PREPARE A TANDEM MILL FOR FUTURE EVOLUTIONS EXAMPLE AT SIDERAR (ARGENTINA)[1]

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Abstract

The steel market is everyday more demanding in terms of final product quality and production costs. In the last five years, Siderar has worked at improving its two tandem cold mills of Ensenada and San Nicolas, focusing on decreasing out of gauge strip portions and overall rolling time. These two mills being already equipped with rather modern AGC and Drive systems, Siderar investigated the possibility of improving its own models based presetting system. In 1998 Siderar decided to install VAI's CORUM™ Model in the Ensenada plant. Based on the excellent results obtained, this same model was purchased in 2003 for the San Nicolas plant. The VAI's CORUM™ model is a self adaptive physical model, including a versatile strategy module that allows processing all types of products, from Sheet to Ultra Tin Plate. Its neural network module manages complex phenomenon such as friction variation in the roll bite. The most spectacular improvements brought by the VAI's CORUM™ model are: decrease of out of tolerance lengths, thanks to a very accurate force prediction on each stand; minimum threading time, thanks to dedicated threading presets adapted to each product's specifics. Moreover, the mill operation was improved by reducing the rolling incidents such as strip break, and by allowing a much more flexible scheduling. Indeed the format changes are very well handled by a physical model and the repeatability of model calculated presets lead to a production stability that benefits both the producer and the end customer.

Key words: Cold rolling mill; Physical model; Throughput and yield improvement.

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1 INTRODUCTION

In 1996, VAI Clecim was awarded a contract by SIDERAR for the supply of the quality package for their plant of San Nicolas.
In 1997, a second contract was signed for the supply of positive work roll bending blocks and automatic work roll change on all the stands for both San Nicolas and Ensenada plants.
In 1998, a third contract was signed for the supply of the VAI CORUM™ mill preset mathematical model for Ensenada plant.
When, in 2002, it has been decided to modernize the models based presetting system in San Nicolas plant, SIDERAR chose to grant once again its confidence to CORUM™ and VAI CLECIM.
As it will be detailed in the remaining part of this article, the power of the VAI CORUM™ model lies in the way it manages to model the cold rolling process. Based on the fundamental equations of Bland and Ford, bettered by a treatment of the strip elastic compression taking account of the strip tensions, the force model is completed by a large number of modules. These ones permit CORUM™ to model with efficiency and accuracy the roll stack deformation, the thermal and flatness phenomena, and finally to optimize the overall set of rolling parameters in order to produce the best possible schedule.

Despites the large product mix of the two plants, the use of the VAI CORUM™ model enabled to roll, with 4-stands mills, products in the following categories:

Definition of the strategies used in SIDERAR using exit thickness range [mm]	
Sheet (S)	2.5 to 0.6
Tin Plate (TP)	0.6 to 0.4
Ultra Tin Plate (UTP)	0.4 to 0.18

One of the motivations of SIDERAR was to use the VAI CORUM™ model optimal schedules in order to roll difficult products such as the UTP products [entry thickness: 1.8mm, exit thickness: 0.18mm], on their 4-stands mill at San Nicolas.

The last part of this article will describe the commissioning periods and the gains obtained for both Ensenada and San Nicolas plants when using the VAI CORUM™ model.

Fig 1: SIDERAR's locations in Argentina

2 THE TWO MILLS CHARACTERISTICS

TANDEM ENSENADA
66" / 1676 mm
22.000 HP / 16.412 KW

STRIP
Low carbon steel
thick 1.80 / 5.00 mm
width 600 / 1600 mm
internal coil diam 610 mm
external coil diam 1950 mm

COIL
thickness 0.18 / 3.05 mm
weight max 25 T
internal coil diam 506 / 610 mm
external coil diam 1828 / 1920 mm

DAVY UNITED 1969	Units	Uncoiler	Stand 1 4 X 1000	Stand 2 4 X 1500	Stand 3 4 X 1500	Stand 4 4 X 1500	Coiler 3 X 750
Nominal Power	HP / KW	400 / 298	4000 / 2984	6000 / 4476	6000 / 4476	6000 / 4476	2250 / 1679
Max Power	KW		2944	4900	4820	4510	
Overload Capacity	%		125	125	125	125	
Max Total Roll Force	T		2000	2000	2000	2000	
Base Roll Torque	kN m		285	287	204	176	
WR min/max diameter	Mm		520/535	530/545	540/555	550/575	
Max Roll Speed	mpm		504	742	1055	1262	
Max Side Bending Crown In	KN		82	82	82	82	
Max Side Bending Crown Out	KN		66	66	66	66	

Fig 2: Tandem characteristics SIDERAR Ensenada, Argentina

TANDEM SAN NICOLÁS
64" / 1625 mm
14.500 HP / 10.817 KW

STRIP
Low carbon steel
thick 1.80/4.00 mm
width 620/1540 mm

COIL
thickness 0.18/2.03 mm
weight max 20.43 T
internal coil diam 558.8 mm
external coil diam 1828.8 mm

UNITED 1963 Rev.:BLISS - GE / 1972	Units	Uncoiler 2 x 150 HP	stand 1	stand 2 2 x 2000 HP	stand 3 2 x 2000 HP	stand 4 2 x 2000 HP	Coiler 2 x 500 HP
Nominal Power	HP / KW	300 / 224	1250 / 933	4000 / 2984	4000 / 2984	4000 / 2984	1000 / 746
Overload	%		1,25	1,25	1,25	1,25	
Total Power	KW		933	3580	3580	3580	
max Roll Force	T		1500	1500	1500	1500	
WR min/max diameter	mm		495/519	509/529	519/539	529/548	
max Roll Speed	mpm		440	598	847	999	
Bending Crown In	T		144	144	144	144	
Bending Crown Out	T		-120	-120	-120	-120	

Fig 3: Tandem characteristics SIDERAR San Nicolas, Argentina

3 VAI CORUM™ PRESETTING MODEL

The VAI CORUM™ presetting model designed for cold rolling mills computes optimum rolling schedules as well as associated control parameters. It ensures the optimization of the mill set-up for achieving the desired product quality and the optimum utilization of the mill facilities.
Besides being an up-to-date software based on advanced controls, the VAI CORUM™ model encompasses the latest concepts and theories:

- Neural network
- Optimal Rolling Schedule by cost minimization
- Optimization for Thread In
- Tension control optimization

The automation system is also designed to have a close interaction between the Level 2 process optimization and the Level 1 TCS (Technological Control System) by providing:

- Regulation gains to the TCS
- Anticipated TCS corrections
- Corrected schedule after a few seconds of high speed rolling

The VAI CORUM™ model basis is a physical modeling of the rolling process consisting of modular on-line sub-models such as:

- Force and power
- Material hardness (yield stress)
- Friction between work roll and strip
- Strip temperature
- Mill stretch
- Flatness
- Roll gap profile

Advanced adaptations are also used in order to improve the model efficiency, but do not replace the fundamental models.

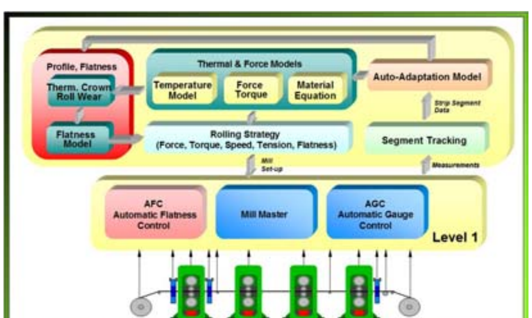

Fig 4: CORUM™ Model Modules and Configuration

Compared to statistical model, the VAI CORUM™ physical models lead to:

- higher accuracy in the prediction,
- less information to be maintained by the operator,
- faster commissioning startup
- and easier product mix extension

The optimization strategy is based on the objective function minimization concept. All the rolling constraints and the objectives are expressed into individual costs.

Example of constraint: rolling force has to stay within the minimum and maximum allowed range. The range is given by the flatness model as well as the stand limits.

Example of possible objectives:

- Balanced power on all the stands
- Minimum rolling time

The quality of the solution is translated into a criterion which is minimal when parameter equals the wished value. On the other hand, the criterion increases when the parameter approaches its limit. The optimization strategy consists of minimizing the total cost, which leads to the best compromise between all the criteria.

The optimization algorithm typically considers constraints and objectives which cover all the quality and productivity issues.

Compared to classical algorithm, the advantages of this solution are:

- In any case, the minimization algorithm leads to the best possible schedule.
- The behavior is continuous, and the solution is unique.
- In classical algorithms, constraints are logical. Here, when a parameter approaches a limit, the cost becomes so high that the minimization algorithm naturally stays away from the limit (security margin).
- The algorithm is easily extensible and maintainable. New constraints or new objectives can be easily added by the customer.

The accurate flatness set-up is achieved with the 3D finite elements roll stack deflection model which calculates the roll force distribution in the roll gap given the actuators set-up.

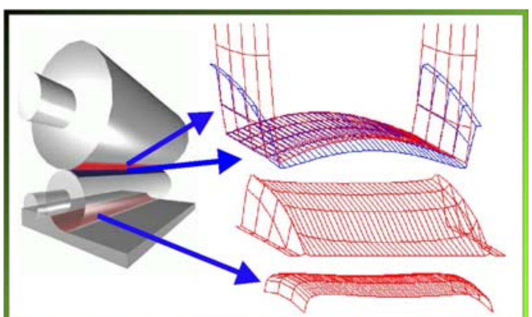

Fig 5: 3D Finite Elements Roll Stack Deformation Model

The self-learning algorithm uses the data feedback from the sensors to correct certain parameters of the physical models.

Two types of adaptations exist in CORUM™ model: the so-called filtering adaptations and the ones using Artificial Neural Network (ANN).

The first category using a learning rate is typically exploited to model trouble-free processes such as stretch and profile.

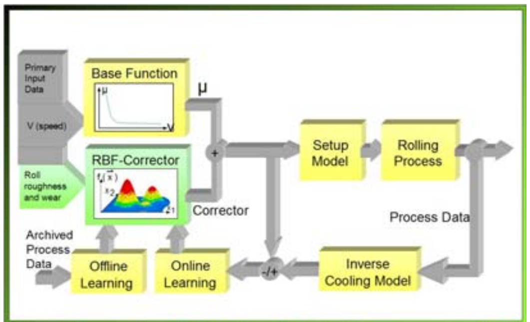

Fig 6: Example of Friction Adaptation Using Neural Network

On the contrary, an ANN allows the VAI CORUM™ model to learn complex processes where numerous possible explicative variables and non-linear dependencies may exist. This kind of adaptation is used to improve the friction coefficient modeling.

Compared to classical adaptations, the use of ANN enables not only to increase the prediction accuracy, but also to learn the process in the region where the adaptation is done and to model complex phenomena where the physical laws are limited.

4 STEEL CLASSIFICATION: SUCCESS STORY KEY FACTOR

One of the major steps explaining the great success story and the extensive use of the CORUM™ model was SIDERAR people ability to group and classify their products into categories. The difficulty of this exercise comes from the fact that no versatile classification exists. Several criteria exist, but finding the good one suiting the whole set of products is the challenge that has been took up.

The original steel classification was based on classes regarding the final use (ship steel, pipe steel …) and not the chemical composition. However, such a classification leads to some inconsistencies. For instance, it was noticed that coils of the same steel class, width and thickness behaved as if they had different hardness.

Based on these considerations, the chemical composition was introduced and a new classification based on steel grades appeared during the year 2003. During this period, the classification based on steel grade significantly improved the head and length performances.

Although the system efficiency increased due to the new classification, some performance variations were observed in some non special steel grades designed for standard use. It has been decided to study this phenomenon and found that all these non special steel grades could be isolated using a new indicator: the equivalent carbon index ($Ceqv = C + Mn/6 + Si/4$). All of these grades had a Ceqv index close to 0.030. A new classification taking account of the steel hardness and based on the Ceqv index has been therefore implemented.

In June 2003, VAI Clecim returned to site for one week technical assistance in order to verify and help to adjust the new steel classification.

Fig 7: 4-Stands Cold Tandem Mill
SIDERAR San Nicolas , Argentina

5 COMMISSIONING AND GAINS OBTAINED

The following figures compare the CORUM™ mode with the two manual mode encountered in each plant. The manual modes are explained hereafter.
In **Ensenada - manual mode**, the operators use a Bland & Ford model based on steel classes and calculated stand stretch curves.
The outputs are:

- Roll speeds (calculated with fixed slip)
- Inter-stand tensions
- Screw positions.

After all these references are downloaded automatically, the operator can make manual adjustment on screws and speed by means of verniers. For long series without thickness and grade changes, the operator can ask the AGC to maintain the presets for the incoming coils.
In **San Nicolas – manual mode**, operators use a statistical model ruled by an expert system. They take steel grades as well as calculated stand stretch curves into account. The outputs are similar to the ones of the Ensenada manual mode.
The head length is the length for which the thickness is out of the tolerances on the strip head. (Thickness tolerances used in this study are in all cases the customer tolerances. However, they are close to the USA norm ½ A.S.T.M.).
CORUM™ provides the AGC with a set of presets for thread and for run. The use of these values by the existing AGC leads to reduce the head length.
The following graphs compare the head length value of the coil ran with CORUM™ presets versus manual mode for coils first of series (first coil on a thickness change). On the x-axis are the different classes for the head length, on the y-axis the number of coils for each class and the cumulated frequency.

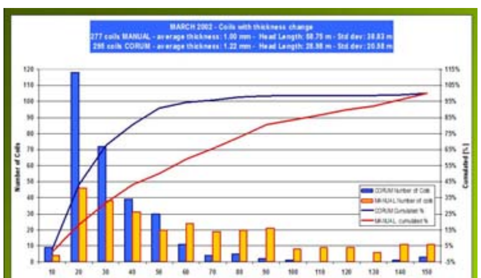

Fig 8: Head length classification and frequency in March 2002

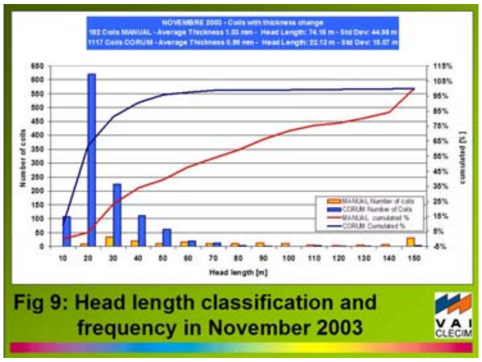

Fig 9: Head length classification and frequency in November 2003

Figure 8 shows values of March 2002 (just after the formal commissioning). Figure 9 shows values of November 2003 after the one week technical assistance of July and some studies done by SIDERAR. These two figures show the impact of the new classification and the corresponding model improvements carried out on the head length classification.

Comparison was also done between the manual mode (Oct 01/Sept 02) and CORUM™ mode (Nov 03) for comparable products.

CORUM™ impact on head length				
	First coil with exit thickness change		**Total coils**	
	Length	N	Length	**N**
Head & Length	**19.9**	**947**	**17.9**	3950
Decrease compared to manual	-38.6	[m]	-14.5	**[m]**
	-66.0	**[%]**	-44.8	**[%]**

The use of CORUM™ also introduced gains on the productivity in two ways. The first one is the decrease of threading time; the second one is the increase of run speed.

CORUM™ impact on threading time [s]				
	First coil with exit thickness change		**Total coils**	
	Time	N	Time	**N**
Threading time	**125.2**	**947**	**114.3**	3950
Decrease compared to manual	-57.7	[s]	-41.6	**[s]**
	-31.6	**[%]**	-26.7	**[%]**

CORUM™ impact on exit speed [m/min]				
	First coil with exit thickness change		**Total coils**	
	Speed	N	Speed	**N**
Average exit speed	**644.0**	**947**	**694.0**	3950
Increase compared to manual	+118.6	[m/min]	+66.7	**[m/min]**
	+22.6	**[%]**	+10.6	**[%]**

From the beginning, operators saw the advantages related to the CORUM™ model use, mainly in short series of heavy gauge. Meetings were carried out with each shift before and during the start up. Functions of the model and data that it takes into

account were explained. Over the weeks, the operators gained confidence in the model and now, when some preset deviation is noticed, it is thought of sensor error.
The same phenomenons appeared at San Nicolas plant. Thanks to the experience gained at Ensenada, the commissioning period for the San Nicolas project was reduced to 2 months including 1 month of shadowing. At the end of the project, CORUM™ presets were well accepted by the operators.
The next figures show the obtained gains in head length (comparison manual and CORUM™ modes).

CORUM™ impact on head length - April/May 2005 SHEET strategy			
	Manual mode	CORUM mode	Decrease compared to manual
Average [m]	**47**	**29**	**-38%**
Std Deviation	21	19	
Number of coils	289	823	

CORUM™ impact on head length - April/May 2005 TIN PLATE strategy			
	Manual mode	CORUM mode	Decrease compared to manual
Average [m]	**58**	**31**	**-46%**
Std Deviation	35	21	
Number of coils	94	148	

CORUM™ impact on head length - April/May 2005 ULTRA TIN PLATE strategy			
	Manual mode	CORUM mode	Decrease compared to manual
Average [m]	**75**	**63**	**-16%**
Std Deviation	35	32	
Number of coils	623	857	

One should note that no production drop was related to CORUM™ model commissioning.

6 CONCLUSION

The use of VAI CORUM™ model in Ensenada and San Nicolas plants brought quality improvements (head length) and productivity increase (reduced threading time and higher run speed).
With subsequent training of the operators, CORUM™ was well accepted and is part of the normal mode of operation. By the implication of its employees, SIDERAR is able not only to maintain the model (including tuning of new grades) but also to achieve model customization.

PREPARANDO UM TREM LAMINADOR PARA EVOLUÇÕES FUTURAS
O EXEMPLO DA SIDERAR (ARGENTINA) [1]

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Resumo

O Mercado siderúrgico está cada vez mais exigente em termos de qualidade do produto final e custos de produção. Nos últimos cinco anos, a Siderar tem trabalhado para melhorar seus dois trens laminadores a frio de Ensenada e San Nicolas, tendo se concentrado na redução da espessura de tira e no tempo total de laminação. Como estes dois laminadores já estavam equipados com sistemas de acionamento e AGC bastante modernos, a Siderar analisou a possibilidade de aperfeiçoar seus próprios modelos tendo como base o sistema de pré-regulagem. Em 1998, a Siderar decidiu instalar o Modelo CORUM™ da VAI na usina de Ensenada. Tendo em vista os excelentes resultados alcançados, o mesmo modelo foi comprado em 2003 para a usina de San Nicolas. O Modelo CORUM™ da VAI é um modelo físico auto-adaptativo que inclui um versátil módulo de estratégia que permite o processamento de todos os tipos de produtos, desde chapas finas até chapas ultrafinas. Seu módulo de rede neural gerencia fenômenos complexos, tais como a variação de atrito na entrada dos cilindros. Os aperfeiçoamentos mais espetaculares introduzidos pelo modelo CORUM™ da VAI são: Redução dos comprimentos fora de tolerância graças à predição precisa das forças em cada cadeira de laminação; Tempo de encaixa mínimo graças às pré-ajustagens adaptados às especificações de cada produto; Além disso, a operação do laminador foi melhorada em função da redução dos incidentes de laminação, tais como rompimento da tira, e da programação muito mais flexível. De fato, as mudanças de formato são gerenciadas de forma extremamente eficiente por um modelo físico, sendo que a repetibilidade das pré-ajustagens calculadas pelo modelo resulta em uma estabilidade de produção que beneficia tanto o produtor como o cliente final.

Palavras-chave: Laminador a frio; Modelo físico; Melhoria de produção e de rendimento.

1 *42ª SEMINÁRIO SOBRE LAMINAÇÃO - Processos, Produtos Laminados e Produtos Revestidos – 25 a 28 de outubro de 2005, Santos– SP - Brasil*

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