Optimisation of the operation of heat exchangers

The problem

- Heat exchangers are crucial elements for the reduction of the energy demand of the processing industry.
- Heat exchangers often suffer from fouling, which decreases the heat transfer and thus the efficiency of the process.
- Cleaning is needed to recover nominal efficiencies.
- The optimal time for cleaning depends on the usage of the heat exchangers. Overall, these are many operation decisions difficult to take for the plant personnel.

The solution

- A methodology for monitoring the fouling of their heat exchangers was developed by Lenzing AG.
- Hybrid models for the heat transfer, the evolution of fouling and for the heat-recovery network layout in Lenzing were developed by UVa.
- Model-based real-time optimisation (RTO) tools were developed to support the operators in such complex decision problems.
- The developed decision-support systems enable a quick reaction to disturbances or load changes.

This project receives funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 723575.

www.spire2030.eu/copro
Optimisation of the operation of heat exchangers

The problem

Operation policy impacts heat transfer

Heat exchangers play a key role in the evaporation and heat-recovery sections at the Lenzing AG site, in Austria, as in many other plants. Their overall heat-transfer coefficient directly affects the steam consumption, which represents about the 60% of the energy consumption for steam and hot water production in a viscose fiber plant.

In Lenzing, the operation of heat exchangers must be adapted to the daily production circumstances. It is well known that the stream flows and temperature differences affect the heat transfer in a heat exchanger (HE). Different control decisions regarding these variables can lead to fulfillment of the production demands, but also lead to different energy demands. In addition, the existence of multiple heat sources with different characteristics, redundant equipment, as well as some degrees of freedom in the layout create a complex decision problem for the plant operators, who are happy to find feasible solutions in many cases.

Furthermore, the progressive fouling appearing on the heat exchanger surfaces due to deposition of organic material worsens the situation, requiring a production-maintenance schedule to keep the resource consumption within reasonable bounds. This issue further increases the complexity of the task of the operators.

The solution

A real-time optimisation approach

The solution proposed within CoPro to approach the above problems is a decision support system (DSS) the core of which are model-based real-time optimisation (RTO) tools. These tools were developed in cooperation of Lenzing AG and the University of Valladolid. The tools are designed to support plant personnel in the complex task of scheduling the operation and maintenance tasks of the HEs, with the aim of improving the overall resource efficiency.

The DSS consists of two tools: Heat-recovery operation and prediction of optimal cleaning times.

The RTO for the heat-recovery section reads the current state of the HE network from the PI system (including the HEs fouling state that is provided by the developed monitoring system) and decides on the best connection and flows of heat sources to the HEs which fulfils the temperature setpoints. Moreover, it also provides suggestions on which HEs should be cleaned based on the proposed operation and the current state of fouling. In the backend the tool solves a mixed-integer nonlinear programming problem, coded in Python-PYOMO, in less than 5 minutes. The core of the tool is a mathematical model of the reconfigurable network layout, and the equations for the heat-transfer physics, including data-based models for the overall heat-transfer coefficient in the HEs depending on their operating conditions.

The cleaning-times prediction tool is implemented in MS Excel to cope with the preferences of the plant personnel, and it serves to predict the best future cleaning instants as well as the type of cleaning for each heat exchanger. The proposal is based on the current and past operation of an HE since its last cleaning. The tool reads operation data from the plant historian and uses the heat-transfer equations and the data-based model for predicting the fouling to compute the operation costs over the time. Then, a computationally cheap (mixed-integer) nonlinear optimisation is solved to find the best trade-off between operation and cleaning costs.

The summary

Improved efficiency of heat exchangers

With the proposed approach to improve the operation of heat exchangers in real time and the two prototypical tools that were developed, we aimed to make the life easier for the plant operators who face serious difficulties in managing such a large number of factors and decision variables simultaneously. The initial tests showed promising benefits in both coordination workload and energy savings. The application shows the potential of applying hybrid modelling and advanced optimisation tools at industrial scale.

The developers

Dr. José Luis Pitarch
Supervision and Process Control group. Systems Engineering and Automatic Control Dept. Universidad de Valladolid 47011 Valladolid, Spain jose.pitarch@autom.uva.es

Dr. Thomas Röder
Lenzing AG, t.roeder@lenzing.com

Dr. Alexander Arnitz
Senior Manager Process Engineering & Technology, Global Utility and Infrastructure Lenzing AG 4860 Lenzing, Austria a.arnitz@lenzing.com

Further information

Prof. Dr. César de Prada
Universidad de Valladolid, prada@autom.uva.es

Maria P. Marcos, M.Sc.
Supervision and Process Control group. Systems Engineering and Automatic Control Dept. Universidad de Valladolid 47011 Valladolid, Spain maria.marcos@autom.uva.es