A new control method for MIMO first order time delay non-square systems

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Abstract

This paper proposes a new method using internal model control (IMC) to design Smith delay compensation decoupling controller for multivariable non-square systems with transfer function elements consisting of first order + time delay. This proposed method is applied to a shell control problem in multiple-input–multiple-output (MIMO) first order plus dead time non-square systems in which the number of input variables exceeds the number of output variables, with input and output variables being 3 and 2 respectively. This method does not only dynamically compensate for shortcomings caused by static decoupling but also overcomes the impact of model error on system performance caused by model approximation and uncertainty. In other words, the design method proposed in this paper is capable of significantly improving dynamic quality and robustness of the control system as can be seen from the simulation results. Moreover, this new method is simple and easy to implement. Integral of squared error (ISE) performance criterion is employed to quantitatively evaluate the design method.

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1. Introduction

Multiple-input–multiple-output (MIMO) systems with multiple time delays and coupling are common in process industries [1–3]. MIMO systems are classified into square and non-square systems depending on the number of input and output variables. Processes with equal number of inputs and outputs are referred to as square systems, while those with unequal number of inputs and outputs are non-square systems. The systems in which inputs exceed outputs, such as shell standard control problem (3 inputs and 2 outputs) [4] and hot oil fractionators problem (4 inputs and 2 outputs) [5] are often encountered in process industries.

The traditional control method for a non-square system involves squaring the system by adding or eliminating variables and then controlling. However, adding a variable can increase control cost while dropping a controlled variable leads to poor performance. Seshagiri and Chidambaram designed Smith delay compensator for multivariable time-delay non-square system [6]. In Smith delay compensator system, the centralized proportional-integral (PI) controller is designed from the extended version of Davidson method, i.e., the derivation process of PI controller is based on the pseudo-inverse of the steady-state gain matrix of non-square system. It simplifies the acquisition process of non-square system pseudo-inverse, especially for non-square systems with multiple time delays. Although this is a static decoupling method, shortcomings can be compensated by tuning controller parameters. Deficiency in tuning the two parameters of the controller by the pole assignment method refers to the fact that these two parameters are mutually confined throughout the entire tuning process which makes the process time-consuming and diminishes the control performance [7].

In this paper, IMC method is used to design Smith delay compensation controller, which provides another method of decoupling control for MIMO first order time delay systems. The designed controller retains the good performance and robustness of the internal model controller, dynamically compensates for shortcomings caused by static decoupling, and also overcomes the impact of model error on system performance by model approximation using genetic algorithm. At the same time, it has good control performance and robust stability for uncertain process.

2. Smith decoupling control system design

2.1. Smith decoupling controller design

For linear stable multivariable time-delay process, Smith decoupling control system adopted in this paper is shown in Fig. 1 where \( G_p(s) \) is the transfer matrix of the process with \( m \) inputs \( n \) outputs.