SIDOR'S STEEL MAKING PLANT AND HOT STRIP MILL PRODUCTION SCHEDULING INTEGRATION AND OPTIMIZATION, 'A STEELPLANNER SOLUTION' AT SIDOR[1]

Orlando Ostos-Roa[2]
Freddy Hormiga[3]
Ronald Pérez[4]
Pierre Beghin[5]

Abstract

Sidor, C.A. has decided to invert on new developments of software for decisions support in the areas of production planning and supply chain logistics in order to reduce production costs. The purpose of this paper is to describe the implementation of an integrated production planning system to optimize the scheduling of the steel making plant (three casters), the hot strip mill and their slab yards, using SteelPlanner modules, in cooperation with A.I.Systems.

Key-words: Production planning; Production scheduling; Slab assignment; Optimization

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[1] *IX Seminário de Automação de Processos – 05 a 07 de Outubro de 2005 – Curitiba - PR*
[2] *Production Scheduling Analist, Sidor, C.A. Pto. Ordaz, Venezuela siroos@sidor.com, +58 2866004453*
[3] *Production Scheduling Analist, Sidor, C.A. Pto. Ordaz, Venezuela, sirhoy@sidor.com, +58 2866004358*
[4] *Production Scheduling Analist, Sidor, C.A. Pto. Ordaz, Venezuela, sirrpx@sidor.com, +58 2866006985*
[5] *Consultant, A.I.Systems, Brazil, pierre.beghin@aisystems.be, +55 21 93236768*

INTRODUCTION

Sidor, C.A. is an integrated steel complex located in Venezuela and member of the Techint Group of Companies as a manufacturer of flat and long steel products. It produces steel through the direct reduction of iron ore and AC electric arc furnaces.

Its wide product mix enables the company to serve an important range of industries and activities such as oil & gas, construction, automotive, home appliances, packaging and canning, hot dip galvanizing lines, distributors and service centers. By 2005 it's expected that Sidor will have a steel production of 5 millions tons.

A.I.S. (Advanced information Systems) is specialized in the development and the implementation of software for decision support in the areas of production planning and supply chain logistics in process industries.

The SteelPlanner is a powerful production planning and control solution, developed by A.I.S., which optimizes the performance of a metallurgical plant in terms of product output, quality, order-to-delivery time and cost.

PROJECT GOALS

The purpose of this solution implementation is:

- To maximize the productivity of the caster and the hot strip mill, by:
  - The maximization of each facility's production capacity.
  - Reducing operational costs associated to the production line scheduling.
- To coordinate and integrate all the production processes, obtaining:
  - An integrated solution of the production planning.
  - An easy way to adjust and/or upgrade the scheduling strategies.
  - A better visibility of potential problems.
- To manage the real due dates, and:
  - Accomplish the customer required due date.
  - Have a caster and HSM schedules that follows their casting and rolling date, respectively.
- To optimize the slab stock inventory level:
  - Minimize the unassigned slab inventory.
  - Follow and accomplish pre-established slab handling & transfer (Caster-to-HSM) plans.

PROBLEM DESCRIPTION

Sidor's hot strip mill consist of two reheating furnaces, one 4-hi reversing roughing mill stand, six 4-hi finishing mill stands and three down coilers. Sidor's continuous caster (3 twin strand casters with fixed width) produces the slabs to be rolled in the hot strip mill.

Given the fact that the hot strip mill is the bottleneck in our production chain, it is important to increase the performance of it, maximize the furnace throughput and diminish setup times on this line, considering all the operational rolling rules and the stock available to roll.

By managing different thickness in the hot strip mill, mainly 175 mm and 200 mm, Sidor is taking care of not having too much furnace throughput reduction due to a mix of slabs that have different transit times in the furnace. The two furnaces can be modeled by a window of 64 meters (representing in average an amount of 56 to 60 slabs in the furnace). On such a window, the slab with the highest transit time determines the pacing of the furnace, so its optimization was the principal reason considered for the BetaPlanner implementation.

Sidor also needs to decrease the production of excess material, getting the best of the programmed heats, knowing that the caster machines are fixed width and that operational and batching constraints must be considered. The scheduling optimization of the continuous caster machines will reduce the production/operational costs.

To apply slab to the production order, Sidor had a system that only considered the standard slab dimensions that the production orders required. This made the unassigned stock very high, poor quality assignments, and a really low inventory of material available to schedule in the hot strip mill.

PROPOSED SOLUTION

The integrated solution is based on different SteelPlanner modules, to solve the daily scheduling issues of the continuous casters and the hot strip mill, create a weekly/midterm plan for the planning of the rounds for the hot strip mill and handle the slab to hot strip mill orders allocation process.

The SteelPlanner modules proposed to solve each task are the following:

BetaPlanner

The BetaPlanner is specifically designed for the scheduling of rolling mills. It includes all necessary functions and advanced search, selection and optimization algorithms to generate fully automatically “optimal” mill schedules.

On the basis of the order book (input file) and the selection (production goal), BetaPlanner generates automatically the Mill schedules. These schedules are optimized according to the jump rules (width, thickness, hardness, temperature), and to logistics and process constraints (improving delivery on due date, reducing production of stock, respecting client constraints, mill limitations, roll wear).

AlphaPlanner

AlphaPlanner is specifically designed for and has been proven in the optimal scheduling of continuous casters. AlphaPlanner gives proper consideration to upstream melt constraints, thereby enabling a realistic cast slab production schedule coordinated with a steel making melt / treat ladle sequence to be created.

ProductMatch

ProductMatch is a system that given a yard of material units, an orderbook and assignment rules, generates in a first phase the matching possibilities among material units and orders (based on scores) and generates an optimal material to order assignment in a second phase.

Material Flow Coordinator (MFC)

The MFC for the Hot End has the purpose of integrating the hot end scheduling environment and is responsible for interfacing flows, orders, material units and job information with Sidor production systems and to interface material units, production orders and jobs to the ProductMatch, BetaPlanner and AlphaPlanner.

The approach of the solution is shown on Figure 1.

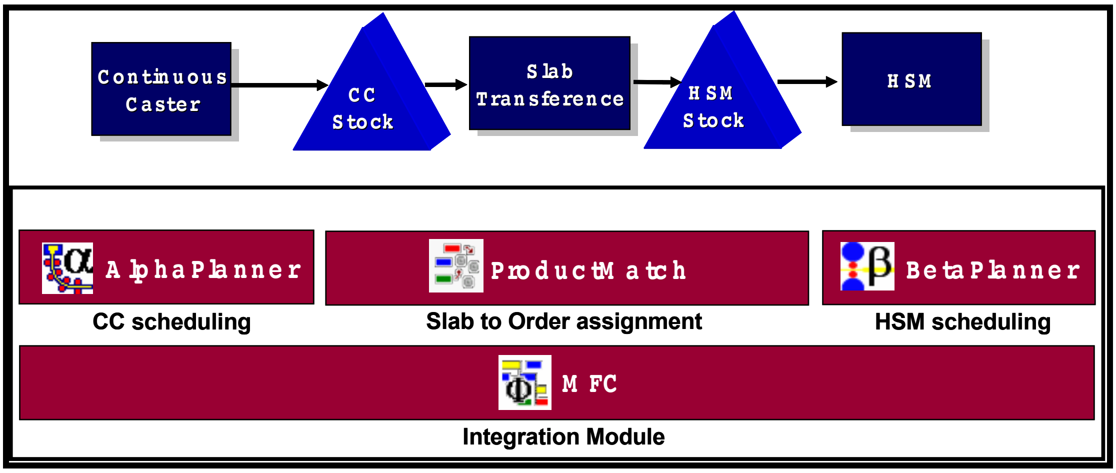


Figure 1

Furnace transit time 'overlapping'

We mean by '<u>Furnace Transit time Overlapping</u>', the loss of productivity (in %) in the hot strip mill due to a mix of slab transit times in the furnace sequence. The reduction of the overlapping has a direct and significant impact on production turn-over.

In order to address this in our scheduling model, a 'window jump function' on the attribute transit time (TTR) was proposed, and called 'Superposicion'. The optimizer calculates the penalty for the transition from a slab TTR, with the maximum TTR in a window of 56 slabs (configurable).

This function is calculated for all windows of 56 slabs, with one slab shift. So for each window of 56 slabs, a penalty is given to the TTR difference in the window as follows:

Jump-Function-Definition "Superposicion"
Attribute "TTR"
Argument-Type Max-Difference Window-size 56 Window-size-Unit "CantDesbastes"
Crossing-Policy "Sequence-Wide"
Limit -1000
Function Name "**FSuperposicion**"
(Function-Definition "**FSuperposicion**" Super-Quadratic
A-POS 0.0 B-POS -10 A-NEG 0.0 B-NEG 0)

RESULTS AND PERSPECTIVES

The project started on June 2004, MFC and ProductMatch were the first modules implemented, and then the BetaPlanner. The BetaPlanner Mid Term and AlphaPlanner are actually in the implementation process, so the results that have been evaluated are the ones from the slabs assignments and hot strip mill scheduling.

Results evaluation

The methodology followed to evaluate the results was made to analyze systematically them during their validation phase, considering:

- The number of assignments and the inventory of unassigned slabs.
- The quality of the assignments, check whether a slab with youngest production date is not assigned instead of an older slab with same dimensions.
- The length and consistence of the HSM coffins.
- Check whether an order with latest due date is not programmed instead of a more urgent order (same characteristics).
- Furnace transit time overlapping rate.
- The response time.

Assignments validation

To check the number of assignment and their qualities, a query report developed by Sidor (shown on Figure 2) helped, where the available slab inventory is classified by their status: 'Assigned', 'Retained' and 'Unassigned', it also classifies them by the slab yard that the material is at, and shows how long ago the slab was cast.

SIDOR **Inventario Planchones** GEGO

PesoPlanchon — Perma

Estatus	Lugar	Tipo	<1 mes	1 - 2 meses	2 - 3 meses	3 - 6 meses	>6 meses	Grand Total
Asignado	**ACERIA**	AsignacionDura	18	9	0	191	139	357
		Estandar	4603	1515	438	474	21	7051
		CorteLongitunidal	76	0	0	0	0	76
		Extra-Refilado	392	230	43	228	0	893
		FormacionColada	63	80	39	62	0	244
		LongFueraPauta	0	0	0	67	0	67
	ACERIA Total		**5152**	**1834**	**520**	**1022**	**160**	**8688**
	LSCC	AsignacionDura	533	113	82	805	376	1909
		Programado	5741	680	58	97	13	6589
		Estandar	18879	1173	326	336	64	20778
		CorteLongitunidal	245	0	38	0	0	283
		Extra-Refilado	523	12	15	69	0	619
		FormacionColada	224	72	59	63	51	469
		LongFueraPauta	0	0	0	21	0	21
	LSCC Total		**26145**	**2050**	**578**	**1391**	**504**	**30668**
	Plataforma	Estandar	1778	0	0	0	0	1778
		FormacionColada	0	8	0	0	0	8
	Plataforma Total		**1778**	**8**	**0**	**0**	**0**	**1786**
Asignado Total			**33075**	**3892**	**1098**	**2413**	**664**	**41142**
Retenido	**ACERIA**	ParaLaminar	3239	1773	397	435	0	5844
	ACERIA Total		**3239**	**1773**	**397**	**435**	**0**	**5844**
	LSCC	ParaLaminar	462	158	118	254	253	1245
	LSCC Total		**462**	**158**	**118**	**254**	**253**	**1245**
Retenido Total			**3701**	**1931**	**515**	**689**	**253**	**7089**
EnfriamientoACamara	**ACERIA**	Asignado	11306	784	21	38	124	12273
		SinAplicacion	1468	226	0	0	0	1694
	ACERIA Total		**12774**	**1010**	**21**	**38**	**124**	**13967**
EnfriamientoACamara Total			**12774**	**1010**	**21**	**38**	**124**	**13967**
EnfriamientoAlAire	**ACERIA**	AsignacionDura	0	36	0	0	0	36
		Asignado	6548	0	0	0	0	6548
		SinAplicacion	348	0	0	0	0	348
	ACERIA Total		**6896**	**36**	**0**	**0**	**0**	**6932**
EnfriamientoAlAire Total			**6896**	**36**	**0**	**0**	**0**	**6932**
SinAplicacion	**ACERIA**	Rota1:2meses	281	143	60	13	0	497
		Rota1:3meses	671	604	144	0	0	1419
		Mas1:3meses	738	540	237	74	0	1589
		RollChance	0	0	100	528	50	678
		EmpalmeNoAfin	146	200	116	14	0	476
		AnchoFueraPauta	25	0	0	0	0	25
		LongFueraPauta	44	73	70	0	0	187
		NoRequerido	578	490	234	0	0	1302
	ACERIA Total		**2483**	**2050**	**961**	**629**	**50**	**6173**
	LSCC	Rota1:2meses	1347	479	163	0	0	1989
		Rota1:3meses	1228	1450	345	0	0	3023
		Mas1:3meses	2046	1615	310	353	50	4374
		RollChance	0	0	256	1089	325	1670
		EmpalmeNoAfin	0	52	0	0	0	52
		LongFueraPauta	39	130	100	0	0	269
		NoRequerido	225	578	128	30	0	961
	LSCC Total		**4885**	**4304**	**1302**	**1472**	**375**	**12338**
	Plataforma	Rota1:3meses	51	0	0	0	0	51
		RollChance	0	0	0	0	12	12
	Plataforma Total		**51**	**0**	**0**	**0**	**12**	**63**
SinAplicacion Total			**7419**	**6354**	**2263**	**2101**	**437**	**18574**

Figure 2. Query report of the assignments made by ProductMatch.

After the implementation the old unused slabs inventory has been reduced on 70%, this because ProductMatch configuration considers three different phases of rules to assign slab to orders, see Figure 3, where the output of one is the input of the next one, and the complexity of the rules goes from phase one to phase three.

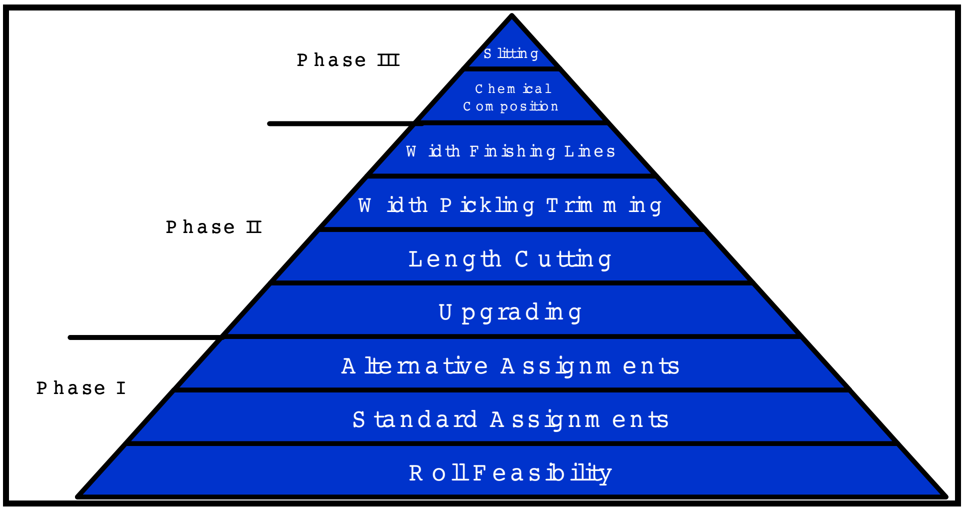


Figure 3. ProductMatch rules phase's configuration.

The slab inventory available to roll by the HSM increased from around 15 thousand tons to around 40 thousand tons.

HSM scheduling results validation

To validate the quality of the scheduling results has been a difficult task; this because the huge number of parameters and constraints to study, but also a query report helped us to study them.

The scheduled coffins are up to 11% longer than before the implementation of BetaPlanner ST, the report that help us evaluated the coffin length is shown in Figure 4.

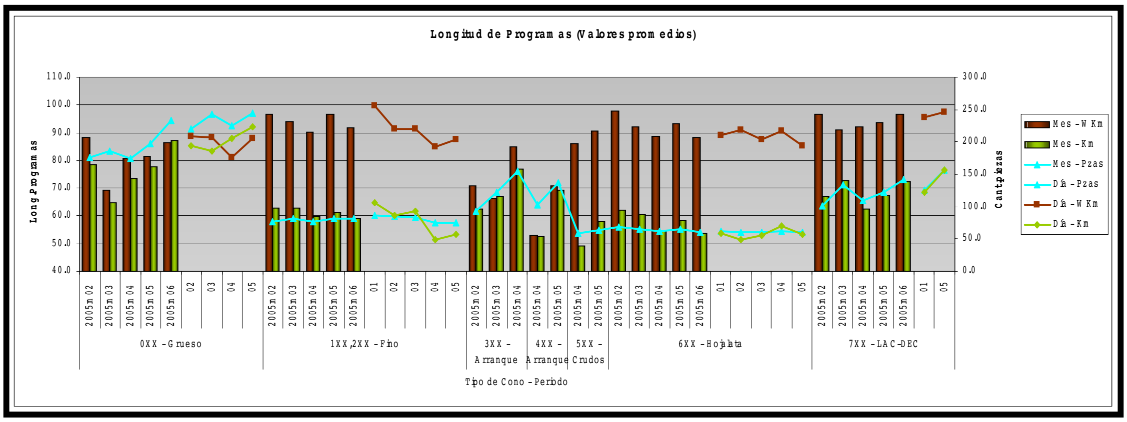


Figure 4. Query report of the coffin length.

The consistency of the scheduled coffins is better; this because BetaPlanner incorporates mathematical models, evaluates different alternatives and includes complex optimization algorithms to schedule the production of the facility.

To solve the furnace transit time overlapping, which is the HSM operating variable that production scheduling has more effect on, the 'window jump function' on the attribute transit time was developed, and implemented. A procedure was follow to evaluate the results; we change the multiplier of the function to study the furnace overlapping in the coffins:

First the multiplier was set to '0', and BetaPlanner calculated a penalty of 0 points and the overlapping of the coffin was 12%, see Figure 5A (next page). Then we change the value of the multiplier to '1', and the penalty given was 4500 points, and a 9% of overlapping (Figure 5B). At last we change the multiplier to '2' and the penalty calculated was 640 points, an overlapping of 4.5% was the result, Figure 5C.

A query report was also developed to follow the overlapping of the scheduled coffins, and the slab's overlapping in the HSM furnace has been decreased up to 4.2%, see Figure 6.

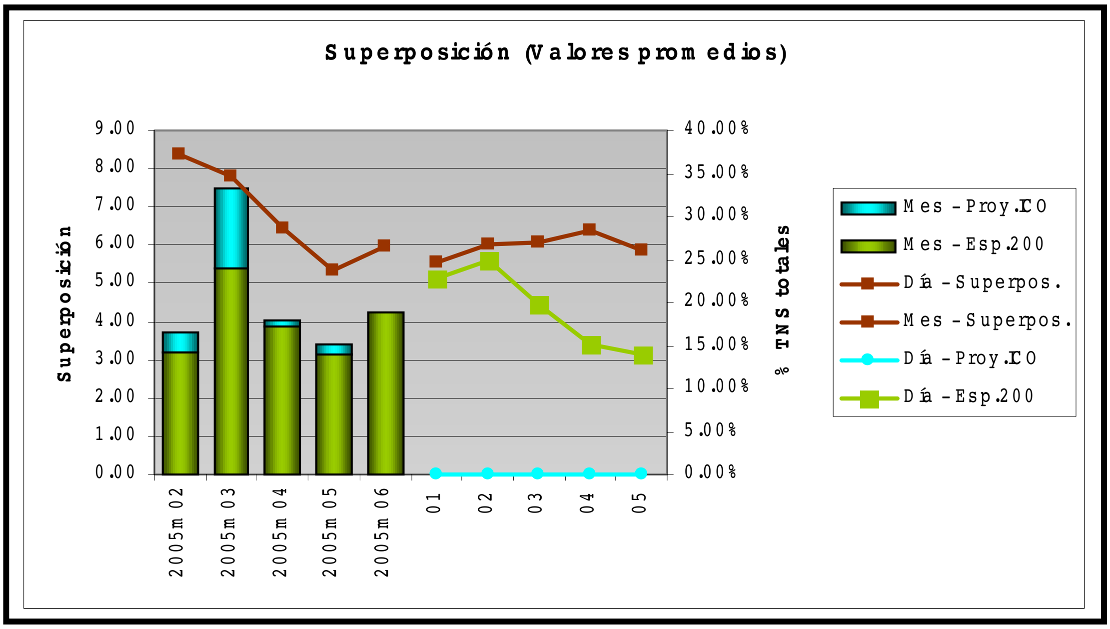
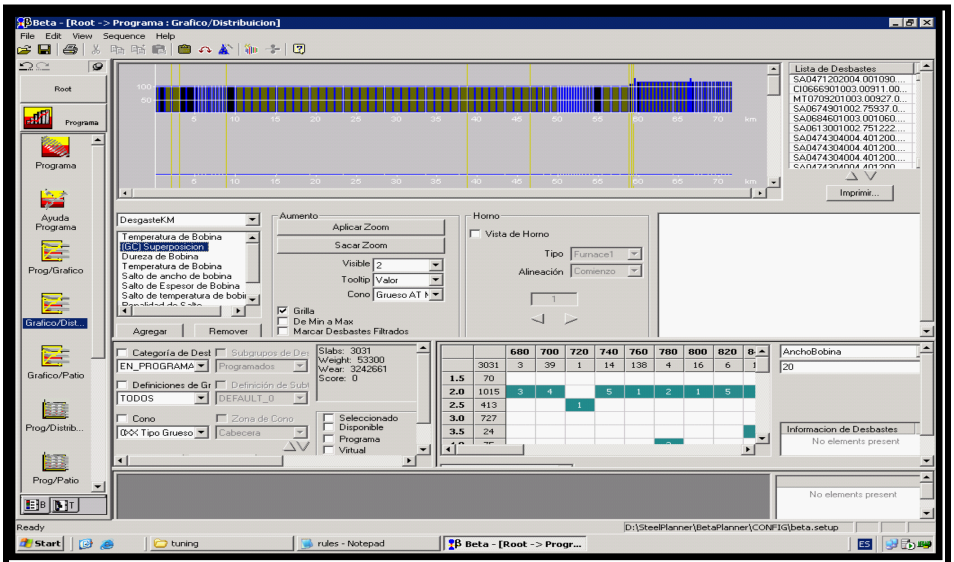


Figure 5. Query report of furnace transit time overlapping.

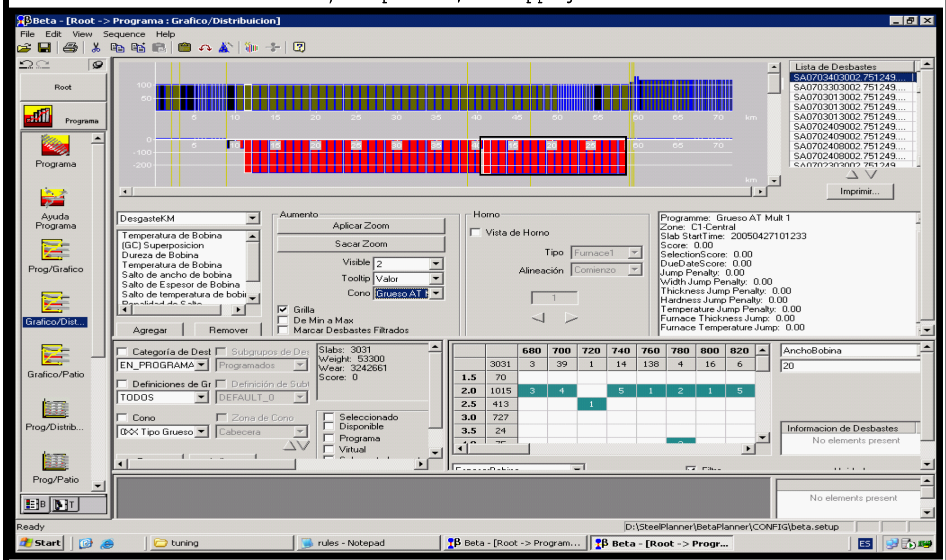
Response time

The average response time of the assignment process depends on the number of feasible matches found; right now it takes around ten (10) minutes to run all three phases optimized.

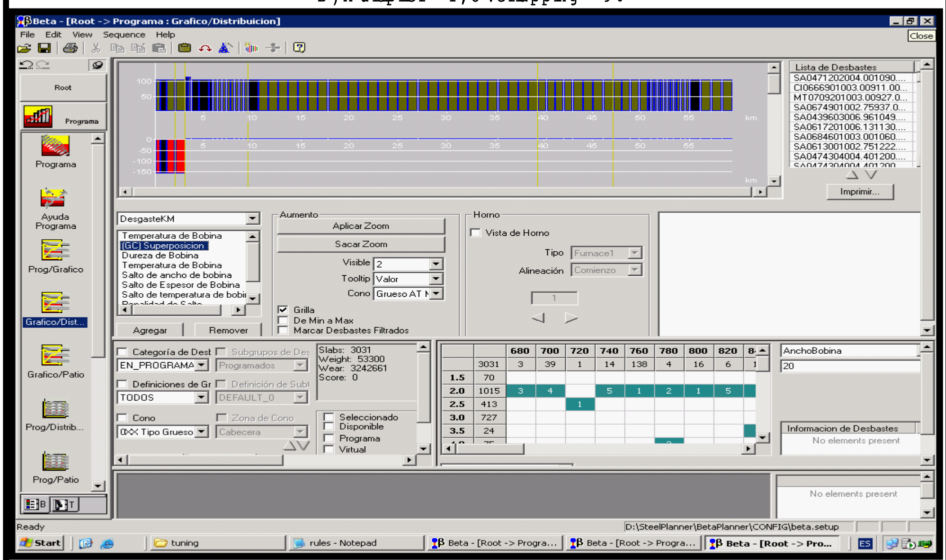
Before BetaPlanner ST implementation, to make a coffin took three (3) hours long, now BetaPlanner schedules four (4) coffins in fifteen (15) minutes, even that the coffins are the optimal that BetaPlanner found, the programmer spends around an hour making some adjustments to them, so in total it will take around an hour and a half (1½) hours to schedule four (4) coffins.



A) Multiplier = 0; Overlapping = 12%



B) Multiplier = 1; Overlapping = 9%



C) Multiplier = 2; Overlapping = 4.5%

Figure 6. Furnace transit time ‘Overlapping’ evaluation.

CONCLUSIONS

The implementation of the integrated solution will allow the production schedules to consider the whole plant situation, so they will become more realistic and improve the performance of the lines. It also allows the availability to schedule the slab's handling and transference between facilities.

By implementing BetaPlanner, the schedules became longer and more consistent (better quality), and now we have the flexibility to analyze the impact that changes on the scheduling rules will do. It response time allows the planner and schedules to work more proactively.

The assignments improvement minimizes the slab stock inventory, and improves the production orders fulfillment and due date accomplishment. It also gives a better quality slabs inventory to be rolled by the HSM.

The solution does cover and solve the problem that Sidor proposed, but it will need to integrate the downstream lines (cold lines) being the second phase of the project.

INTEGRAÇÃO E OTIMIZAÇÃO DA PROGRAMAÇÃO DAS ACIARIAS E DO LAMINADOR DE TIRAS A QUENTE NA SIDOR, UMA SOLUÇÃO 'STEELPLANNER' NA SIDOR

Orlando Ostos-Roa
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Pierre Beghin

Resumo

Sidor C.A. decidiu investir em novas implementações de software de suporte a decisão em áreas de planejamento da produção e logística da cadeia de suprimentos, com o objetivo de reduzir custos. O objetivo deste documento é descrever a implementação de um sistema integrado de planejamento da produção visando a otimizar a programação das aciarias (três máquinas de colada contínua), um laminador de tiras a quente, e seus pátios de placas, usando os módulos SteelPlanner, em cooperação com A.I.Systems.

Palavras-chave: Planejamento de produção; Programação da produção; Alocação de placas; Otimização.