DETECTION AND IDENTIFICATION OF STICTION IN CONTROL VALVES BASED ON FUZZY CLUSTERING METHOD

By

MUHAMMAD AMIN DANESHWAR

Thesis submitted in fulfillment of the requirements for the degree of

Doctor of Philosophy

August 2016

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to Dr. Norlaili Mohd Noh, my supervisor for her help, for believing in me, for her invaluable guidance and supervision in making sure that I am always on the right track and making this research possible for me.

I am most grateful to my mother, Nazdar, my brothers, my sisters, my father in-law, and my mother in-law for their support.

I don't, forget help and useful comments of my dear friend Sadegh Aminifar.

Last, but definitely not least, I am really grateful to my lovely wife, Shiva, my son, Raman, my daughter, Avan. Without their endless support and belief in me, this thesis would never have been accomplished.

I would like to thank Alexander Horch (ABB, Germany), Claudio Scali (University of Pisa, Italy), Sirish Shah and Bau Huang (University of Alberta, Canada), Shoukat Choudhury (Bangladesh University of Engineering and Technology), Jin Wang (Peking University, China), Cludio Scali (University of Pizza, Italy), Nina F. Thornhill (Imperial College London, UK), and Peter He (Tuskegee University, USA) for their permission to using their experimental and industrial data to check the performance of proposed methods of detection, diagnosis and identification.

This thesis was supported by Universiti Sains Malaysia with RU-PRGS grant number 1001/PELECT/8046015.

I would like to dedicate this thesis to my late father Muhammad Ali (who passed away three years ago). He encouraged me all the way from preschool to my postgraduate studies; I wish he was here to see his dream come true.

TABLE OF CONTENTS

Page

CHAPTER TWO : LITERATURE REVIEW AND THEORETICAL BACKGROUND

CHAPTER THREE : METHODOLOGY

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF SYMBOLS

A_i	The antecedent fuzzy set
C	Number of clusters
C_v	Valve coefficient
$\mathrm{D}_{\mathrm{ik}}^2$	Squared inner-product distance norm
e	Error
F	Volumetric flow rate
F_a	Applied force
F_f	Applied external force
F_i	Fuzzy covariance matrix
f_d	Dynamic friction
F_r	Spring force
f_s	Static friction
F_v	Viscous friction
I_{stic}	Stiction performance index
J	Slip Jump
J_m	Cost function for clustering

K	Process gain
K_c	Controller gain
m	Amount of fuzziness
$\mathrm{MSE}_{\mathrm{sin}}$	Mean-squared error for sinusoidal fitting
MSE_{tri}	Mean-squared error for triangular fitting
N	Length of data (Number of samples)
OPhg	Upper bond of control signal
OPlw	Lower bond of control signal
R^2	Goodness-of-fit
r_{xy}	Correlation coefficient
S	Stick band plus dead band
sg	Specific gravity of the fluid
stp	Moving state of the valve
$\mathrm{T_d}$	Time delay
$\mathrm{T_{fin}}$	Time window
T_s	Sampling time
τ_l	Zero-crossing for negative lags of CCF
τ_r	Zero-crossing for positive lags of CCF

r_0	CCF at lag zero
U	Fuzzy partition matrix
u_s	Control signal at resting state of the valve
V	Vector of cluster prototypes (centers)
x_{ss}	The value of the input signal when the valve gets stuck
z_k	Data of the *k*-th sample
$\propto$	Valve design parameter
ΔP_v	Pressure drop across the valve
θ_{th}	Threshold
Ω_i	The degree of activation of the i-th rule