Preface

Design of efficient control systems is vital for any process industry for maintaining the product quality, meeting the safety needs, improving the energy efficiency and reducing the environmental pollution. The conventional Proportional Integral Derivative (PID) controllers are commonly used in majority (over 95%) of the process industries due to their simple configuration and wide range of applications. Tuning of PID controller is, however, a challenging task since it involves an in-depth understanding of both dynamic and static behaviours of process. Model based controller design techniques like the Direct Synthesis (DS) method and the Internal Model Control (IMC) method have come up as superior alternatives to the conventional PID controllers since they can be implemented within the PID controller framework without any additional hardware requirements. Moreover, the DS and Internal Model Control (IMC) based PID controllers have the added advantage of possessing only one tuning parameter as compared to three in the PID controller.

A process transfer function, derived from an appropriate mathematical model is an inherent necessity for the design of model based control systems. The process modeling activity is broadly classified into two categories: (a) Theoretical modeling and (b) Process Identification. Theoretical models are based on first principles and rigorous in nature. An in-depth understanding of the physical and chemical nature of the process is the primary requirement for the development of theoretical models. Process identification, on the other hand, involves development of empirical and black (purely box data driven) models, based on extensive experimental/plant data.

From the controller design perspective, processes are categorized as Single Input Single Output (SISO) or Multiple Input Multiple Output (MIMO) processes. The Single Input Single Output (SISO) processes are simper to design since they have only one control loop involving one controlled variable (CV) and one manipulated variable (MV). The Multiple Input Multiple Output (MIMO) processes have multiple control loops and interaction among control loops is a primary factor in deciding the appropriate CV-MV pairing for each control loop.

Most chemical and biochemical processes are multivariable in nature, inherently nonlinear, possess time-varying parameters and are subjected to process uncertainties. Also chemical and biochemical reactors are known to exhibit multiple steady states and stability of the operating steady state plays an important role in the controller design methodology.

Based on the literature review and above facts, this thesis is divided into seven chapters. Chapter 1 deals with the general introduction to the process control, necessity of process control, challenges of exercising adequate control, importance of process modelling and identification in control studies, controller design strategies for Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) processes.

Chapter 2 covers the literature review on design and tuning of Internal Model Control (IMC) based PID controller and its applications to Single Input Single Output (SISO) stable, Single Input Single Output (SISO) unstable, and Multiple Input Multiple Output (MIMO) systems. Chapter 3 provides the detailed derivations of conventional and model based controller design techniques. Chapter 4 describes the details of modeling, identification and Internal Model Control (IMC) based PID control of Two Input Two Output process (e. g. a quadruple tank setup) operated at non-minimum phase condition. Chapter 5 is devoted to an in-depth experimental and modeling study on identification and Internal Model Control (IMC) based controller design for a stable nonlinear Single Input Single Output (SISO) process (annular conical tank). Chapter 6 presents the study of theoretical modeling and Internal Model Control (IMC) based controller design for two unstable nonlinear Single Input Single Output (SISO) processes using examples of continuous bioreactor and non-adiabatic jacketed CSTR. The work is summarized and scope of future is discussed in Chapter 7. The literature cited in the thesis is referenced. The work presented in the thesis is fully documented in the form of journal publications.