COMPACT STEEL PLANT SCHEDULING WITH SIGMAPLANNER: AN AIS STEELPLANNER DIRECT CHARGE SOLUTION AT TERNIUM MEXICO [1]

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Abstract
In order to maximize the productivity of its Compact Steel Plant installation (mini-mill) in Monterrey, Ternium Mexico has conducted a project in collaboration with A.I.Systems developing and implementing an automatic scheduling system. The objective is to maximize sequence length, reduce grade transitions and dimensions transitions, respecting due date constraints. The project was carried out in 3 phases. The first phase consisted in configuring the model of the process, collecting scheduling rules and practices, and implementing a scheduling editor. This step resulted already in a first business release with user benefits. In a second step, detailed scheduling was automated with SigmaPlanner optimizer, focusing on rules and cost function configuration. In a third step, a midterm planning phase was carried out to improve orders selection in batches and general load balancing. The implementation of the schedule editor and wizard allowed fast results in editing, as well as tools for analysis and evaluation of sequences. This led to a revision and a complementary formalization of scheduling rules. The solver development, implementation and tuning allowed to automate the scheduling process using advanced algorithms to explore the solution space, and diminish substantially production costs relative to over-rolling.
Key words: Production planning; Production scheduling; Compact steel plant; Mini-mill; Optimization.

PROGRAMAÇÃO DE UMA ACIARIA COMPACTA COM SIGMAPLANNER: UMA SOLUÇÃO STEELPLANNER DA AIS PARA ENFORNAMENTO DIRETO EM TERNIUM MEXICO

Resumo
Com o objetivo de maximizar a produção do seu mini-mill em Monterrey, Ternium Mexico conduziu um projeto em collaboração com A.I. Systems desenvolvendo e implantando um sistema de programação da produção automátizado. O objetivo é maximizar o comprimento das sequências, reduzir transições de qualidades de aço, e transições dimensionais, respeitando datas de entrega. O projeto foi conduzido em 3 fases. A primera fase consistiu em configurar um modelo do processo, colletando regras e práticas de programação, e implantando um editor de programação. Este paso já resultou em um primeiro entregável com benefícios para o usuário. Em um Segundo passo, a programação detalhada foi automatizada com o solver do SigmaPlanner, apontando no respeito das regras e na função objetivo. Em uma Terceira etapa, o planejamento a medio prazo foi implantado de forma a melhorar a seleção de pedidos por lotes e asegurar o balanço da carga de planta. A implantação do editor de programa com um assistente permitiu resultados rápidos, assim como ferramentas de análise e de avaliação das sequências. Isso levou a uma revisão e formalização complementar das regras de programação. O desenvolvimento do solver, a implantação e o tuning permitiram automatizar o processo de programação, usando algoritmos avanzados para explorar o espaço de soluções, e minimizar substancialmente custos de produção relacionados a over-rolling.
Palavras-chave: Planejamento de produção; Programação da produção; Aciaria compacta; Mini-mill; Otimização.

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1 INTRODUCTION

Starting in April 2007, Ternium Mexico has conducted a project with A.I. Systems to create the first automatic mini mill scheduler in its CSP (Compact Steel Plant) facility of Monterrey.
Originally the Compact Steel Plant had a unique caster line. The scheduling tool could only support by design one single caster and one mill.
An expansion of the Compact Steel Plant consisted in building an additional caster to increase throughput. The original scheduling tool was therefore not able anymore to manage this new resource in its scheduling model.
The scheduling of this unit required then to take into account an extra caster (with ladle definition, tundish design and grade transition) with the additional complexity of synchronizing them among themselves and with the hot strip mill scheduling rules (strip thickness transition, roll wear, warm up and intermediate roll changes). Moreover, instead of a manual tool, scheduling should be automated and optimized.

2 GENERAL OVERVIEW

The Compact Steel Plant is composed of 2 single strand continuous casters that feed a common hot strip mill through a furnace tunnel, with no intermediate inventory. The hot strip mill feed is therefore 100% direct charge.
The yearly production is about 2 million tons.
The production manages about 30 different grades grouped in 5 grade families
The width range is from 902 mm to 1,371 mm and the gauge range from 0.9 mm to 12.7 mm.
The details of the production unit are shown on Figure 1.

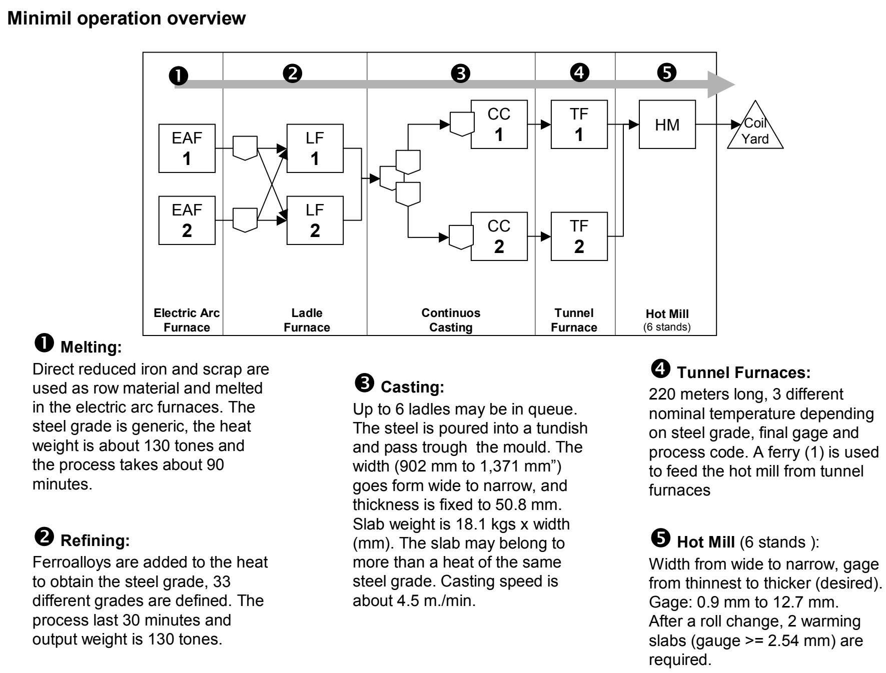

Figure 1 – Minimill operation overview.

2. 1 Project Scope

The project covers the following scope:

- Detailed schedule generation for Ternium Hylsa's Mini-Mill.
- Schedule time horizon of 1-2 days, with details for the first day for short term;
- Schedule time horizon of 1 week, for midterm;

The mini-mill has the particularity of having two strands leading to a tunnel furnace followed by the rolling mill, without any buffering. Therefore, the detailed scheduling must consider both casting constraints and milling constraints.

2.2 Project Goal

The main objectives of this implementation are:

- To maximize the global throughput of the installation using an optimizer to ensure the tradeoff between all the rules in a wider time horizon. Each coil not produced by the mini-mill has to be purchased as slab from an external supplier and must be rolled on a conventional hot strip mill, resulting in a higher production cost.
- Minimize unassigned coils that are required to bridge orders in sequence. Producing unassigned coils for transitions results in a high loss. By a better global scheduling, this cost can be reduced.
- Improve due date compliance (service);

More specifically also:

- Respect startup dimensions;
- reduce grade transition costs;
- minimize width jumps, thickness jumps;
- synchronize both casters widths;
- maximize tundishes usage;

3 METHODOLOGY

3.1 Team Organization

The project involved jointly:

- the IT model's department
- the caster and mill production people
- the scheduling people to review the scheduling rules, and practices
- the A.I. Systems consultants and developers.

3.2 Project Phasing

The project has been divided in 3 parts so as to deliver intermediate solution to supply chain and better the solution thanks to the feedback from the use of SigmaPlanner in the day to day scheduling operations.

1) Manual schedule editor: develop a semi automatic solution that model one caster and one mill to replace the existing solution and start re engineering rules and schedule's practices. Validate the process model, and have a first deliverable for the schedulers.

2) Automated Scheduling: based on the Sigma model, build the dedicated solver and strategy to manage at the same time the caster schedule and the mill schedule.
3) Midterm scheduler: this phase will provide a global approach of scheduling the CSP line with a weekly schedule so as to provide a global optimum in the scheduling of the line that will respect scheduling rules, due dates and internal flow constraints for downstream lines.

4 PROPOSED SOLUTION

The proposed solution consists in summing the existing components of SteelPlanner:

- Components of AlphaPlanner for casters scheduling;
- Components of BetaPlanner for hot strip mill scheduling;

in order to build in short development time an integrated environment that models casters and mill as one single system, including process model, scheduling rules and user interfaces:

$$\Sigma = \alpha + \beta$$

Sigma letter symbolizes:

- Summing AlphaPlanner and BetaPlanner components;
- Summing the benefits of having already tested components;
- Sum their respective existing and validated user interfaces;

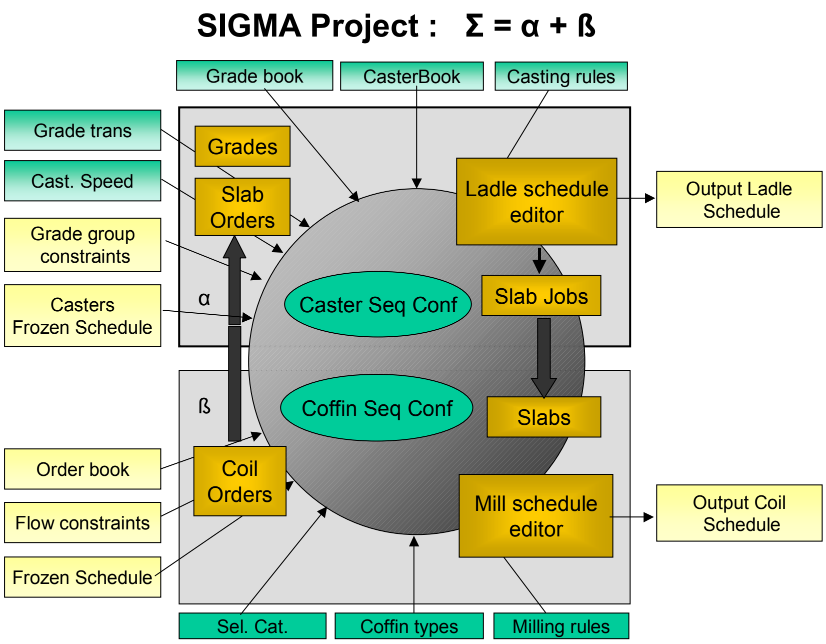

Figure 2. SigmaPlanner components.

The internal modules of SigmaPlanner are shown on Figure 2, integrating AlphaPlanner and BetaPlanner components.
As casters are the bottleneck of the installation, the resolution strategy we have chosen consists in scheduling both casters simultaneously and project their schedules to the hot strip mill and then update the mill schedule to fit with milling rules.

Once solved the caster problem, the system ensures the best combination of ladles in every caster and minimize difficult transition as well as we have synchronized caster width between casters.

5 RESULTS

1) <u>Manual Scheduling</u>: This phase lasted from April to November 2007. It consisted in:

- Configuration of the rules;
- Training on manual editing

By then all the schedules of the CSP line of Ternium Mexico have been provided by SigmaPlanner.

Manual scheduling enabled to better understanding scheduler's procedures, way of working and resulted in an intermediate usable deliverable, supplying already benefits, and a better understanding of the problem to tackle automation and optimization.

Figure 3 shows a user interface used for manual scheduling.

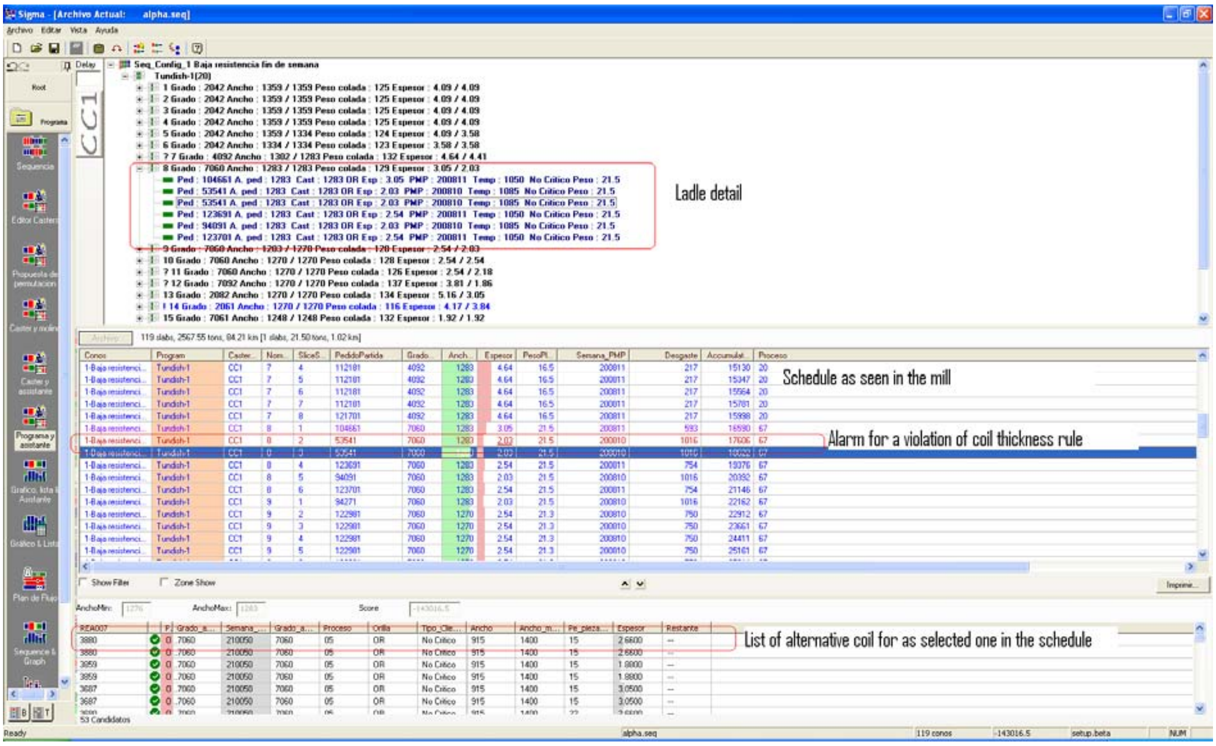

Figure 3 – Schedule editor user interface.

2) <u>Automated Scheduling</u>:

Thanks to the feedback of the first phase we design synchronization rules and provide an automatic calculation with 2 casters working in parallel.

It consisted in:

- Simulations;
- Tuning;
- Training;
- Documentation;

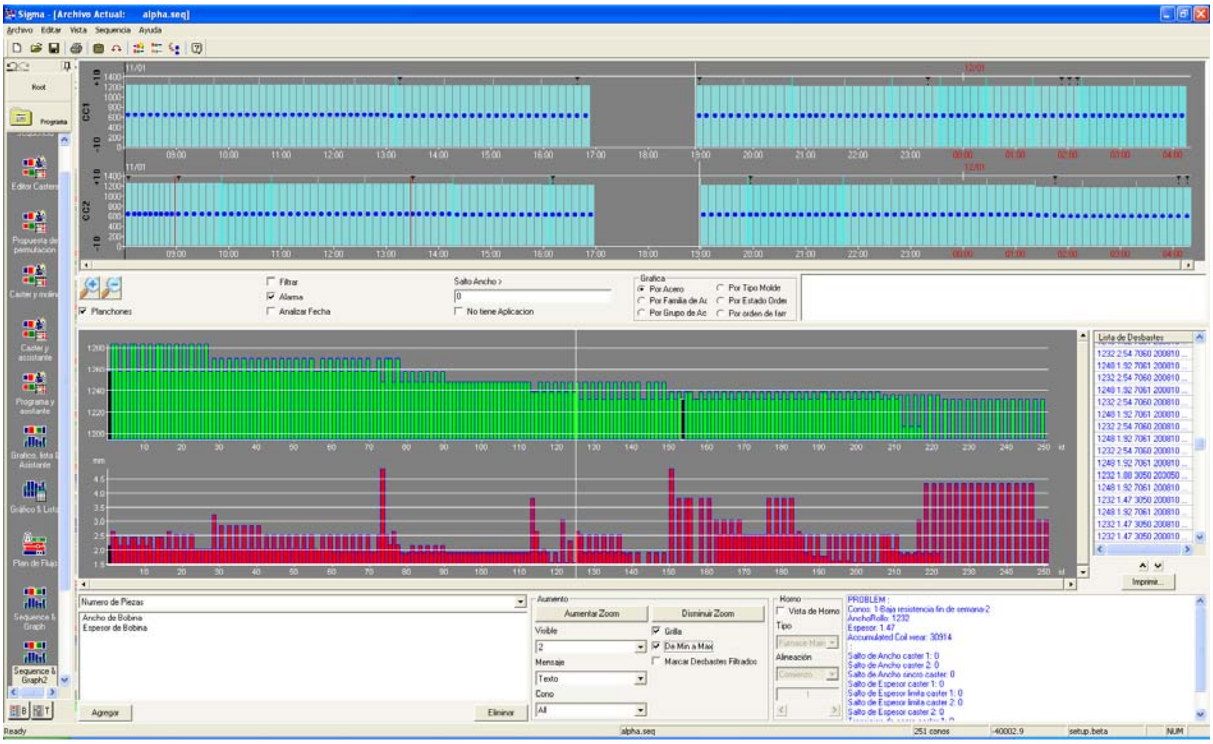

Figure 4 – Schedule Gantt chart.

The fine tuning of the automatic solution was finished in July 2008.
Figure 4 shows a user interface showing both caster schedules and the corresponding hot strip mill schedule.

3) Midterm Scheduling:
The Midterm solution was based on BetaPlanner Midterm algorithm, selecting batches of grades by grade families, used to pre-configure casters patterns as casting sequencing constraints.
The project consisted in:

- Simulations;
- Tuning;
- Training;
- Documentation;

The project was finished in September 2008.

6 GENERAL CONCLUSIONS

The implementation of the schedule editor and wizard allowed fast results in editing, as well as tools for analysis and evaluation of sequences. This led to a revision and a complementary formalization of scheduling rules as collateral benefit.
The solver development, implementation and tuning allowed to automate the scheduling process using advanced algorithms to explore the solution space, and diminish substantially production costs relative to over-rolling.
The new solution supports multi caster sequencing. Moreover, it is one of the components of the broader implementation of the SteelPlanner solution at Ternium Mexico covering scopes from capacity planning, hot strip mills scheduling, material assignment optimization and master scheduling, as described in an article of ABM automation seminar.(1)

REFERENCES

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