Chapter 14
Conclusions and Future Research Challenges

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14.1 Summary of the Book

To close this book, let us reiterate the goal of the book and ponder what we have achieved. As stated in the introduction, the aim of control loops is to maintain processes at the desired operating conditions, safely and efficiently. A poorly performing control loop can result in disrupted process operations, degraded product quality, higher material or energy consumption, and thus decreased plant profitability. Therefore, control loops have been increasingly recognised as important capital assets that should be routinely monitored and maintained. The performance of the controllers, as well as of the other loop components, should thus be improved continuously, ensuring products of consistently high quality. To achieve this goal, each component of the control loops should be monitored. The components of control loops include the actuator, sensor, controller and process. Each component is subject to possible faults or less-than-expected performance. Process and control monitoring has been a topic of active research over the last two decades. Actuator-fault detection along with sensor-fault detection has also been studied extensively in the fault-detection research community. The most important actuator in process industries is the control valve, and it has surprisingly received little attention until recently. The main problem of a control valve is the stiction, which is not only common in process control loops but has also caused the most trouble. Many surveys [10, 26, 92] have indicated that about 20–30% of all control loops oscillate due to valve problems.

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This astonishing number motivates an active research in valve-stiction detection, which is the key step in diagnosing the root-cause of oscillations. This book provides a comprehensive overview of the state-of-the-art stiction-detection and quantification methods developed over the last 10 years. Several key researchers who have been actively engaged in seeking solutions for valve-stiction detection have contributed to this book. The topics covered are widely ranged including stiction modelling, oscillation detection, stiction detection and quantification, and diagnosis of the root-cause of oscillations.

The book starts from an introduction to the physical mechanism behind the phenomena of stiction. Mathematical models are the best description of the physical phenomena. There are two types of models to describe the stiction: models that are derived from physical principles and models that are derived from process data. A detailed physical model has a number of unknown parameters, and it has been found difficult to use such a model for the purpose of stiction detection. It, however, provides useful insight into the phenomena that are observed in practice and indicates which effects must be captured in a simplified model. Data-based models are commonly used in monitoring and diagnosis. They are simple and easy to use, but they also have limited ability in extrapolation, particularly when a model is completely determined from data. The data-based models presented in this book follow certain physical principles of the stiction and thus they capture the phenomena better than the completely black-box models, while keeping simplicity in the structure. These models are represented by only two or three parameters. Due to their effectiveness in practical use proven by numerous simulations and applications, this book has devoted its attention to the data-based stiction models only. Chapters 2 and 3 present three data-based stiction models, which are adopted by several subsequent chapters. The three models presented here are complementary but also competing to some extent. This comes as no surprise as the physical phenomena of stiction are complicated and require the knowledge of many physical parameters; the data-based models attempt to reproduce the physical phenomena with only two or three parameters. Different models therefore capture different aspects of the stiction phenomena.

Valve stiction in control loops very often causes oscillations in the form of limit cycles. However, oscillations can be introduced by other root-causes, such as poor controller tuning and/or external oscillating disturbances. Therefore, appropriate oscillation detection methods have to be developed. Oscillation detection is certainly not new and has been studied extensively, particularly in the signal-processing community. The most classical methods are based on the power spectrum density (PSD) and the auto-correlation function (ACF). Oscillations appear as marked peaks in PSD. Their magnitude and frequencies can be determined directly from it. However, the PSD can be easily blurred by noise, non-sinusoidal oscillations, and time-varying frequencies. The ACF is a smoothed version of the original time-domain signal; thus it has similar limitations as the original one. Both PSD and ACF of oscillation signals may be visualised by human eyes. However, to be able to visualise the oscillations is different from being able to detect them automatically by a computer program. Computer-based detection is important since a real process consists of hundreds of interacted variables, and routinely visualising PSD or ACF for