Industry 4.0 framework for Continuous Pharmaceutical Manufacturing (CPM)

INTRODUCTION

- Deployment of Cyber-Physical Systems (CPS) in manufacturing is gaining momentum due to the recent advancement of technology and push towards Internet of Things.
- The implementation of this Industry 4.0 framework helps capture large volumes of process data from the entire manufacturing cycle.
- Continuous pharmaceutical manufacturing (CPM) plants heavily rely on analytical laboratory data and the manufacturing floor data for quality control and assurance.
- With the developed framework, different process systems engineering tools can be applied to advance understanding of the CPM processes.

OBJECTIVES

- Develop an industry 4.0 framework to collect and store CPM pilot plant and analytical laboratory data.
- Setup a cloud data lake for efficient data storage and extraction.
- Utilize the integrated framework to develop real-time material tracking using dynamic residence time distribution (RTD) profiles for CPM line.
- Use machine learning approaches to train a feeder-refill model in the direct connection of CPM to predict feeder output with material properties and process parameters that are collected using the framework.
- Establish a hybrid model to support supplemental knowledge meaningful of the process, operations with data, aiming to capture the variabilities of the process that are not well-characterized in the mechanistic model.

INTEGRATED INDUSTRY 4.0 FRAMEWORK

- Collection of analytical data
- To collect analytical data from laboratory experiments/analytical equipment, an electronic laboratory notebook (ELN) solution was implemented
- The ELN solution (SciCord) is a cloud-based ELN hosted on the Microsoft Azure
- Templates were developed to standardize data collection for each experiment
- Material properties were extracted automatically from the experimental data and updated into a material property database
- A material property database was populated with prior knowledge values which could be extended with data from the analytical experiments

- Collection of process data
- The pilot plant is connected a control software (DeltaV) which can acquire data from all the process equipment
- Process data are then sent to a local historian (OSI PI server) to store data
- Product quality data from PAT sensors are directly sent to the PI using OPC UA protocols
- A cloud-based data collection software (Bigfinite) is used to collect the data from the PI server and store it on the cloud

- Data Extraction and transfer
- The material property database is stored as an SQL database on Azure and can be extracted into a local computer intoutil using MS Excel
- This MS excel sheet can be incorporated into gPROMS using foreign objects (FO) protocol
- Bigfinite can import data from the ELN database using its proprietary SQL data feeder program

CONCLUSION AND FUTURE WORK

- An integrated framework was developed which would serve as the basis for real-time studies and higher fidelity models.
- Proposed methodology for dynamic RTD models built using the process data generated from the integrated framework.
- The methodology proposed can be extended to other unit operations resulting in a dynamic RTD model for the complete line can later be utilized for real-time lot-to-lot delineation.
- Data obtained from the framework were used to evaluate performance of different machine learning algorithms and to capture process variabilities in a feeder-refill system.
- Further improvement will focus on model selection, algorithm development, and the real-time integration between the data-driven models and the framework.

REFERENCES


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