Planning Smelter Logistics: A Process Modeling Approach

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Abstract

A dynamic logistic model, based on High Level Petri Nets, was generated to aid the planning of potroom activities, potroom traffic and logistic equipment needed for a smelter expansion project. This model includes all relevant pot-tending operations, such as anode changing with cavity cleaning and covering, metal tapping, alumina feeding, beam raising, bath tapping, pot stoppage and start-up, gantry transfer and crane maintenance exchange.

The workflow and traffic patterns in the smelter were simulated to analyze equipment utilization and bottlenecks. The rule-driven model incorporated such features as operation scheduling, collision detection as well as the entire material handling process. Pointers for the optimization of the potroom layout, e.g. the consequences of an additional passageway, could therefore be deduced. This discrete event simulation predicts the capacity utilization of logistic equipment, like cranes and service vehicles.

A visualization tool provides a dynamic follow-up to all simulated procedures and traffic activities of the model.

Introduction

If not well organized and suitably equipped, pot operations, such as anode changing, metal and bath tapping, cutting out and restarting pots, can result in backlogs due to bottlenecks in using cranes, forklifts and other logistic equipment. On the other hand, decisions about carrying out an upgrade to overcome such bottlenecks are associated with tremendous costs. Furthermore, due to the complex interdependencies which exist in the use of logistic resources, there is often no clear-cut way of finding the most efficient investment plan. A simulation model is therefore a useful aid to the decision-making process. The main goals of simulating complex logistic systems are to safeguard investment decisions, shorten development cycles and optimize potroom operations. When applying such a simulation model, statements about the dynamic behavior of the system can already be deduced during the planning phase. Based on the information obtained, the optimum variants regarding the static system structure and the dynamic processes in the system can be determined.

This particular simulation was carried out for a smelter expansion project which expanded two potrooms from 60 to 90 pots each. The detailed course of the smelter is shown in Figure 1. It was used for the evaluation of the traffic frequency and identifying vehicle collision conflicts. The original smelter comprised two potrooms with a total of four sections (Section 1, 4, 2, 5). The additional 60 pots were housed in Sections 3 and 6, see diagram. The rodding shop, storage areas, casthouse skimming station and an outside network of roadways were also included in the simulation model.

The expansion resulted in a 50% higher workload for the central units, e.g. the casthouse, skimming station and rodding shop, as well as for the roof filling station for the cranes. A decision about installing additional cranes can therefore be made by taking the use of a dense phase system, optional tapping and tending vehicles and an additional gantry connection into consideration.
The model shall determine the workloads of the cranes and vehicles. These figures can be used for the verification of the model as well as for comparison with different configuration set-ups. The definition of workload as used in this context is shown in Table 1, taking the time-averaged utilization of a crane as an example.

<table>
<thead>
<tr>
<th>Table 1: Workload definition</th>
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<tr>
<td>Possible utilization</td>
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<td>Actual utilization</td>
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<tr>
<td>Workload</td>
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<tr>
<td>Waiting</td>
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<td>7%</td>
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<td>Total workload (i.e. model simulation)</td>
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</table>

In this context, the meanings of workload and utilization have to be explained. The real workload of a crane, i.e. when it is actually performing a task, is less than the actual utilization. When the crane is in transfer between the roof filling station and back, or during the driver's rest period, the crane cannot be used for any other task. It is therefore "occupied" for this duration. Crane maintenance is also included, in the model and added to the working time. But, as manpower is not taken into account in this simulation model, the driver's rest periods are not part of the modeled total workload.

As a result, the optimized demand of the transport units and equipment is defined, course bottlenecks are visualized and a model for supporting process improvements is built up.

**Workflow**

A huge logistic model is required to simulate the whole workflow pattern inside the potroom, including the traffic to and from the rodding shop, lining shop, maintenance shop and casthouse.

With regard to the original potroom with a total of 120 pots, 6 different types of material - namely AlF₃, alumina, anodes, bath, butts and metal - had to be taken into account. This material flow is handled by 4 cranes, 4 types of vehicle and other tools, such as jacking frame, pouring spout and lids. The anode rodding shop and casthouse were assumed to have unlimited storage space available.

The resulting daily work schedule comprises the metal tapping of 120 pots, the anode changing of 90 pots and feeding alumina twice to 120 pots; bath tapping and pouring is also scheduled for 20 pots. On a weekly basis, AlF₃ feeding is scheduled for 120 pots, beam raising for 10 pots with 1 pot stoppage and 1 start-up added to the work schedule. Equipment is shared for all these tasks.

Based on the original work schedule, all these tasks had to be enlarged in line with the expansion to 180 pots.

Figure 1: Course of smelter model.