Hot Strip mill simultaneous material assignment and scheduling system[1]

An optimisation of standard slab types management with Beta-Matcher

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Summary

The production detailed scheduling has a substantial impact on the performance of a Hot Strip Mill. The optimal usage of the slab yard to satisfy order due dates, maximize hot charge, satisfy scheduling rules and load balancing is a highly profitable challenge. The following document presents the implementation of SteelPlanner Beta-Matcher system of A.I.Systems for the material assignment and scheduling of Siderar hot strip mill in San Nicolas, and the benefits of a schedule dependant slab to order assignment.

Keywords

Assignação, seqüênciamento, laminador de tiras a quente, otimização

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Introduction

Siderar is the largest steel company in Argentina. It is a fully integrated producer that makes coke, pig iron and steel from raw materials, in order to manufacture rolled sheets and coated products. Currently Siderar reaches production levels of 2.4mt annually.

A.I. Systems is a Belgian company specialized in software development and implementation for decision support in the areas of production planning and supply chain optimisation specifically for the steel industry.

Siderar and A.I. Systems have collaborated in implementing optimisation systems for a better assignment of the slab yard considering the demand characteristics but also optimising the hot strip mill process.

Project purpose

The objectives of the project were:

General objectives:

- Improve the slabs assignment and decrease the stock of un-assigned slab,
- Increase the number of hot charge schedules.

Specific objectives:

- Select the best combination of coffin type and sequence of coffin types to satisfy the demand with the available and forecast material.
- Make a better usage of the available material by assigning orders that can be scheduled together in one round, preferentially hot, and respect daily flow constraints per product family.
- Make an optimal usage of alternative slab types, to globally better satisfy the demand.
- Batch virtual rounds of hot charge to generate the casters demand for hot charge.

Problem description

The most important way to increase performance (and reduce production cost) from the scheduling is loading the slabs in the furnaces before they are cold. But it is only effective if an important amount of hot slabs are loaded in a continuous way without any interruption by cold slab loaded. The rounds where the whole slabs are scheduled to use hot ones are called “Hot Charge”.

Siderar works with unassigned slabs to minimize complicated movements of material and to reduce the necessary space to locate them. Besides it gives to the scheduling task more flexibility due to slabs might be used by any order that require for its dimensional and chemical features, and the decision of to

which order will be rolled may be postponed until the slab has to be picked up in order to be loaded into the HSM furnaces.

The unassigned slabs schema implies that to schedule the HSM, and also to calculate the actual demand of slabs to the Continuous Caster is necessary to simulate the assignment of the whole slabs stock to HSM demand (orders). Is the assignment process part of the HSM detailed scheduling or is it possible to separate in two steps?

The assignation of material units to orders and the scheduling of the orders can be separated in two processes but leading to sub-optimal solutions. Since there are two processes there is two alternatives or:

- The orders are scheduled without material unit assigned and in a second phase material units real or virtual are assigned to the orders of the schedule to make the solution feasible, or

- The material units are first assigned to orders and then the assigned orders are scheduled in feasible schedules.

The first approach is often used in mid-term scheduling where the material units can't match the orders.

The second one, pragmatically, is often used in short-term scheduling when it is of the first importance to have feasible schedules, and to make the problem less complex to manage.

- ***Scheduling before assignation***

The first alternative lead to assignation to virtual material beyond what it is necessary and then poor assignation.
Suppose we have two orders "A" and "B" and two material units "a" and "b", "a" is available on day 1 and is suitable for both order "A" and "B", "b" is available on day 2 and is suitable only for order "B".
If we choose to schedule order "B" on day 1 and order "A" on day 2 we will need to assign "A" to a virtual material unit "va" and keep material unit "b" in the stock.

	Day One	Day Two
Material units	"a"	"b" + "va"
Orders	"B"	"A"

In this case, if Continuous Caster could provide the "a" slabs in time we had increase the slab stock, that is not desirable, or if not, we have an unfeasible solution for HSM scheduling.

- ***Assignation before scheduling***

The second alternatives badly scheduled orders or even worst in case of required flows (e.g. startup material) on gap in the schedule.
Suppose we have four orders “C1” and “C2” of type “C” and “B1” and “B2” of type “B” and four material units “c1” and “c2” of type “c” and “b1” and “b2” of type “b”. Suppose both order types can consume both material types but orders of type “B” prefer material of type “b”. If we pre-assign we will choose to assign orders “B” to material type “b” and orders “C” to material type “c”. Suppose that the material unit availability and order due date follows the following distribution:

	Day One	Day Two
Material units availability	“b1”, “b2”	“c1”, “c2”
Orders due dates	“C1”, “B1”	“C2”, “B2”

Then the schedule induced by this assignation will be of the kind:

	Day One	Day Two
Material units	“b1”, “b2”	“c1”, “c2”
Orders	“B1”, “B2”	“C1”, “C2”

which is sub-optimal because both “B2” and “C1” are not scheduled according to their due date.

Proposed Solution

In order to address these problems, we implemented Beta-Matcher system, as a solver to satisfy the above mentioned objectives, scheduling and assigning slabs and orders simultaneously.

Beta-Matcher

The inputs of Beta-Matcher are:

- The material units both available and virtual (that could be produced), aggregated when possible in slab types
- The milling orders (coil orders demand) and
- The matches that bind together material units and orders. A match is a link between an order and material unit that could be assigned to that order; it is a potential assignation (see Figure 1)

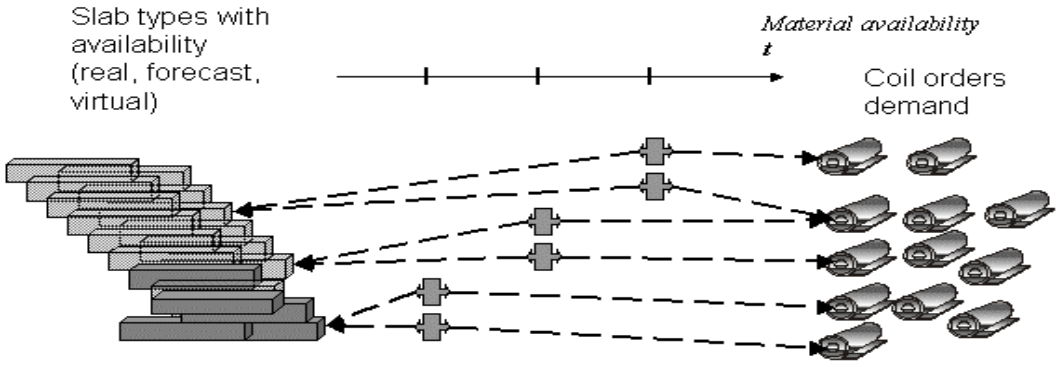

Figure 1: Possible matches between orders and slab types

- A description of the relevant time horizon in term of time buckets in order to reduce the size of the problem.
- The type of available coffin types with their description in term composition size and flow constraints,
- Product flows constraint for each time buckets,

The goal of Beta-Matcher is to choose and schedule rounds in each bucket and schedule matches in rounds so that:

- The coffin constraints are respected in term of composition, size and flows,
- The material is available at the time it is programmed, and in case of a hot charge round, all slabs are hot.
- The selected orders in the rounds respect due date constraints
- The cumulated process time of the scheduled round do not exceed the available capacity.
- The induced assignation do not assign twice a given material unit,
- No orders are over assigned

This conditions are represented graphically in Figure 2
Moreover,

- The product flows constraints, representing the necessary load balancing constraints of the plant must be respected,
- The resulting schedule must be feasible and optimal in term of flows, due date, campaign setup and campaign constraints.
- And maximize an objective function that take into account orders and material units selection scores and order due date scores.

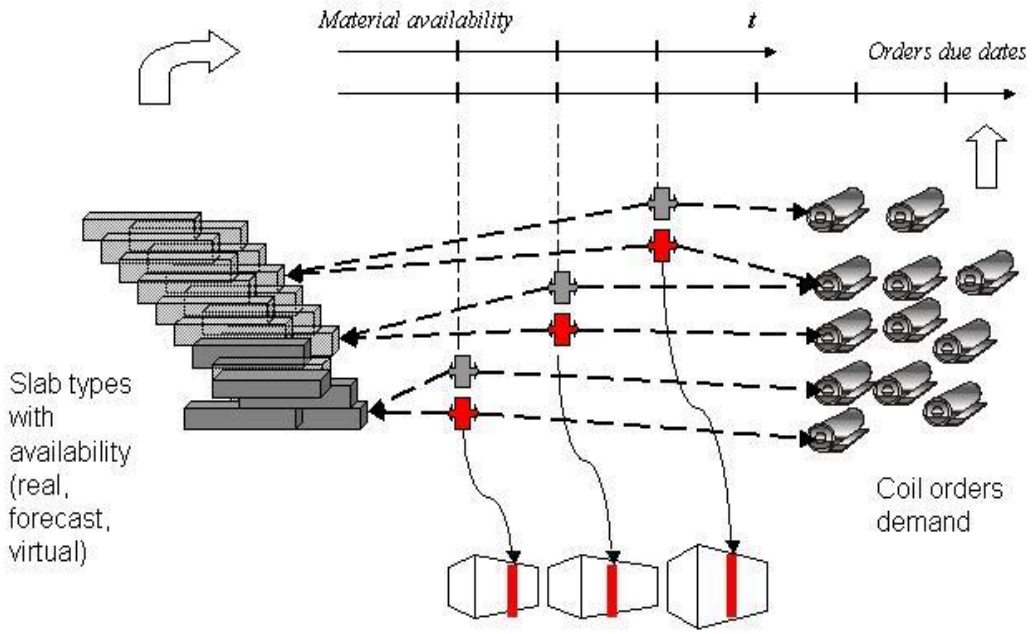

Figure 2: Selection of slabs, orders and coffin types to generate schedules

The global picture to be solved globally with all constraints is therefore represented in Figure 3:

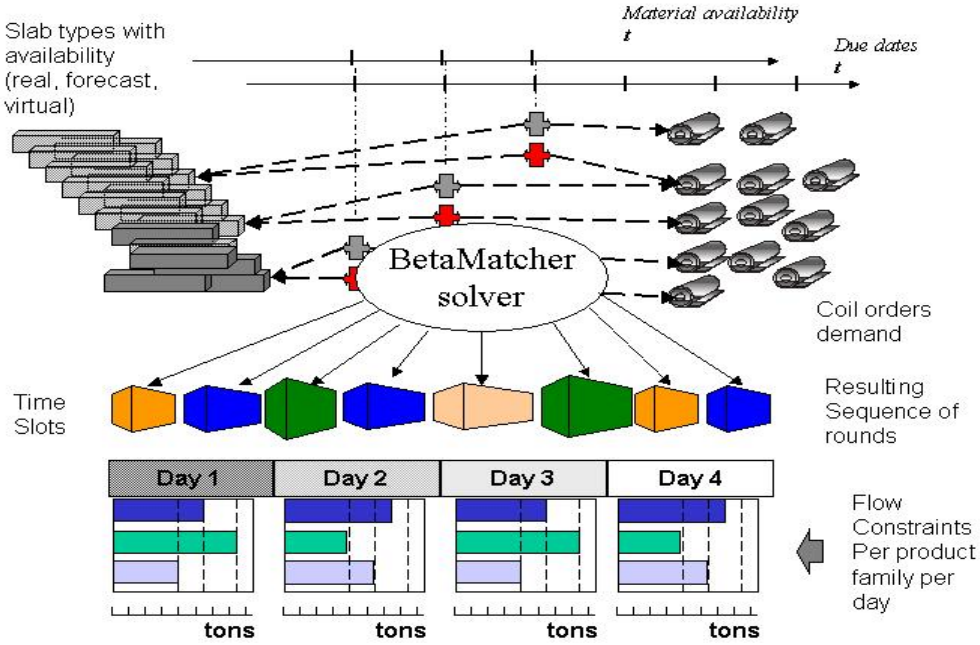

Figure 3: Beta-Matcher solver: selection of slabs, orders and coffin types to generate schedules respecting material availability, flow constraints, due dates, and batching hot slabs in hot charge rounds

Configuration of Beta-Matcher at San Nicolas plant, SIDERAR

The configuration at Siderar of Beta-Matcher complements the already existing configuration and rules of BetaPlanner, a scheduling system for assigned slabs. Part of the configuration of BetaPlanner has been reused for Beta-Matcher, as for example the coffin design rules.

Matching combinations

A first step of implementation consist in the module containing the matching rules depending on the order characteristics and the slabs characteristics: a matching score is associated to the different possibilities, the perfect match will have the highest score, alternative matches (like alternative steel grades, or needing conditioning), will have a lower score.
The combination of possible matches between orders and slab types happens to be around 20.000.

Typical size of the problem

The problem given to Beta-Matcher is the whole demand with typically the following magnitude:

Volume of orders	170.000 - 200.000 tons
Number of order	1700-2000 orders
Macro matches	15000 – 20000 combinations (160.000 real combinations)
Real slabs	3500 slabs (about 35.000 tons)
Forecast CC slabs	1000 slabs (about 10.000 tons)
Virtual slabs	15000 slabs (about 150.000 tons)
Number of slab types	about 800 slab types
Coffin types	about 12 coffin types
Resolution horizon	about 7 to 10 days (20 to 30 rounds)
Product Families	about 10 product families for load balancing with daily flow constraints

Results and perspectives

Results evaluation

A difficult task has been practically to evaluate the quality of the results given that two problems were solved in one step, and given the huge amount of constraints generated on the problem.
However, about 15 query reports and check lists on the results were made to analyse systematically the results during the validation phase, among which:

- The number of remaining unassigned slabs with order candidates;
- Check whether a virtual slab is not scheduled before a real slab of same type with compatible availability;
- Check whether an order with latest due date is not programmed instead of an another order, more urgent and with same characteristics.
- Respect of flow constraints;

Response time

Substantial developments have been carried out in the solver to reduce the response time given the huge amount of possible combinations. The average response time of the Beta-Matcher on such configuration has been from 40 minutes to an hour nowadays. This phase does not including the detail scheduling, but is very important to have the slab yard assignment, and therefore calculate the casting orders balance and due dates, as well as the hot charge requirements.

After this phase, a detailed scheduling algorithm of BetaPlanner carries out the detailed sequencing rules for the first rounds.

Assignment improvements

The previous assignment system was a rule based assignment system. The advantage of a global resolution as in Beta-Matcher is a better use of alternative material, and a better use at the right moment in time considering the capacity of the hot strip mill line and it's scheduling constraints. The assignment rate is from 80 to 90% of the slab yard. It happens to be slightly lower than the rule based system, but the assignment is better fit to the demand, the flow constraints and the hot strip mill constraints. A post processing finishes the remaining assignments.

Hot charge rate

To improve the hot charge rate, special hot charge coffins have been designed, to batch hot slabs.

The main expectation stands in increasing the hot charge rate. With the "assign slabs to orders then scheduling" schema carried out during last year the hot charge has reached in the better months a 5%. This amount is obtained with a lot of manual changes to the material assignment after Betaplanner finishes the program. With Beta-Matcher it is expected to reach a monthly average of 20%, almost the technical maximum given the order book content and the logistics restrictions.

Change management and impact in current programmers tasks

The implementation of such a system leads to a cultural change, as the tasks of assigning slabs and sequencing slabs are collapsed in one single system and the decision is done globally. The way of thinking a sequence changes, the tools to manage material units orders and reassignment also.

Moreover This system will induce an important change in the daily scheduling task. With Beta-Matcher we hope to decrease the operational time to make revisions and adjustments by 50%.

Conclusions

Beta-Matcher is part of the Steel Planner solution. The optimal assignment of a standardized slab yard, organized in slab types is at the heart of a steel plant logistics management. The assignment result and the schedule is the basis to generate the demand for the casters. The result of that optimization will be propagated to the others optimizers in order to coordinate the scheduling of the whole plant.

Resumo en português:

A programação da produção tem um impacto substancial na performance dum laminador de tiras a quente. O uso ótimo do pátio de placas de forma a satisfazer datas de entrega, maximizar a carga quente, satisfazer regras de programação, balanço da carga de produção, é um desafio com alto retorno de benefícios. O seguinte documento apresenta a implementação do sistema Beta-Matcher da família SteelPlanner de AI Systems para assignação e programação de placas para o laminador de tiras a quente de Siderar em San Nicolas, e os benefícios de uma assignação de placas condicionada pelo seqüenciamento do laminador.