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MODELLING AND ENERGY EFFICIENCY IMPROVEMENT IN CHEMICAL BATCH OPERATIONS USING DATA-DRIVEN SYSTEM IDENTIFICATION

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Abstract – Chemical batch processes generate large amounts of measurement data, making it difficult to identify which variables are most important for understanding and improving energy use. As energy efficiency becomes increasingly relevant for both cost and sustainability, it is essential to analyze power demand in a systematic way. This paper presents a practical, data driven approach for studying a complex chemical process with the goal of understanding and predicting the power consumption during different operating stages. The contribution begins by examining all available process data, which includes many measurement channels describing temperatures, rotational speed, height level and other process behaviors. Since working with too many variables can be inefficient and may hide important effects, a correlation analysis is carried out first. This step helps to remove redundant or non informative signals and allows the focus to remain on the variables that have the strongest influence on energy consumption. Reducing the number of variables improves the clarity of the analysis and provides a good basis for building reliable models. After selecting the most relevant measurements, the power demand of several key process steps is investigated. These steps represent typical phases of the batch process, especially heating and mixing. The power consumption within each phase is analyzed with respect to important input variables: product temperature, agitator rotational speed, and container filling level. This analysis shows how different operating conditions influence energy demand, for example how viscosity changes affect agitator load or how temperature gradients impact heating requirements. These findings are essential for building accurate models that reflect real process behavior. Using the most important variables, a system identification procedure is then applied to model the dynamic relationship between the selected inputs and the observed power demand. Three model structures are tested and compared: ARX (Auto Regressive with eXogenous input), OE (Output Error), and ARMAX (Auto Regressive Moving Average with eXogenous input). Each model type captures different aspects of the process dynamics, including delays, disturbances, and deterministic trends. The identification process includes parameter estimation, validation, and evaluation based on prediction accuracy. From the best performing models, continuous time transfer functions are derived. These transfer functions describe how the power demand responds to changes in the chosen process variables and allow simulations of energy consumption under a wide range of operating scenarios. This provides a useful tool for optimization, process design, and potential improvements in control strategies. Overall, the paper shows that combining correlation based variable reduction, targeted power-demand analysis, and advanced system identification methods offers an effective approach for understanding the energy behavior of complex chemical batch processes. The resulting models support more efficient and sustainable operation by enabling improved predictions and optimization of power consumption.

Keywords – Chemical process; energy consumption; power demand analysis; system identification

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