

Model-based control of particulate processes

Panagiotis D. Christofides^{a,b,*}, Nael El-Farra^c, Mingheng Li^d, Prashant Mhaskar^c

^aDepartment of Chemical and Biomolecular Engineering, University of California, Los Angeles, CA 90095, USA

^bDepartment of Electrical Engineering, University of California, Los Angeles, CA 90095, USA

^cDepartment of Chemical Engineering and Materials Science, University of California, Davis, CA 95616, USA

^dDepartment of Chemical and Materials Engineering, California State Polytechnic University, Pomona, CA 91768, USA

^eDepartment of Chemical Engineering, McMaster University, Ont., Canada L8S 4L7

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Abstract

In this work, we present an overview of recently developed methods for model-based control of particulate processes. We primarily discuss methods developed in the context of our previous research work and use examples of crystallization, aerosol and thermal spray processes to motivate the development of these methods and illustrate their application. Specifically, we initially discuss control methods for particulate processes which utilize suitable approximations of population balance models to design nonlinear, robust and predictive control systems and demonstrate their application to crystallization and aerosol processes. Finally, we discuss the issues of control problem formulation and controller design for high-velocity oxygen-fuel (HVOF) thermal spray processes and close with few thoughts on unresolved research challenges on control of particulate processes.

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Keywords: Particulate processes; Order reduction; Model-based feedback control; Crystallization; Aerosol processes; Thermal spray processes

1. Introduction

Particulate processes (also known as dispersed-phase processes) are characterized by the co-presence of and strong interaction between a continuous (gas or liquid) phase and a particulate (dispersed) phase and are essential in making many high-value industrial products. Particulate processes play a prominent role in a number of process industries since about 60% of the products in the chemical industry are manufactured as particulates with an additional 20% using powders as ingredients. Representative examples of industrial particulate processes include the crystallization of proteins for pharmaceutical applications, the emulsion polymerization for the production of latex, the fluidized bed production of solar-grade silicon particles through thermal decomposition of silane gas, the aerosol synthesis of titania powder used in the production of white pigments, and the thermal spray processing of nanostructured

thermal barrier and wear resistant coatings. The industrial importance of particulate processes and the realization that the physicochemical and mechanical properties of materials made with particulates depend heavily on the characteristics of the underlying particle-size distribution (PSD) have motivated significant research attention over the last 10 years on model-based control of particulate processes. These efforts have also been complemented by recent and on-going developments in measurement technology which allow the accurate and fast on-line measurement of key process variables including important characteristics of PSDs (e.g., Larsen et al., 2006; Rawlings et al., 1992, 1993). The recent efforts on model-based control of particulate processes have also been motivated by significant advances in the modeling of particulate processes. Specifically, population balances have provided a natural framework for the mathematical modeling of PSDs in broad classes of particulate processes (see, for example, the tutorial article (Hulburt and Katz, 1964) and the review article (Ramkrishna, 1985)), and have been successfully used to describe PSDs in emulsion polymerization reactors (e.g., Dimitratos et al., 1994; Doyle et al., 2002), crystallizers (e.g., Braatz and Hasche, 2002; Rawlings et al., 1993), aerosol reactors (e.g., Friendlander,

* Corresponding author. Department of Chemical and Biomolecular Engineering, University of California, Los Angeles, CA 90095, USA. Tel.: +1 310 794 1015; fax: +1 310 206 4107.

E-mail address: pdc@seas.ucla.edu (P.D. Christofides).

Modelbased Control Of Particulate Processes

**Paul M.J. van den Hof, Carsten
Scherer, Peter S.C. Heuberger**



Modelbased Control Of Particulate Processes:

Model-Based Control of Particulate Processes Panagiotis D. Christofides, 2002-10-31 The interest in control of particulate processes has been triggered by the need to achieve tight distributed control of size distributions that greatly influence particulate product properties and quality Drawing from recent advances in dynamics of infinite dimensional systems and nonlinear control theory control of particulate processes using population balances has evolved into a very active research area within the field of process control This book the first of its kind presents general methods for the synthesis of nonlinear robust and constrained feedback controllers for broad classes of particulate process models and illustrates their applications to industrially important crystallization aerosol and thermal spray processes The controllers use a finite number of measurement sensors and control actuators to achieve stabilization of the closed loop system output tracking attenuation of the effect of model uncertainty and handling of actuator saturation Beginning with an introduction to control of particulate processes the book discusses nonlinear order reduction and nonlinear robust and constrained control of particulate spatially homogeneous processes and nonlinear control of spatially homogeneous particulate processes The synthesis of the controllers is performed by using geometric and Lyapunov based control techniques The book includes comparisons of the methods followed for controller synthesis with other approaches and discussions of practical implementation issues that can help researchers and engineers understand the development and application of the methods in greater depth The methods are applied to continuous and batch crystallization processes a titania aerosol reactor and a thermal spray process to regulate product size distribution The resulting benefits in closed loop performance robustness and actuator saturation handling compared to other techniques for control of particulate processes are demonstrated through computer simulations The book assumes a basic knowledge about population balances and nonlinear control Researchers and graduate students in process control particle technology and control systems theory applied mathematicians and process control engineers will find this book a useful resource

Model-Based Control of Particulate Processes Panagiotis D. Christofides, 2013-04-17 Particulate processes are characterized by the co presence of a continuous phase and a dispersed particulate phase and are widely used in industry for the manufacturing of many high value products Examples include the crystallization of proteins for pharmaceutical applications the emulsion polymerization reactors for the production of latex the aerosol synthesis of titania powder used in the production of white pigments and the thermal spray processing of nanostructured coatings It is now well understood that the physico chemical and mechanical properties of materials made with particulates depend heavily on the characteristics of the corresponding particle size distribution This fact together with recent advances in dynamics of infinite dimensional systems and nonlinear control theory has motivated extensive research on model based control of particulate processes using population balances to achieve tight control of particle size distributions This book the first of its kind presents general methods for the synthesis of nonlinear robust and constrained

feedback controllers for broad classes of particulate process models and illustrates their applications to industrially important crystallization aerosol and thermal spray processes The controllers use a finite number of measurement sensors and control actuators to achieve stabilization of the closed loop system output tracking attenuation of the effect of model uncertainty and handling of actuator saturation

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Nonlinear Model-based Control of Particulate Processes Timothy Yeechung Chiu, 2000

Model-Based Control: Paul M.J. van den Hof, Carsten Scherer, Peter S.C. Heuberger, 2009-08-05 Model Based Control will be a collection of state of the art contributions in the field of modelling identification robust control and optimization of dynamical systems with particular attention to the application domains of motion control systems high accuracy positioning systems and large scale industrial process control systems The book will be directed to academic and industrial people involved in research in systems and control industrial process control and mechatronics

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Handbook of Continuous Crystallization Nima Yazdanpanah, Zoltan K Nagy, 2020-02-04 Continuous crystallization is an area of intense research with particular respect to the pharmaceutical industry and fine chemicals Improvements in continuous crystallization technologies offer chemical industries significant financial gains through reduced expenditure and operational costs and consistent product quality Written by well known leaders in the field The Handbook of Continuous Crystallization presents fundamental and applied knowledge with attention paid to application and scaling up and the burgeoning area of process intensification Beginning with concepts around crystallization techniques and control strategies the reader will learn about experimental methods and computational tools Case studies spanning fine and bulk chemicals the pharmaceutical industry and employing new mathematical tools put theory into context

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