

6 Intelligent Hybrid Model with a Neurofuzzy Process Estimator for a TPFBBR 129

6.1 Introduction 129
6.2. Fuzzy System 131
6.2.1 Fuzzy Sets 131

6.2.2 Fuzzy Inference System 133

6.2.3 Takagi & Sugeno (TS) Fuzzy Model 140

6.3 Neurofuzzy Modelling 140

6.3.1 Contact Points of Fuzzy System and Artificial Neural Networks 140

6.3.2 Background of Neurofuzzy Systems 143

6.3.3 The Architecture of the ANFIS Neurofuzzy System 147

6.3.4 Hybrid Learning Algorithms of the ANFIS 149

6.4 Intelligent Hybrid Modelling for a TPFBBR 152

6.4.1 Reaction-Diffusion Model 152

6.4.2 Axial-Dispersion Model 152

6.4.3 Intelligent Hybrid Model for a TPFBBR 155

6.5 Results and Discussion 158

6.5.1 Results of Neurofuzzy Process Estimators 158

6.5.2 Predictions of Dynamic Performance using Hybrid Model of TPFBBR 176

6.6 Conclusions 183

7 Conclusions 184

7.1 Summary 184

7.2 Applicability of Models Developed in This Thesis 186

Nomenclature 191

References 194

Appendices 207

A. Main FORTRAN program for a TPFBBR used in Chapter 4 207
B. Some routines for multilayer feedforward neural network (MFNN) trained by extended Kalman filtering (EKF) learning algorithm used in Chapter 5 216

LIST OF FIGURES

Figure		Page
2.1	Three-phase fluidised bed reactor (TPFBR)	9
2.2	The TPFBBR system	10
2.3	Flow pattern in a three-phase fluidized bed reactor	13
2.4	Illustration of mass transfer processes in FBBR	20
2.5	Axial solid distribution in a TPFBR (Tang & Fan, 1989)	27
2.6	Biofilm development processes	29
3.1	Schematic diagram of experimental apparatus	36
4.1	Schematic of biofilm growth with a volume element of biofilm	44
4.2	Design and simulation scheme for a TPFBBR	67
4.3	Time progression of the average biofilm thickness and biofilm density (U_L= 0.066 $cm/\sec$, U_G= 0.48 $cm/\sec$, d_{sp}= 570 μm)	71
4.4	Time progression of the average biofilm thickness and biofilm density (U_L = 0.0325 $cm/\sec$, U_G= 0.42 $cm/\sec$, d_{sp}= 570 μm)	72
4.5	Time progression of the average biofilm thickness and biofilm density (U_L = 0.03 $cm/\sec$, U_G= 1.2 $cm/\sec$, d_{sp}= 710 μm)	73
4.6	Time progression of the average biofilm thickness and biofilm density (U_L = 0.062 $cm/\sec$, U_G= 0.36 $cm/\sec$, d_{sp}= 275 μm)	74

4.7 The substrate concentration profiles in the liquid phase as a function of bed height at the different times (U_L = 0.078 $cm/\sec$, U_G = 0.842 $cm/\sec$, d_{sp} = 570 μm) 77

4.8 The substrate concentration profiles in the liquid phase as a function of bed height at the different times. (U_L = 0.03 $cm/\sec$, U_G = 1.2 $cm/\sec$, d_{sp} = 710 μm) 79

4.9 3-D plots of phenol concentration profile as function of bed height and time (U_L =0.078 $cm/\sec$, U_G = 0.842 $cm/\sec$, d_{sp} = 570 μm) 80

4.10 3-D plots of phenol concentration profile as function of bed height and time (U_L = 0.03 $cm/\sec$, U_G = 1.2 $cm/\sec$, d_{sp} = 710 μm) 81

5.1 Neural network models 86

5.2 Architecture of the multilayer feedforward neural network 90

5.3 Common activation functions used in neural network 91

5.4(a) The training phase of MFNN 93

5.4(b) The prediction phase of MFNN 93

5.5 Backpropagation flow chart 98

5.6 The architecture of the neural network trained with C-C after 2 hidden units have been added 100

5.7 Generalized regression neural network 105

5.8 Architecture of the sequential neural network model 110

5.9(a) Comparison of prediction results between modelling with data transformation and raw data for neural process estimator 118

5.9 (b) Comparison of prediction results between modelling with data transformation and raw data for neural process estimator 118

5.9 (c) Comparison of prediction results between modelling with data transformation and raw data for neural process predictor 119

5.10 (a)	Results of the neural process estimator for the biofilm thickness using data set 1	122
5.10 (b)	Results of the neural process estimator for the biofilm density using data set 1	122
5.11(a)	Results of the neural process estimator for the biofilm thickness using data set 2	123
5.11(b)	Results of the neural process estimator for the biofilm density using data set 2	123
5.12(a)	Prediction results of the neural process predictor (MFNN with EKF) using data set 1	125
5.12(b)	Prediction results of the neural process predictor (GRNN) using data set 1	126
5.12(c)	Prediction results of the neural process predictor (MFNN with EKF) using data set 2	126
5.12(d)	Prediction results of the neural process predictor (GRNN) using data set 2	127
6.1	Conventional sets vs. fuzzy sets	131
6.2	Different shapes of membership functions	132
6.3	Typical fuzzy sets for temperature	132
6.4	Graphical representation of fuzzy operator	135
6.5	General structure of fuzzy inference system	136
6.6	General structure of fuzzy inference engine	137
6.7	Max-Min and Max-Dot interface	139
6.8	Max-Dot interface with unioned and summed results	139
6.9	The main advantage of the neurofuzzy system	144
6.10	The architecture of the ANFIS neurofuzzy model	147
6.11	Types of hybrid model; (a) Serial hybrid model (b) Parallel hybrid model	155
6.12	The structure of hybrid model presented for a TPFBBR	157

6.13	The structure of heuristic searching algorithm for neurofuzzy system	161
6.14(a)	The result plots of the heuristic searching algorithm for structure indetification for biofilm thickness using data set 1(when MF=3): (a) 2 input selection cases	162
6.14(b)	The result plots of the heuristic searching algorithm for structure indetification for biofilm thickness using data set 1(when MF=3): (b) 3 input selection cases	163
6.15	Initial membership functions for each variable (data set 1)	165
6.16	Membership functions after learning for each variable (data set 1)	166
6.17	Plots of training and testing data distriubution on each input variable (data set1)	166
6.18	Neurofuzzy model prediction of biofilm thickness with observed value: (a) data set 1 (b) data set 2	167
6.19(a)	The result plots of the heuristic searching algorithm for structure indetification for biofilm density using data set 1(when MF=3): (a) 2 input selection cases	170
6.19(b)	The result plots of the heuristic searching algorithm for structure indetification for biofilm density using data set 1(when MF=3): (b) 3 input selection cases	171
6.20	Membership functions on each variable (a) before learning (b) after learning (data set 1)	173
6.21	Plots of training and testing data distriubution on each input variable (data set1)	174
6.22	Neurofuzzy model prediction of biofilm density with observed value: (a) data set1 (b) data set 2	175
6.23	3-D plot of time and biofilm thickness on biofilm density (data set 1)	175

6.24	The substrate concentration profiles in the liquid phase as a function of bed height at the different times for data set 1	177
6.25	The substrate concentration profiles in the liquid phase as a function of bed height at the different times for data set 2	178
6.26(a)	3-D plots of phenol concentration profile as function of bed heights and time (data set 1)	179
6.26(b)	3-D plots of phenol concentration profile as function of bed heights and time (data set 2)	180
6.27(a)	3-D plots of phenol concentration profiles within the biofilm: (data set 1)	181
6.27(b)	3-D plots of phenol concentration profiles within the biofilm: (b) data set 2	184
7.1	Different modelling paradigms	187

LIST OF TABLES

TABLE		PAGE
2.1	The comparisons of biomass concentration among biological processes (Perry, 1996)	13
2.2	Summary of empirical equation for M.F. velocity	15
2.3	Steady-state biofilm density and biofilm thickness values from different types of reactors	32
3.1	Experimental conditions	37
3.2	Composition of synthetic growth medium	38
4.1	Summary of qualitative effects of tested parameters on detachment	49
4.2	Values of parameters used in simulation	66
4.3	Operating conditions for model simulations	68
4.4	Boundary conditions for each biofilm growth model simulation	69
5.1	Categorisation of some neural networks	87
5.2	Operating conditions	113
5.3	Continuous data transformation function used in the neural process estimator	115
5.4	RMSE comparisons between data transformation and raw data for neural process estimator and predictor	116
5.5	Continuous data transformation function used in the neural process predictor	117
5.6	RMSE results of the neural process estimator for data set 1 and 2	121

5.7 Topologies of each neural network 124

5.8 The comparison of RMSE for MFNN with EKF and GRNN 125

6.1 The most popular logical fuzzy operators 135

6.2 Some examples of the neurofuzzy system 145

6.3 Learning schemes of neurofuzzy system 151

6.4 Identification results for structures of neurofuzzy models using the heuristic searching algorithm over biofilm thickness (data set 1) 164

6.5 Identification results for structures of neurofuzzy models using the heuristic searching algorithm over biofilm density (data set 1) 172