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Research Article

Multilinear Model of Heat Exchanger with Hammerstein Structure

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The multilinear model control design approach is based on the approximation of the nonlinear model of the system by a set of linear models. The paper presents the method of creation of a bank of linear models of the two-pass shell and tube heat exchanger. The nonlinear model is assumed to have a Hammerstein structure. The set of linear models is formed by decomposition of the nonlinear steady-state characteristic by using the modified Included Angle Dividing method. Two modifications of this method are proposed. The first one refers to the addition to the algorithm for decomposition, which reduces the number of linear segments. The second one refers to determination of the threshold value. The dependence between decomposition of the nonlinear characteristic and the linear dynamics of the closed-loop system is established. The decoupling process is more formal and it can be easily implemented by using software tools. Due to its simplicity, the method is particularly suitable in complex systems, such as heat exchanger networks.

1. Introduction

Most physical systems are inherently nonlinear. Nonlinearity is especially pronounced in systems with wide ranges of desired behaviours and variable set points. There are a lot of such systems in the process industry [1, 2]: pH reactors, distillation columns, polymerization reactors, heat exchangers, and so forth. In order to solve the problem of design and high precision tracking control of such systems, it is necessary to have a better understanding of their nonlinear characteristics.

Linear control theory provides many confirmed methods and tools for controller design with desired performances and robustness. Unfortunately, that theory is limited to strictly linear systems or certain classes of nonlinear systems with small deviations around the nominal operating point. In real systems with a wide operating range and multiple operating points, where nonlinearity cannot be ignored, different control strategies are necessary. In order to use the vast potential of linear control theory, at the same time taking into account nonlinearities, various modifications of classical control design are proposed.

The multilinear model (or multimodal) control approach which has been shown to be suitable for strongly nonlinear systems with multiple operating points, tracking control, and wide operating ranges [3–7] has been drawing attention recently. The main idea is to present the nonlinear system as a set of linear systems where classical controller design techniques can be easily applied. The multilinear model control design framework includes four steps: determination of the global (nonlinear) mathematical model of the plant for the whole operating region; approximation of the nonlinear model by means of a set of linear models; local controller design for each particular operating region; global controller design of the whole nonlinear system.

There are two important questions which should be answered in the multilinear model control design approach: how to decouple a nonlinear system into a bank of locally linear subsystems and how to design a global controller according to the desired performances of a nonlinear system.

This paper gives the answer to the first question. The literature mainly uses the gap-metric based method where the minimal linear model set is determined for the given threshold value in order to span the expected operating range of a nonlinear system [4–7]. For a special class of nonlinear systems, such as nonlinear systems with Hammerstein-like structures, the authors in [8, 9] used the Included Angle Dividing (IAD) method for creating a minimum set of models. Numerous nonlinear heating, ventilating, and