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Abstract

In the steel plant, we have 3 main processes, the iron making process, the steel making process and the rolling process. In the rolling process, we have many facilities including hot rolling mill, cold rolling mill, annealing mill and galvanizing mill. Each mill in the rolling process is linked closely interacting each other. Because each mill has specificity and technical limit for its product, we have inventories between mills for a flexible schedule. Although the inventory assures the stable production, high inventory level causes low delivery performance and production opportunity loss cost. The object of the mill balancing system is to control inventories in rolling mills.

In the each rolling mill, the scheduling unit is called a roll which is a sequence of coils, and between rolls we have a roll shifting job. Each roll has a special work type and coils in a roll are packed by the work type. To make a schedule for rolls in hot rolling mill, we have several constraints like a roll-size range, earliest start time for each coil. In addition to the constraints in hot rolling mill, we must consider the effect of material flow for the following processes and the delivery date of each coil. To make a scheduling system which considers these constraints, we use ILOG SOLVER & SCHEDULER. This system has a function for the roll cycle decision and the roll packing. We also implement a rescheduling logic when work environment changes or we get unsatisfactory result.

We have developed the prototype system and are under the development of the real system by the due date of 97.12.E. If we have develop this system, the inventory level will decrease by 30~40%.

1. Introduction

In POSCO, the steel making process is composed of 3 main parts, the iron making process, the steel making process and the rolling process. In the iron making process, we get the molten iron in the blast furnace from the limestone, iron ore and bituminous coal. The molten iron is transferred by the torpedo car to the converter. In the converter, the molten iron is oxidized and we get the steel as the form of the slab. In the rolling process, we get the final products by rolling slabs. In <Fig 1> the overall steel making process is described.

From the iron making process to the steel making process, it is the goal to maximize the amount of the molten iron. On the other hand, from the steel making process to the rolling process, the job sequence is decided by the delivery date, facility specification and other constraints. POSCO has many production lines, and products from one production line are transferred to the other production line for additional processing or delivered to the customer as final products. The route of product differs each other by its order specification or processing type. In the rolling process we need certain amount of coils or slabs for rolling. This schedule unit is called a roll, the sequence of coils or slabs. In making a roll there exist several constraints. The constraints are described in the later part of this paper.

The hot rolling mill connects the steel making process and the rolling process. In the hot rolling mill, some types of slabs are directly rolled from the steel making process without heating again. This is called as HCR(Hot Charge Rolling). If we have high ratio of HCR, the production cost reduces.

As so far, the schedule for each process has not been integrated. So, each factory has many inventories and the HCR ratio was low. To overcome these problems, POSCO is developing the integrated process control system since 1996. In this system, we use ILOG SOLVER and SCHEDULER.

2. The Architecture of the System

The newly developed system is composed of 4 sub systems. Sub systems are the cast scheduling system, the rolling scheduling system, the cast-rolling scheduling system and the mill balancing system.

The mill balancing system gets the information about capacity and repair from the capacity allocating system and makes a schedule satisfying the inventory level constraints. The schedule result is connected to the rolling scheduling and the cast scheduling system, and in the cast-rolling scheduling system we make a time schedule using the result of the cast scheduling system.

We set our focus on the mill balancing system which makes a schedule for the rolling processes considering material flow and constraints in each process. The hot rolling mill is the major concern because it connects the steel making process and the rolling process. There are #1 and #2 hot rolling mill in POSCO, and now our development is for #2 hot rolling mill.

3. Constraints to be Considered

In the hot rolling mill, we have two types of constraints, the roll cycle constraints and the roll packing constraints.

3.1 Roll Cycle Constraints

The type of a roll is decided by the type of scheduled rolls. There are 7 roll types in the #2 rolling mill. They are BP, NO, CR, Humul, Pakmul, STS300 and STS400. The schedule for STS300 and STS400 is given by the capacity allocating system. Other five types belong to two rough types, a thick type and a thin type. CR and Humul belong to the thick type and BP, NO, and Pakmul belong to the thin type. Constraints are described as

¨ç basic roll cycle : thick ¡æ thin ¡æ thin
¨è if 3 continuous thin types are inevitable : after 2 thin types, BP ¡æ NO ¡æ CR
¨é if the thin type is insufficient : 1 thin type can be skipped
¨ê after repair : 1 thick type
¨ë before STS300 or STS400 : thick type
¨ì after STS300 or STS400 : thin type
¨í 3 continuous BP or NO is not permitted

3.2 Roll Packing Constraints

Each roll has roll packing constraints to pack a roll. For example, roll packing constraints for a BP roll are described below.

- BP roll has
  ¨ç more than 40 Ilban BP coils.
  ¨è less than 30 D&I coils.
  ¨é less than 10 Pail-Can coils.
  ¨ê less than 30 coils in the same width group.
- The sequence in the BP roll
  if D&I coil exists,
    Adjustment slabs ¡æ Normal BP slabs ¡æ D&I slabs ¡æ Pail-Can slabs ¡æ Normal BP slabs ¡æ Hot rolled slabs
  else
    Adjustment slabs ¡æ Pail-Can slabs ¡æ Normal BP slabs ¡æ Hot rolled slabs
  Each roll has the range of the number of slabs.
- BP roll : 60 ~ 80 slabs

- NO roll : 50 ~ 80 slabs
- CR roll : 80 ~ 130 slabs
- Humul roll : 90 ~ 150 slabs
- Pakmul roll : 90 ~ 120 slabs

4. The Goal of the System

The goal of the mill balancing system is to make a schedule for overall process which satisfies constraints and control the inventory level in the inventory control range. High inventory level is not good because that causes longer processing time and loss of opportunity costs. And, low inventory level is not good because that may cause the lack of sufficient coils for rolling. In the galvanizing process, we have the chance coils which are rolled on predefined day(chance day). To supply chance coils before chance day, we must make a good schedule in the prior process.

5. Representing and Solving the Problem

To represent the problem, we declare the roll as a activity and the hot rolling process a unary resource. The roll processing time is represented by the duration. The number of cluster is converted by the ton/hour to the processing time, so the processing time min, max is represented by the duration min, max. The start time of each activity represents the job start time for a roll.

For the roll scheduling, we use several functions described below.

¨ç set the min and max of the roll size : setDurationMin(), setDurationMax()

¨è get information of the roll : getName(), getStartTime(), getDurationMax(), etc.

¨é set the roll start time : setStartTime()

This logic flow is described in < Fig 3 >.

In the hot rolling process, we have two scheduling levels, the roll cycle deciding and the roll packing. Every day we schedule about 6 rolls and each roll is composed of about 30 slab clusters. We group slabs of the same specification into the slab cluster to reduce the object number.

There are interactions between two levels. If a roll is packed, the flag of success is returned, otherwise the flag of fail is returned. When a roll is packed the scheduling start position is moved by the roll processing time. We choose a candidate roll type and send arguments of roll type, roll size and roll start time to the roll packing routine. In case a roll can't be packed, the packing is retried with the reduced roll size.

When we make a schedule of rolls, the result of the schedule can not meet our goal. In this case, we need backtracking to the previous part of the schedule. To do the backtracking, we store the result of the schedule in the array and when we need backtracking, we add constraints by this array. This is a sort of rescheduling. The flow chart is described in < Fig 4 >.

6. Conclusions

We have described the logic flow for the constraint-base scheduling in the mill balancing system. Generally, scheduling problem is very difficult to solve in the real world. There are so many data and constraints to be considered. So, we have divided the scheduling system into 4 sub systems by its functions. 4 sub scheduling systems are linked interactively and each system has real-time data interface. The scheduling engines of sub systems are supported by ILOG SOLVER & SCHEDULER. To strengthen the usability, we also support user-friendly system environment. Now, the whole scheduling system is under development and some parts are already developed.