# Preface

The subject of this book is the method of PID controller tuning based on the continuous cycling principle. Relay feedback for tuning was proposed by Åström and Hägglund in the 1980s and has been completed since then by numerous modifications aimed at enhancing some features of the original method. The majority of these modifications concern parametric methods of tuning that are based on the identification of certain underlying process models. The method presented herein is non-parametric. It features a *holistic* approach to test and tuning, or *coordinated test and tuning*, in which the test parameters are selected not arbitrarily or a priori but together with the tuning rule to be applied. As a result, this method provides exact values of a specified gain or phase margin and does not require any iterative procedure. Another novel feature is the introduction of *process-specific optimal tuning rules* in the non-parametric setup. This allows an engineer to use the flow loop-optimised tuning rules for flow loop tuning, level loop-optimised tuning rules for level loop tuning and so on, and obtain in most cases a better result than generic tuning rules would yield.

We hope readers might also find the presented approach to obtaining optimal tuning rules an interesting one. It involves a nontraditional solution of the optimisation problem. We also believe that the recently developed *dynamic harmonic balance* principle, which is presented in this book, may attract reader interest as well.

A person studying the subject of automatic control might benefit from this book by learning how linear and nonlinear control theory are brought together to solve a very important practical control problem—optimal tuning of PID controllers. A practising control engineer might gain new insights into PID controller tuning. The presented method is simple in realisation and efficient in terms of practical results. The reader can use the provided MATLAB code to incorporate the various components of the presented theory and tuning method.

When deriving tuning rules for particular types of industrial processes, focus is given to the most common process industry applications: flow, temperature, pressure and level control loops. It is assumed in most situations that the process is manipulated through control valves (or dampers), and more specifically through pneumatically actuated control valves. In various industries different features of loop tuners are important. In this book we assume that tuning could be carried out on a live process (i.e. during plant operation), so that such features as minimum disturbance to the process and short time required for tuning are of great importance.

Chapter 1 is introductory. It traces the history of tuning—and in particular, non-parametric tuning. Differences between parametric and non-parametric approaches are discussed. The issue of the selection of proper complexity of the process model is illustrated by an example of curve fitting.

Chapter 2 covers the methods of non-parametric tuning of PID controllers. The closed-loop Ziegler–Nichols method and Åström–Hägglund's relay feedback test are reviewed. It is shown that they allow one to generate test oscillations at the point corresponding to –180° of the phase characteristic of the process. However, it is also shown that generation of oscillations in the third quadrant would be beneficial. A number of non-parametric tuning methods based on various modifications of the relay feedback test (RFT), which are capable of producing test oscillations in the third quadrant, are reviewed.

In Chap. 3, the modified relay feedback test (MRFT) is introduced as a further logical development of the closed-loop Ziegler–Nichols method and Åström–Hägglund's relay feedback test. Methods and criteria of tuning are presented in general and for every considered typical process: flow, level, pressure and temperature processes. With the criterion of optimisation selected and the mechanism of disturbance generation analysed for each of the considered processes, the optimal tuning rules are obtained by solving the *optimisation problem on the domain of parameters* characterising the situational aspects of the implied process model.

Chapter 4 illustrates possible ways to improve the accuracy of the tuning rules via an example of the flow loop. It is shown that the precise model of the flow process is nonlinear even if the installed characteristic of the valve is linear. This nonlinearity is revealed as an apparent time constant of the actuator dynamics, which depends on both the amplitude of the relay test and the selection of the operating point. It is shown that we benefit by using the precise nonlinear model of the flow loop when finding optimal PID tuning rules.

Chapter 5 covers the exact model of oscillations in the system arising from the modified relay feedback test. The exact model can be used for parametric tuning that includes identification of the process model parameters. The development here is based on the *locus of a perturbed relay system* (LPRS) method. We present the LPRS for the conventional relay feedback system, the MRFT and the test containing the two-relay controller.

Chapter 6 provides the model of transient oscillatory motions in a system using the modified relay feedback test. The treatment is based on the concept of the *dynamic harmonic balance*.

Chapter 7 covers the practical implementation of this book's tuning method in software for distributed control systems. The most critical issues encountered in the implementation are covered. Industrial software used in the process industry is described.

Some chapters of the book can be read independently of others. For example, practising engineers may be more interested in Chaps. 1, 2, 3 and 7. They can omit other chapters without sacrificing an understanding of the main ideas of non-parametric tuning and the modified relay feedback test in particular. At the same time researchers may find the material of Chaps. 5 and 6 interesting from the perspective of finding exact models of the oscillations and analysis of transient oscillatory modes, respectively.

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