# Realization of Online Optimizing Control in Semi-batch Polymerizations

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# Abstract

The goal of this work is to address the challenge of developing and implementing online optimizing control schemes for the time optimal operation of semi-batch polymerizations. Two semi-batch polymerization reactors are used as case studies to evaluate the advanced control solutions that are proposed. The first reactor belongs to the company Evonik Industries AG and is located in Marl (Germany). The second reactor is the well-known Chylla-Haase Reactor [1, 2], which is widely accepted as a benchmark problem for the temperature control of polymerization reactors. Different optimizing schemes of different complexities that simultaneously optimize the cooling power and the monomer dosage online during the process operation are proposed and thoroughly tested. Crucial factors for a successful industrial implementation like the development of a reliable process model and the online compensation of model uncertainties are discussed in detail. A novel approach for the online compensation of the model uncertainties is proposed and a full nonlinear model predictive controller (NMPC) for the time optimal operation of semi-batch polymerizations is introduced. Moreover, a simplified optimizing control scheme that tracks operation conditions near to optimality in a feedback fashion is also proposed and implemented at the industrial process providing very good results. The effectiveness of the control schemes is illustrated by simulations and results taken from the application at the real plant.

# Zusammenfassung

Das Ziel dieser Arbeit ist es, auf die Herausforderungen der Entwicklung und Umsetzung von optimierenden Regelungsschemen für den zeitoptimalen Betrieb von Semi-Batch Polymerisationen einzugehen. Zwei verschiedene Polymerisationsreaktoren werden verwendet, um die vorgeschlagenen Regelungsschemen zu testen und zu bewerten. Der erste Reaktor ist am Chemiepark Marl der Firma Evonik Industries AG im Betrieb. Der zweite Reaktor ist der berühmte Chylla-Haase Reaktor, der weitgehend als Benchmarktest für die Temperaturregelung der Semi-Batch Polymerisationsreaktoren anerkannt wird. Regelungsschemen verschiedener Komplexität, die gleichzeitig die Kühlleistung und die Monomerdosierung während des Betriebes des Reaktors online optimieren, werden vorgeschlagen und getestet. Die entscheidenden Faktoren für eine erfolgreiche industrielle Umsetzung dieser erweiterten Regelungsmethoden werden ausführlich diskutiert (z.B. die Entwicklung eines zuverlässigen Prozessmodells und die Online-Kompensation der Modellfehler). Ein neuer Ansatz für die Online-Kompensation der Modellfehler wird vorgeschlagen und ein nichtlinearer modellprädiktiver Regler (NMPC) für den zeitoptimalen Betrieb von Semi-Batch Polymerisationen, der auf diesem neuen Ansatz basiert, wird schließlich entwickelt. Darüber hinaus wird ein vereinfachtes optimierendes Regelungsschema vorgeschlagen und erfolgreich getestet. Die Effektivität der vorgeschlagenen Methoden wird durch Simulationen und Testen in der realen Anlage nachgewiesen.

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*”As soon as you touch the limit, something happens and you suddenly can go a little bit further. With your mind power, your determination, your instinct, and your experience as well, you can fly very high.”*

**Ayrton Senna da Silva**

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