

Modellierung und Regelung komplexer dynamischer Systeme

Band 64

Kevin Schwarzingner

Modelling and Control of Plastic Extrusion Machines

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Linz, September 2023

Kevin Schwarzingner

Abstract

A temperature control concept for a highly efficient and therefore well insulated extruder without active cooling is presented. The purpose of the control concept developed is to ensure a suitable production condition, which is defined by a constant melt temperature within a desired temperature range. The desired melt temperature is critical for the product quality and is specified by the operator. The control concept is model based. Two mathematical models are derived to describe the thermal dynamics of plastic production machines. The accuracy of the derived finite volume model is validated by a high-order finite element model. The developed control concept consists of several superimposed layers. The first layer includes heating tape temperature control which is implemented as a simple PI controller. The next layer consists of an observer (smart sensor) and a model predictive controller. The smart sensor is a disturbance observer that estimates the heat flow between the extruder cylinder and the processed material, including the thermal influence of the conveying screw. This configuration has the advantage of decoupling the thermal control problem from the specific granulate. A model predictive controller calculates appropriate temperature trajectories for the heating tape temperatures to achieve the desired temperature profiles within the extruder, while meeting any defined process or manufacturer related restrictions. A developed concept of set point adjustment during operating point changes enables fast operating point changes by determining optimal cylinder temperature trajectories. A material independent melt temperature controller forms the top layer of the developed concept. The melt temperature controller varies the desired cylinder temperatures to achieve the desired melt temperature.

To prove that the concept is applicable to different extruder types, experiments on two different extruder types are discussed. The performance of the proposed control concept during preheating processes, extrusion startups, operating point changes and disturbance scenarios is analysed by simulations but mainly by experiments on industrial extruders.

Kurzfassung

Es wird ein Temperaturregelungskonzept für einen hocheffizienten und damit gut isolierten Extruder ohne aktive Kühlung vorgestellt. Aufgabe des entwickelten Regelungskonzepts ist es, einen adäquaten Produktionszustand zu gewährleisten, der durch eine konstante Temperatur der Schmelze innerhalb eines gewünschten Temperaturbereichs definiert ist. Die Solltemperatur der Schmelze ist entscheidend für die Produktqualität und wird von der Bedienungsperson festgelegt. Es handelt sich um ein modellbasiertes Regelungskonzept. Es werden zwei mathematische Modelle, um die thermische Dynamik einer Kunststoffproduktionsmaschine zu beschreiben, hergeleitet. Das Finite Volumen Model wird durch ein hoch genaues Finite Elemente Modell validiert. Das entwickelte Regelungskonzept besteht aus mehreren überlagerten Schichten. Die erste Schicht umfasst die Heizbandtemperaturregelung, die als PI Regler implementiert ist. Die nächste Schicht besteht aus einem Beobachter (Smart Sensor) und einem modellprädiktiven Regler. Der Smart Sensor ist ein Störgrößenbeobachter, der den Wärmefluss zwischen dem Zylinder und dem verarbeiteten Material, einschließlich der thermischen Einwirkung der Förderschnecke, schätzt. Diese Konfiguration erlaubt eine materialunabhängige Regelungsstrategie. Ein modellprädiktiver Regler berechnet geeignete Temperaturvorgaben für die Heizbandtemperaturen, um die gewünschten Temperaturprofile im Extruder zu erreichen und gleichzeitig alle definierten prozess- oder herstellerepezifischen Beschränkungen zu erfüllen. Ein weiteres überlagertes Konzept ermöglicht schnelle Betriebspunktwechsel durch Ermittlung optimaler Zylindertemperaturverläufe. Ein materialunabhängiger Schmelzetemperaturregler bildet die oberste Schicht des entwickelten Konzepts. Die gewünschten Zylindertemperaturen werden variiert, um eine gewünschte Schmelzetemperatur zu erreichen.

Um die Anwendbarkeit des Konzepts auf unterschiedliche Extrudertypen zu untermauern, werden Versuche auf zwei verschiedenen Extruderaufbauten durchgeführt und diskutiert. Die Performance des entwickelten Regelungskonzepts während Aufheizprozessen, Extrusionsstarts, Betriebspunktänderungen und Störungsszenarien wird durch Simulationen, vor allem aber durch Versuche an industriellen Extrudern analysiert.

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