

Preface

Aim of the Book

Control performance monitoring (CPM) technology has progressed steadily since the key research step taken by Harris [41]. CPM has emerged as an important area of scientific and technological development in the last decade. Considerable effort has been devoted to the development and application of different CPM methodologies in various industrial fields, such as refining, chemicals, and petrochemicals, mineral processing, mining and metal processing, as well as pulp and paper.

The diversity of causes of poor performance in industrial control loops has provided the main motivation for exploring different CPM techniques. The cause of poor performance is not limited to controller design and tuning; other elements in the control systems, such as sensors and actuators, are often responsible for the poor performance. In a recent study by Paulonis and Cox [92], it was reported that the performance of 42% control loops was in the categories of “fair” and/or “poor”. In other studies by Bialkowski [10] and Ender [26], it was found that in 30% of control loops, output cycling and increased output variability was due to instrument performance issues (such as valve backlash, dead time, *etc.*). Thus, a solution to any control-loop performance problem will all too often involve diagnosis and analysis of oscillation and valve-stiction problems. Besides the detection and diagnosis of sticky control valves, it is also important to be able to quantify stiction so that a list of sticky valves in order of their maintenance priority can be prepared.

This book is a collection of contributions from several internationally leading researchers on automatic detection and diagnosis of static friction (stiction) in control loops manipulated by valves, and contains by now the most comprehensive survey of state-of-the-art and advanced techniques. Not only does it present the principles, assumptions, strengths and drawbacks, but also provides guidelines and detailed working procedures for the implementation and application of each method. An exhaustive comparison of the described approaches on nearly 100 control loops from different industrial fields (building, chemicals, pulp and paper, mineral processing, mining, and metal processing) is included.

Stiction is a sophisticated non-linear phenomenon. Its detection and quantification has been identified as a highly challenging academic as well as industrial problem. There does not exist a single “perfect” solution; each method has its assumptions, strengths, and weaknesses. Thus, it is imperative for readers to have access to different options, and compare and choose the most appropriate one for a given process-operating condition. In this respect, the book provides a good resource for researchers and industrial practitioners to find a variety of basic as well as advanced methods for solving valve-stiction problems. The methods presented include techniques for diagnosis plus quantification of stiction with both open-loop and closed-loop methods. The reader will learn how the different methods work, what key issues should be considered, and how to parametrise them. The comprehensive comparative study gives readers useful guidelines in choosing the appropriate method. Moreover, users will have access to MATLAB[®] software associated with the book so that they can directly benefit from the book by applying the methods to their data. The software are available to the public and can be downloaded from <http://www.ualberta.ca/~bhuang/Stiction-Book/>.

Readership

The algorithms presented in this book are the state-of-the-art, and are demonstrated and compared on industrial case studies from different industrial fields (building, chemicals and petrochemicals, mining, mineral and metal processing). The book will thus serve academic and industrial staff working in all these industries on control systems design, maintenance or optimisation.

The book presents – in one place – some material published in the archival literature over the last several years as well as advanced material developed most recently. It is aimed primarily at researchers and engineers in process control and industrial practitioners in process automation, but it is also accessible to postgraduate students and final-year students in process-control engineering.

Outline of the Book

The book, which has 14 chapters, is divided into two parts. Chapter 1 is an introduction to the general topics and problems treated in the book. Part I is devoted to reviewing the state-of-the-art in stiction modelling and oscillation detection, and is divided into three chapters. Chapter 2 reviews stiction models with emphasis on simple data-driven relationships between controller output (OP) and valve position (VP), *i.e.* one- and two-parameter models, and gives examples that investigate the validity and compare the behaviour of three representative stiction models available in the literature. New alternative data-driven models of stiction are proposed in Chap. 3 and compared with earlier modelling approaches. Oscillation detection

is one of the first tasks to be carried out when analysing control-loop performance. The different techniques for oscillation detection are described and discussed in detail in Chap. 4. Their applicability to industrial control-loop diagnosis is critically evaluated on various simulation and industrial case studies.

Part II of the book presents basic and advanced methodologies for stiction diagnosis and quantification, and contains ten chapters. In Chap. 5, pattern-based stiction-detection and quantification methods that assume the availability of the manipulated variable (MV), *i.e.* VP, are treated. In all subsequent chapters, the stiction detection is based only on the knowledge of OP and PV, which reflects industrial practice, where MV is usually not known, except for flow control loops, where PV and MV are considered to be coincident. Chapter 6 describes the simplest stiction-detection method based on cross-correlation between OP and PV. Since this method is only applicable to self-regulating processes, another method based on shape analysis (histogram) is also presented in this chapter for detecting stiction in integrating plants. Chapter 7 discusses a method for stiction detection based on curve fitting of the output signal of the first integrating component located after the valve in a control loop, *i.e.* OP for self-regulating processes or PV for integrating processes. Considering the similarity between the oscillation shapes of PV in loops affected by valve stiction and those obtained by a relay operating in closed loop on a first-order-plus-time-delay process, a technique based on shape determination is described in Chap. 8. Chapter 9 presents a method for detecting stiction-like behaviour in feedback control loops based on extracting features from a time series record of PV, delivering the probability that stiction is present (ranged 0–100 %). Chapter 10 discusses a new procedure for quantifying valve stiction in control loops using separable least-squares and global optimisation algorithms, assuming that the process dynamics can be described by a Hammerstein model. In a similar context, a novel stiction-detection strategy based on closed-loop identification is proposed using closed-loop operating data along with a general analysis on identifiability of the stiction loops in Chap. 11. Chapter 12 presents a novel methodology that bridges gaps in oscillation diagnostic methods. A power spectral density (PSD) based oscillation detection method followed by a model-based approach for identifying and quantifying the root cause of the oscillations is proposed. In all these chapters, the described methodologies are illustrated with simulated data and industrial data. In Chap. 13, an exhaustive comparative study of all methods presented is given, involving a large number of data sets gathered from different industrial plants, assessing the relative efficiency of the techniques, and delivering guidelines for selecting the right method for the application at hand. Chapter 14 provides a summary and a look forward to future research challenges within the topic treated in the book.

In Appendix A, some information about the industrial control loops considered throughout the book is given. Appendix B contains a short overview of the two prominent methods for non-linearity detection in the CPM area, *i.e.* the bicoherence technique and the surrogate analysis method.

Acknowledgements

This book is an outcome of a project initiated by the principal editor to establish an international database of industrial loops from different fields, to implement a common graphical user interface (GUI) for oscillation and stiction detection, and to compare oscillation and stiction-detection methods.

The editors would like to thank *all* the contributors for their very spontaneous enthusiasm and agreement to contribute to the book and particularly to the comparative study in Chap. 13. For this purpose, industrial data (Appendix A) were provided by courtesy of: Ashish Singhal and Timothy Salsbury for loops BAS 1–8; Alexander Horch for loops CHEM 1–3 and PAP 1–10; Peter He and Joe Qin for loops CHEM 4–6; Biao Huang for loops CHEM 7–12; Nina Thornhill for loops CHEM 13–17 and CHEM 40–64; Claudio Scali for loops CHEM 18–28 and CHEM 32–39; Shoukat Choudhury and Sirish Shah for loops CHEM 29–31, PAP 11–13, POW 1–5 and MIN 1.

As far as possible, we have tried to achieve a common framework for all chapters presented. The contributors were all asked to produce precise algorithms that can be easily implemented by the reader, to demonstrate their methods in simulation and industrial studies, and to use similar notation. Also, overlap in text and figures was minimised, and cross-references between the chapters were created. All this will hopefully help readers to easily understand and compare the techniques proposed. We are grateful to all contributors for their forbearance in meeting the many requests for clarity and consistency.

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