Optimal operation of sterilisation processes in food production

The problem
- Sterilisation is a crucial process in order to fulfill sanitary constraints in the food industries.
- At Frinsa, the sterilisation process is performed in a set of parallel batch sterilisation units that are placed between continuous processing lines.
- Being an energy-intense process, steam is a limited common resource for the sterilisers, and its availability influences their processing times.
- Due to food safety constraints, there is a maximum waiting time for every sterilisation process starting-time. Failure in proper coordination results in bottlenecks or impaired food safety.

The solution
- An on-line closed-loop scheduling tool was developed that gathers and distributes the carts with cans among the sterilisers, and schedules the sterilisation processes in real time.
- The solution was integrated within ASM MES system, adapting in real-time to the real state of the sterilisation section.
- An HMI was developed to communicate to the operators which actions to take.

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The problem

Steriliser scheduling: sharing steam and reacting to changes

At Frinsa, different can formats are produced concurrently every day. They must undergo a batch thermal treatment to achieve a specified micro-organism lethality threshold. The time-temperature profiles of sterilisation differ for the different types of cans, so the different sterilisation units work with different settings with steam as the common heat source. If several sterilisers consume steam at the same time, it may not be possible to follow the planned profile, due to the drop of pressure in the supply line, which results in changes of the batch cycle time.

While there is a weekly production plan that is generated by the ERP system, in practice there are always changes and uncertainties in the arrival of the canned products. Usually, the operators have to cope with these changes. The cans are introduced in carts, which are sorted, gathered and loaded in the sterilisers up to their maximum capacity. To prevent a decrease in the quality of the final product, there is a maximum waiting period before which the cans must be sterilised. The sterilisation processes have to be synchronised properly, avoiding surpassing the waiting periods for each set of cans and avoiding bottlenecks. The system has to cope with changes in: the arrival of carts, and the processing times in the sterilisers.

The solution

A real-time scheduling software for the sterilisation section

A closed-loop scheduling tool was developed that operates in real-time using a moving horizon approach. The prediction horizon covers a certain future time-interval, but only the actions that are computed by the optimiser for the next few minutes are implemented whereas the rest of the time horizon is included to prevent unfeasible situations. The forecast of the arrival of carts is included in the formulation, as well as the current state of the section, including the carts that are waiting to be sterilised and the state of the producing lines. To access the actual state of the plant, the solution connects to the database of the MES system, thus it is able to update the plant status information in real-time at every iteration.

The optimisation problem addresses two main challenges: the gathering of the carts and their assignment to the sterilisers, while considering quality and sanitary constraints; and the constraints on the shared resources. The carts are gathered in groups up to the maximum capacity of the sterilisers. Different formats can be mixed as long as their sterilisation profiles are similar.

The problem arose by the shared-steam concurrent consumption has been tackled following two different approaches: the first one constraints the maximum amount of resource available every time and supposes that the sterilisers perform properly; another one considers the alterations over the sterilisation profiles when some process coincide in time, but does not constraint the concurrent consumption. In both cases, models are used to predict the steam demand of the sterilisers for given profiles and the availability of steam. In addition, some models, developed by CSIC, are used to ensure that sufficient sterilisation has been obtained. The problem is formulated as a mixed-integer linear programming optimisation problem.

On-line scheduling

The sterilisation section in the tuna canning plant creates a bottleneck for the production of the plant. With the developed decision-support system, the recommendations offered to the operators improve the productivity of the section by proper gathering and assignment of carts. The problem of sharing the steam flow has been addressed which would otherwise lead to infeasible solutions. Due to the iterative moving horizon solution and the tight connection to the MES, the system reacts online to all unpredicted situations.

The developers

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Further information

Fig. 1: Optimal time-temperature profile compared to the one that results if there is lack of steam.

![Optimal time-temperature profile compared to the one that results if there is lack of steam.](image1)

The optimisation system is connected to the ASM MES system. It collects information about the progress of the production, including the sterilisation traceability. Several optical readers were installed in the section to detect when cart has been put in one of the units in the producing lines or in the sterilisers. In addition, the MES system also collects information about the production itself to forecast the arrival of carts.

This data from the MES database is accessed through a web service. The solution obtained gives the optimal schedule for the next hours. This process is repeated every few minutes to adapt to unexpected situations and uncertainties. A crucial element is the visualisation to the operators. For this, an intuitive HMI has been developed that indicates the next actions to them.

Fig. 2: Deployment scheme of the solution proposed.

![Deployment scheme of the solution proposed.](image2)