

Chapter 7. Summary and Scope of Future Work

7.1 Summary of the Thesis

Following significant conclusions could be drawn on the basis of the experimental studies and modeling and simulation carried out in the present work:

1. The modeling and IMC based PID control have been investigated for the control of the experimental quadruple tank system. An IMC based PID decoupling controller has been designed and tuned for a two-input two-output quadruple tank process, operating at the non-minimum phase. The open-loop experimental data have been used for the system identification of the quadruple tank process (evaluation of the parameters of multivariable process transfer function matrix). Transmission zeros of the multivariable process transfer function matrix have been evaluated to confirm the non-minimum phase behaviour. Relative gain array (RGA) has been evaluated to confirm the interaction among the two control loops and appropriate selection of the input-output pairing of the controlled and manipulated variables using the RGA analysis is ensured. The IMC based PID controller has been designed for two independent decoupled open loop equivalent transfer functions using the standard IMC rules. The IMC based PID decoupling controller parameter has been tuned to provide good set-point tracking properties as evaluated from the quantitative performance indices such as Integral of Square of Error (ISE), Integral of Absolute Error (IAE), offset and percentage overshoot. The results of the developed control scheme agree well with the results for similar two-input two-output processes available in open literature.

2. For developing the mathematical model and IMC based PID control strategy of single-input single-output (SISO) stable nonlinear process, the case of liquid level variation in annular conical tanks has been considered. Such process vessels are used for handling and processing solid mixtures, slurries and viscous liquids. The dynamics and control of the annular conical tank liquid level nonlinear process has been studied and experimentally validated. Mathematical model of the process has been developed and the process parameters are identified using the open loop experimental data obtained from the experimental setup. The effect of process nonlinearity on the process parameters has been established. The superior performance of the IMC based PID controller has been established from both the closed loop simulations and experimental data.
3. The case of modeling and IMC based PID control of single-input single-output (SISO) unstable nonlinear process has been considered using the example of continuous bioreactors and non-adiabatic jacketed continuous stirred tank reactors that are used in biological wastewater treatment, food processing and petrochemical industries.

A state space and transfer function model for the biochemical reactor exhibiting substrate inhibition kinetics has been developed and the existence of multiple steady states at specified operating conditions and kinetic parameters have been studied. Conditions for stability of the steady states have been established. It has been shown that the efficient control of the bioreactor at the unstable steady-state operating point can be achieved by the optimum tuning of the IMC based PID controller.

In the case of non-adiabatic jacketed CSTR, the existence of one unstable and two stable steady states has been verified from the steady state simulations of the state

space time domain model under specified operating conditions and system parameters. It has been shown that an IMC based PID controller can be effectively used to control the reactor temperature at the unstable steady-state operating point. The closed loop response of the designed IMC based PID system has indicated that the dynamics of the system is fast enough to warrant a satisfactory operation of the CSTR at the unstable steady state. The performance indices have also shown promising results for the tuning method used for this problem.

7.2. Scope of Future Work

On the basis of the experimental studies and modeling and simulation carried out in the present work, future work may be carried out in the following areas:

1. It is recommended to develop infrastructure (an adequate data acquisition system) to interface the experimental setup with a personal computer for implementing a digital PID controller.
2. The design aspects of the IMC based PID controller have been extensively studied in the present work. The controller tuning methods may be further explored.
3. The modelling, simulation and IMC based PID controller design and tuning strategies developed in the present study may be extended to other chemical/ biochemical processes like bioremediation, bio filtration and microbial fuel cell systems.