GUROBI
OPTIMIZATION

Pentair Water Solutions, Ltd.

Production Scheduling

Using optimization to improve the efficiency of metal casting through reduced waste and fewer defects.

Business Situation

Pentair Water Solutions manufactures a range of irrigation-related products on a metal casting production line. The manufacturing process involves pouring molten metal into a series of molds across two pouring lines. The process is quite complex, owing to the huge number of molds involved (1300), the fact that each product requires precise and potentially different metal temperatures and cooling schedules, and the fact that the two pouring lines share resources (e.g., the ladle that pours the molten metal). Pentair wanted to know whether optimization technology could improve their operation. As a result, they assembled a small team, including Mr. Hofheins and Mr. Upadhyay from Pentair Ltd. of Australia, Professor Allen Holder from Rose-Hulman, and Brent Austgen, a student at Rose-Hulman, to study the problem.

Building the Model

One thing became clear immediately: a brute-force approach to the model wasn't going to work. Given the number of molds needed over the course of a week, a naive model would require roughly 2^1300 decision variables - more than the number of atoms in the universe.

> **"Along with excellent technical support, we've found Gurobi to be a very fast, reliable and accurate solver."**
>
> *— Pankaj Upadhyay, Pentair, inc.*

The first modeling breakthrough came when the team realized that they only needed to consider production scenarios that satisfied all of the manufacturing restrictions. They took advantage of this observation by combining short sequences of production steps and including only those that satisfied temperature and weight restrictions. This formulation still resulted in a very large optimization problem, but the team showed that the model was computationally viable.

While validating the results with Pentair, however, several additional complicating factors were identified. In particular, an assumption about the manufacturing restrictions imposed by an up-stream process turned out to be incorrect, and it was exactly this assumption that had been leveraged to solve the problem. For a time, it appeared that the new optimization model would have to be scrapped.

Brent and Prof. Holder started a regime of meeting for several hours each day in an attempt to find a remedy. This intensive effort led to the observation that, while the original model didn't capture some important features of the problem when used over the entire planning horizon, it could be used to optimize smaller time segments. This formed the basis of a two-stage model: a global model first decomposes the week's demands into hourly buckets, and then the original model optimally schedules the molds for each hour.

Results

With the two-phased approach, Gurobi produces feasible solutions to the first global model in about 5 seconds, and reduces the optimality gap to around 40% in only 20-40 seconds. The models in the second stage solve to optimality in only 10-15 seconds. By comparison, when Pentair had tried free solvers, they found that the free solvers required much longer runtimes, and often failed to find feasible solutions at all. Pentair was very happy with the performance of Gurobi, the model and the resulting schedules. The end result was the team was able to meet the goals for improving quality, increasing output rates, and reducing costs.

Pentair

Pentair Water Solutions

Pentair Water Solutions is a global business unit of Pentair and a leading manufacturer and supplier of water and environmental solutions. We provide market leading products and services for the most challenging applications throughout the water, irrigation, mining, building, oil & gas, power and process industries.

Rose-Hulman

Rose-Hulman Institute of Technology is a world leader in engineering, science, and mathematics education and its undergraduate engineering college has been ranked #1 by US News & World Report for 16 consecutive years.

Team structure

Brent Austgen is a 2014 Rose-Hulman alumnus with a triple major in mathematics, electrical engineering, and computational science. He is an employee of Intel Corporation in Urbana-Champaign.

Allen Holder is a mathematics professor at Rose-Hulman with an expertise in mathematical programming. He has received several teaching and research distinctions.

Mr. Hofheins is Operations Director at Pentair, specializing in efficient manufacturing strategies.

Mr. Pankaj Upadhyay, Lean Manager at Pentair, is a LEAN/Six Sigma certified Black Belt in DMAIC & DFSS and specializing in Foundry technology and metallurgy.

Optimization relative to Lean and Six Sigma

The ladle scheduling optimization effort has helped identify opportunities that can be addressed by other quality efforts such as Lean and Six Sigma. In this particular case, Lean tools don't lend themselves well since Lean is based on a Pull System, and a foundry is a push system given that you can not pull from the Furnace - it must be scheduled. However, the Ladle Scheduling program has identified issues which were previously hidden and that can now be addressed using Six Sigma tools such as Design of Experiments.