Upstream and downstream synchronization for automotive paint shop scheduling

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Introduction

Paint shop scheduling is a very complex manufacturing process that need to fulfil several technical/industrial constraints at the same time. Some constraints are due to the painting process itself, while some other constraints come from the interaction between the paint work center with the upstream and downstream processes.

In order to provide an optimal painting schedule, not only one needs to optimize the paint sequence to get the least paint waste, and best painting performance, but one also needs to take into consideration the other work shops interacting with the paint line itself. This will make sure that the overall plant schedule is well synchronized and feasible.

This abstract will focus on the approaches that has been used in a scheduling software implemented for a market leader in automotive parts painting.

Problem Description

The overall production process is composed of 3 main steps (in order):

1. Injection: prepare the parts to be painted
2. Painting: paint the injected parts
3. Assembly: add components, assemble parts

2 important points are to be noted:

- The injection shop feeds the painting shop with parts. Similarly, the paint shop feeds the assembly shop with parts.
- The inventory space between injection & paint, and paint & assembly is limited. It is more a buffer than an inventory.

Each work center is governed by a set of specific rules. For example, the injection process require long production runs to be efficient since each mold change takes several minutes/hours. However, the paint shop relies on very short runs, and paint colors can be changed very quickly which allows for a high reactivity to the final automotive assembly line, with a just in time delivery policy.

Although there is some literature (see e.g. [1], [2], [3] and [4]) on the optimization of the sequence of cars in the paint line in car assembly plants, there is to our knowledge very little work on the synchronization between the paint shop and the upstream and downstream shops.

The studied real-life paint shop scheduling problem comes from one of the painting plants of a supplier to various automotive manufacturers worldwide. The paint line is a carousel comprised of so-called “masts”. Each mast holds a part carrier, carrying one type of parts. The painting carrousel moves the parts into the painting workshop, where the parts are painted and dried, and then brings the parts to the unloading area. Loading and unloading processes are manual operations. The scheduling is generally determined for the next 24 hours.

Solution Approaches

Two components are essential to efficiently solve the problem described in the previous section:

- The paint line scheduling model
- The overall scheduling process

The scheduling problem is modelled as a multicriteria Mixed Integer Program (MIP). One specific constraint that has not been modelled in the literature is the material flow constraint. Due to the model complexity (very high number of Boolean variables), a material flow constraint needs to be added in order to take into consideration both the parts coming from the injection, and the parts consumed by the assembly line. This constraint needs to have the right granularity. Two constraints are then added to make sure that the paint line only consume available parts, and that the limited space after paint line is respected.

Regarding the overall scheduling process, since solving the fully integrated plant scheduling in a reasonable time is not possible, each work center is scheduled independently. In order to make sure that the paint line is well synchronized with both downstream and upstream flows, the injection and assembly schedules are given as input. Those two schedules will generate the constraints to be applied in the paint line scheduling model.

Conclusions

This paint scheduling problem is modelled as a complex Mixed Integer Program. An optimal paint line scheduling is a scheduling that optimizes the painting sequence, but also takes into consideration constraints coming from the upstream and downstream work centers. This can be solved by adding material flow constraints to the paint scheduling model, and by ensuring that the scheduling processes are well integrated together.

In the presentation, we will introduce the problem and solution approaches, discuss their advantages and limitations.

Références

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