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Robust Control of a Multivariable System

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Abstract

This paper presents the mathematical modeling of a multivariable process used in level control, under the assumptions that all pipes are filled with fluid and the inertial effects caused by flow variations, in case of small accelerations, are neglected. Because of the way the two tanks are interconnected and interact with each other, the resulting mathematical model is nonlinear. In the paper it is proposed a robust control algorithm for this plant developed based on H-infinity loop shaping procedure. The required computations and the study of the behavior of the system are done in the Matlab simulation environment.

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Keywords: mathematical modelling; level control; robust control; H-infinity loop shaping; singular value; lower-order controller.

1. Introduction

In the chemical industry many of the control applications deal with level, flow, pressure and temperature processes. In order to control such processes classical control structures can be used (e.g. PI) since they have simple configurations and are easy to implement and exploit. However, in case of processes described by nonlinear models the control performances provided by such controllers decay rapidly and they are no longer effective. Therefore, a series of controller design procedures have been developed, which provide optimal and robust behavior.

The interaction between two coupled tanks, as well as their mathematical model were studied in [1,2]. The mathematical model of the plant and four control strategies, which include also experimental approaches based on Ziegler-Nichols and fuzzy logic, were developed in [3,4,5]. Coupled tanks in different, interacting or non-interacting, configurations and their Simulink models are available in [6]. The studies [7,8] contains the mathematic models based on the state-space equations of the coupled tanks. Model predictive controllers optimized by using

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genetic algorithms were studied and implemented in [9]. PI and MRAC (Model Reference Adaptive Control), for the linearized mathematical model of the coupled tanks and the comparative results of the different strategies are shown in [10]. Other studies were focused on implementation of state transition algorithm for tuning the multivariable PID controller [11] or complex control structures using the Smith predictor [12]. The robust design procedures, based on normalized prime co-factors and the H-infinity synthesis are developed in [13,14].

This paper aims at extending the before mentioned studies by clarifying the mathematical model of a level process, determining a robust control structure by using H-infinity design procedure techniques and finding the reduced order controller, which is able to keep unchanged, as much as possible, the dynamics of the higher order system. These studies are done with the help of the existing Matlab functions for solving the Riccati equations, the co-prime factorization, the minimal H-infinity (H_{inf}) synthesis and for finding the reduced forms [15,16,17].

2. The mathematical modeling of the coupled tanks process

Generally, level control systems are done using error based controllers having an upstream or downstream control valve and freefall or pump discharge. Fig. 1 shows two coupled tanks (T1, T2) characterized by: the inlet flows F_{a1} and F_{a2}, the outlet flows F_{e1} and F_{e2}, the surfaces at the base of the tanks A_1 and A_2 and the level of fluid inside the tanks L_1 and L_2. In the control loop schematics LT1 and LT2 represent the level transducers, LRC is the level controller and recorder, FV1 and FV2 are the flow valves.

If the inlet flows F_{a1} and F_{a2} are used as control signals for regulating the level inside the tanks, then the outlet flows F_{e1} and F_{e2} are considered the disturbance signals in the control system.

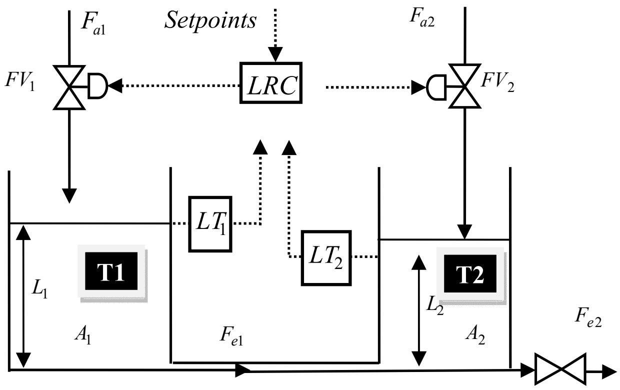

Fig. 1. The schematic representation of the coupled-tanks system.

Finding the mathematical models for the filing and draining process considers constant sections of the tanks and variable input and output flows (freefall discharge, which depends on the level inside the tank).

In case of a variable outlet flow, in stationary regime (zero accumulation in the system) the amount of fluid introduced in the system is the same as the amount which is drained, for each of the two tanks. In dynamic regime, the difference between the input and output quantities is accumulated in the system [7]:

$$\begin{cases} A_1 \dfrac{d}{dt} L_1 = F_{a1} - F_{e1} \\ A_2 \dfrac{d}{dt} L_2 = F_{a2} - F_{e2} + F_{e1} \end{cases}, \tag{1}$$

where: $F_{e1} = \alpha_1 \sqrt{L_1 - L_2}$, $F_{e2} = \alpha_2 \sqrt{L_2}$, α_1, α_2 represent the coefficients of the control valves FV1, FV2.