Planning and scheduling of make and pack processes

Coupled layout

Formulation stage

Packing stage

Decoupled layout

Formulation stage

Packing stage

Buffer

The problem

• Scheduling optimisation for companies from the consumer goods industries, such as P&G, is a challenging task due to the continuously increasing demand, tight operating constraints and the large variety of similar products.

• Efficient models are missing to derive nearly optimal solutions that minimise the changeover times, which causes production down times and an unnecessary use of resources.

The solution

• Optimisation-based solutions were developed for the scheduling problem of the current plant layout at P&G, in a collaboration between CERTH and P&G. A significant reduction in the total changeover time was achieved.

• Scheduling of a flexible plant layout was studied in a cooperation of TUDO and P&G. In this layout, the production and packing stages are decoupled, enabling a higher utilisation of the different lines but making the scheduling problem even more complex.

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The problem

Increase productivity by decreasing production downtime

In the production facility of P&G that is considered here, more than 300 different final products have to be scheduled weekly on a number of parallel production lines. The production process consists of the formulation and the packing stage and product-dependent changeovers take place in both stages. According to the current plant layout, the stage with the lower rate constitutes a varying bottleneck of the process. Frequent re-scheduling actions take place due to demand variations.

The current layout significantly reduces the plant flexibility since it needs to synchronise the production rates of the two stages within a line. In order to overcome these limitations, the two stages can be decoupled by using a buffer. In such an agile layout, products can be transferred from the formulation stage to any packing line, and variations in the production speeds can be mitigated.

The solution

Combine and conquer

Within CoPro, efficient optimisation-based approaches were developed for the scheduling problem of the current plant layout and of a possible layout with a buffer. The approaches rely on recent developments in continuous process scheduling coupled with efficient decomposition-based solution techniques for the solution of large problem instances. For the current layout, the packing stage is scheduled in detail while feasibility constraints related to the formulation stage are imposed in order to generate feasible schedules. Full satisfaction of the underlying operational constraints is achieved and planned maintenance activities are taken into account.

In order to evaluate the proposed scheduling framework, a tool was developed in collaboration between P&G and CERTH that enables the data exchange via a direct communication of the GAMS modelling platform and the ERP systems of the plant. P&G validated the proposed optimisation approach, using both historical data and real-time tests in the plant. The generated schedules (see Fig. 1), were positively evaluated by the plant operators and a significant reduction of the total changeover time is achieved.

For the flexible layout, a decomposition approach is consisting of two complementary elements was used. One element deals with the optimal utilisation of the buffer and the formulation lines, while the other takes decisions on the allocation of the final products. The latter element generates a near-optimal packing stage schedule which is optimised for load balancing and minimum changeovers. As it is computationally prohibitive to compute such a packing stage schedule over long time horizons of several days at once, the problem is decomposed in time into multiple sub-problems by iteratively shifting the time horizon forward and fixing the previous decisions.

For a known packing stage sequence, an iterative procedure was developed to satisfy the technical constraints that were related to the intermediate buffer and the formulation stage, in particular the limited size of the buffer. In the second step, the exact timing of the operations is performed such that the schedule is executable. Starting from a list of products and due dates according to the demands by the customers, the tool returns optimised schedules with a minimum of parametrisation.

The implementation is written in the Julia programming language, which has been optimised for high performance and ease of use.

The optimised production schedules (see Fig. 2) for the modified layout serve two purposes. First, the engineers who decide on the final configuration of the plant layout are provided with a tool to investigate different configurations with respect to the benefits that can be realised, in particular the attainable throughput. Second, when the layout has been modified, the scheduling algorithm provides high-quality schedules to the operators to facilitate their planning decisions.

Automated workflows, significant improvements

The developed scheduling solutions demonstrate that and optimised schedules can yield significant benefits for the producers of consumer goods. For the operators, the developed workflow provides quick and efficient decision support by delivering near-optimal schedules within short response times. Extensive studies using real data illustrated a significant reduction of the lead times of the final products and of the labour-intensive product changeovers. For the decoupled layout the developed scheduling tool helps to explore the design space of the plant reconfiguration by providing realistic data on the possible gains when the plant is scheduled optimally. The throughput of the plant can be increased significantly with an intermediate buffer.

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Fig. 1: Illustrative Gantt chart of four packing lines based on real data.

Fig. 2: Illustrative Gantt chart of six formulation and packing lines in the decoupled layout.