THE MINIMILL FOR STAINLESS & SPECIAL STEEL LONG PRODUCTS AT BAOSTEEL SHANGHAI No. 5 P.R. OF CHINA - COMMISSIONING AND PERFORMANCE TEST RESULTS[1]

Francesco Toschi[2]

Abstract

This paper will show and analyze the results achieved in the rolling mill during the first stage of operations, which was the commissioning period from October 2003 to July 2004. The complexity of the plant and the different process routes available both in the meltshop and the rolling mill highlight how production planning and the knowledge of the whole team working towards the same target are fundamental to simplify and speed up the whole production process. The performance test schedule was drawn up by taking into account the required grades and market requirements. A detailed process data sheet for a particular grade and size was prepared and, after approval by the customer, the document was distributed to all the key people involved in the operations. All the data was stored in an on-line database to facilitate checking and updating. To complete the preparation activities an off-line simulation was done to verify critical temperature and inductor and/or waterbox set-up modifications.

Key words: Rolling Mill; Commissioning; Planning; Production process; On-line data base; Simulation.

A MINIMILL PARA PRODUTOS LONGOS, AÇOS ESPECIAIS E INOXIDÁVEIS, NA BAOSTEEL SHANGAI No 5 P.R. CHINA – RESULTADOS DO COMISSIONAMENTO E TESTES DE PERFORMANCE

Resumo

Esse trabalho irá mostrar e analisar os resultados atingidos na laminação durante o primeiro estágio de operações, cujo período de comissionamento foi de Outubro de 2003 a Julho de 2004. A complexidade da planta e as diferentes rotas de processos, ambos disponíveis na aciaria e no laminador destacam como o plano de produção e o conhecimento de todo o time trabalhando para o mesmo alvo, fundamental para simplificar e acelerar todo o processo produtivo. A tabela de testes de performance foi elaborada considerando os graus requeridos e as necessidades do mercado. Uma folha de dados do processo detalhado para um grau e tamanho particular foi preparada e, depois de aprovada pelo cliente, o documento foi distribuído para todas as pessoas chaves envolvidas nas operações. Todos os dados foram guardados em um banco de dados on-line para facilitar o conferimento e atualização. Para completar as atividades de preparação uma simulação "off-line" foi realizada para verificar temperatura critica e modificações no indutor e/ou caixa de água.

Palavras-chave: Laminação; Comissionamento; Planejamento; Produção; Banco de dados on-line; Simulação

1 *Technical contribution to 44th Rolling Seminar – Processes, Rolled and Coated Products, October 16 to 19, 2007, Campos do Jordão – SP, Brazil.*
2 *Danieli Morgårdshammar - Italy*

FOREWORD

At the beginning of 2002, the Baosteel Group contracted Danieli for the supply of a new special steel minimill to Shanghai No.5 Steel Co. Ltd to be installed in the province of Baoshan-Shanghai.

The new plant, successfully started up in Autumn 2003, has a 350,000-tpy design capacity and features all the latest Danieli technologies and "high-tech" equipment available in steelmaking, casting, rolling, on-line processing and heat treatment of specialty and stainless steel bars, wire rod and bar-in-coils.

Fig1. Panoramic view of Shanghai No.5

The new minimill is made up of an electric steel meltshop with 60-t EAF, LF, twin-tank VOD station, AOD converter, alloy addition system, 3-strand conticaster plus auxiliary services including fume treatment plant and automation system. The CCM is directly connected to the Rolling Mill RHF for hot charging. The range of steels includes austenitic, ferritic and martensitic stainless, valve, bearing, engineering, free cutting grades and other specialty steels in 160x160 mm billets produced at the new meltshop and subsequently hot rolled in the new bar & rod mill.

The 18-stand rolling mill also includes a 4-pass KOCKS/Danieli 3-roll RSB Reducing & Sizing Block. The mill includes production, finishing and on-line heat-treatment facilities for straight bars, wire rod and bar-in-coils. To this end, slow/natural cooling for straight bars, slow/natural/fast cooling for wire rod and bar-in-coil are provided. In-line annealing of stainless steel coils in a rotary-hearth furnace and direct water quenching of austenitic-steels are also provided.

Construction of the new plant went ahead according to a very tight project schedule. The commissioning stage started right on schedule on 31 October 2003, with the first hot-rolled bar successfully delivered onto the cooling bed and the first conticast billets produced in the meltshop. Project execution for this state-of-the-art plant took only 19 months, from order placement to start-up. Plant tuning and set-up were done in the following months until the performance test stage for the various technological areas and production outlets that make up the plant.

ROLLING MILL HIGHLIGHTS.

The rolling mill basically consists of the following technological areas:

Billet reheating area:

The reheating furnace, with a nominal capacity of 80 tph, is directly connected to the CCM for billet hot charging.

Rolling mill area:

A high pressure billet descaler is positioned at reheating furnace outlet. The 6-stand high speed roughing mill is located at a suitable distance from the first intermediate stand so that the bar is free between the roughing & intermediate mills, and the proper rolling speed can be selected at stand n°1 entry side. 12 SHS housingless stands arranged in H/V configuration with quick changing facilities make up the intermediate and prefinishing mill. An induction furnace made up of two converters for a total power of 2400 kW is provided at stand #7 entry side, in order to ensure the correct rolling temperature and perfect temperature uniformity throughout the rolled stock cross-section and length, before entering the intermediate mill. The DSC waterbox system is provided to control the temperature of the bars being fed into the KOCKS for the low temperature process, the cooling bed discharging temperature and the coiling temperature.

A KOCKS-Danieli RSB 3-roll Reducing & Sizing Block is used as a finishing mill for all the products. With the automatic quick changing facilities and based on a wide “Free size rolling “ capability, the 4-pass RSB acts as finishing mill for straight bar & bar-in-coil production and as prefinisher for the subsequent wire rod production outlet.

Straight bar production outlet:

A rake-type cooling bed with feeding and delivery services allows uniform final bar cooling. Step-by-step and continuous running allow the bar to reach the correct temperature in the cutting-to-length station. For this purpose a cold shear and two abrasive disk saws are provided for bar cutting depending on the steel grade and the requirements of the final customer. The bar finishing facilities are equipped with automatic counting and bundling as well as slow cooling boxes for martensitic stainless steel bars.

Wire rod & bar-in-coil production outlets:

The latest generation of high-speed laying head was selected based on the range and grade to be coiled and particularly the strict requirements on surface defects that need to be fulfilled.

The roller conveyor for final cooling is equipped with a water spray system, fast and slow cooling facilities and two reforming pits to be used depending on the steel grade and process route required. Pit 1 is located immediately after the laying head, for stainless steel coil formation and delivery directly to the rotary type furnace. Pit 2 is located at the end of the roller conveyor for steel grades treated on the roller conveyor.

Two Garret coilers and associated walking beam coil conveyor with fast & slow cooling facilities are provided for the production of big bar in coil. A swiveling elevator feeds hot coil to the rotary type furnace. This device is the same as the one used for wire rod coils coming from Pit number 1. An overhead C-Hook conveyor with compacting/tying facilities is used for both wire rod & bar in coil production outlets.

In-line heat treatment facilities:

The 21-m-dia rotary type furnace for in-line annealing and solution heat-treatment of wire rod coils and bar in coils is positioned at coil outlet side for quick charging. In the furnace a wide range of steel grades are heat-treated, with the possibility of off-line heat treatments during bar production. At the furnace exit side there is a multi step water tank for fast quenching of austenitic stainless grades. On the roller conveyor, downstream the laying head, a water spray system for direct solution heat-treatment of stainless steel grades is positioned. The system is made up of two modules for uniform water distribution, taking into account the differences in mass on the roller conveyor.

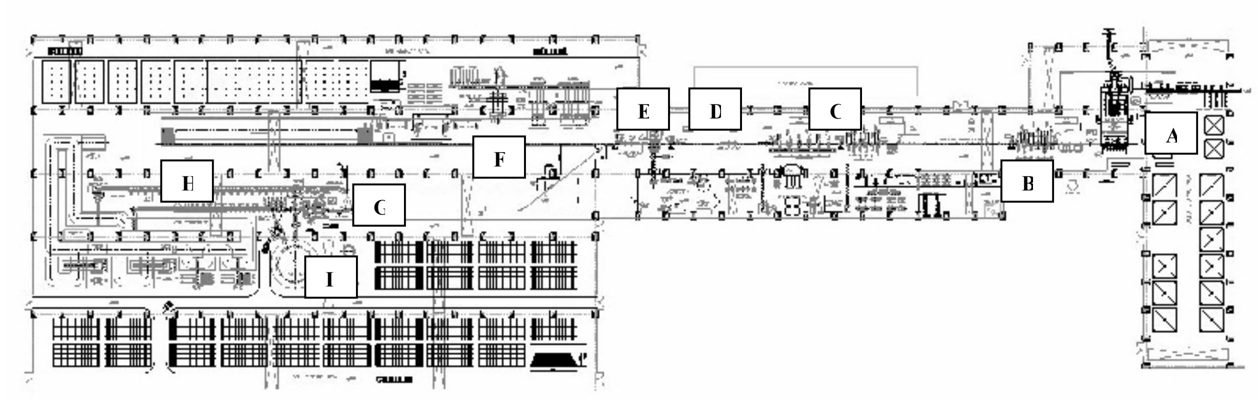
As already mentioned, the DSC system maintains the correct rolling temperature in the rolling mill’s critical points. The following in line heat treatments are possible:

- Low temperature rolling (by DSC system)
- Slow cooling of straight bars (by slow cooling boxes after cut to length station)
- Solution heat-treatment for coils (by rotary furnace and water quenching tank)
- Recrystallization annealing for coils (by rotary furnace)
- Isothermal annealing for coils (by rotary furnace)

- Solution heat-treatment for wire rod with fine grain structure (by water spray on the roller conveyor)
- Slow cooling for wire rod (by heat-retaining hoods on roller conveyor)
- Fast cooling for wire rod patenting (by fans on the roller conveyor)

GENERAL LAYOUT AND TECHNOLOGICAL AREA

The rolling mill layout is shown in Fig 2 together with the most important technological areas:



A: reheating furnace; B: roughing mill; C: intermediate/prefinishing mill; D: DSC waterbox system E: KOCKS/Danieli RSB finishing block; F: slow cooling boxes; G: bar in coil/wire rod area; H: wire rod roller conveyor; I: rotary furnace.

Fig. 2. Layout and technological area of the mill.

STEEL GRADE AND PRODUCTS

For the entire production the starting material is CCM square 160-mm billets in 10-meter lengths or square 120-mm blooming billets in 10-m lengths. The dimensioning grades and sizes are given in table 1 while the final delivery condition of the products is given in table 2.

Table 1

Steel Group	Typical grade	Straight bar	Bar-in-coil	Wire-rod
Austenitic stainless steel	AISI 304	X	X	X
Sulphide austenitic stainless steel	AISI 303	-	-	X
Austenitic valve stainless steel	21-4N	X	-	X
Martensitic stainless steel	AISI 420	X	-	X
Martensitic valve stainless steel	HNV3	X	-	X
Ferritic stainless steel	AISI 430	X	-	X
Hardening stainless steel	17-4 PH	-	-	X
Bearing steel	AISI 52100	X	X	X
Spring steel	AISI 9260	X	X	X
Cold heading steel	AISI 1045	X	X	X
Low alloyed steel	AISI 4140	X	X	X
Carbon structural steel	AISI 1045	X	X	X
Free cutting steel	AISI 1211	X	X	X

Table 2

Production line	Max finishing speed	Product range	Product supply
	(m/s)	(mm)	
Straight bar	all grades: 16.0	Round: 15.0 – 50.0	Bundle length: 3.5 – 12.0 m Bundle weight: 1.5 – 4.0 t
Bar in coil	all grades: 12.5	Round: 18.0 – 40.0	Coil weight: max 1.9 t
Wire rod	specialty steel: 105 stainless steel: 80 valve steel: 80	Round: 5.0 – 20.0 Round: 5.0 – 20.0 Round: 5.0 – 14.0	Coil weight: max 1.9 t

Fig. 3. View of the rolling mill area

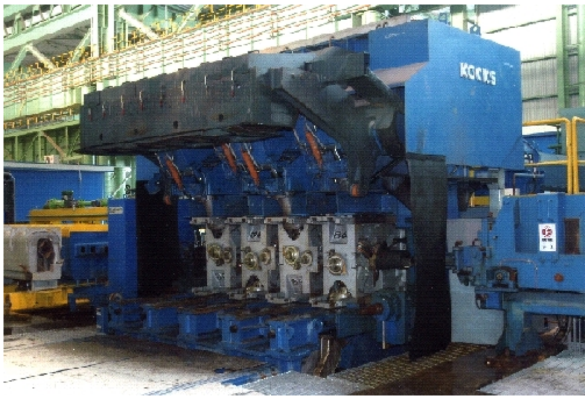


Fig. 4. View of the Kocks/Danieli RSB block

PRODUCTION ROUTES AND TECHNOLOGICAL HIGHLIGHTS OF THE PROCESS

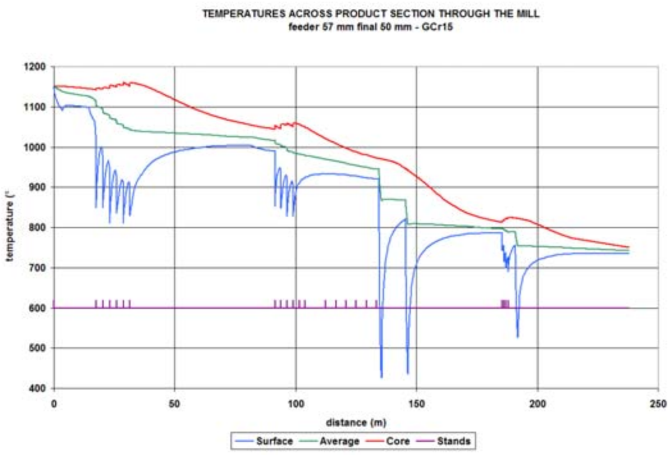
Straight bar production

Finishing rolling of all straight bars is done in the KOCKS/Danieli RSB Reducing & Sizing Block. The finishing rolling temperature is controlled by the waterboxes located upstream the RSB, whilst the proper bar temperature at cooling bed entry is selected and maintained by the water boxes located after the RSB. The whole system is PLC controlled and the temperature is regulated by field pyrometers. The temperature regulation system use 4 pyrometers for feedback and feedforward correction. Thanks to the accuracy of the induction furnace the temperature profile at stand #7 entry side is basically flat with a maximum deviation of 10°C along the billet.
Except for martensitic stainless grades, natural air cooling plus downstream off-line heat treatment are provided.
Martensitic grades enter the slow-cooling boxes after the cut-to-length station, at cooling bed delivery side. The slow cooling box system is made up of multiple boxes moving on rails and positioned on one side of the roller table before the layer forming station. A single box can receive 3.5 t. An overview of the installation is shown in Fig 5 and Fig 6.

Fig 5. Slow cooling box area overview

Fig 6. Details on bar discharging into one box

A typical temperature profile from off-line simulation trends across the product section for a 50-mm-dia GCr15-grade bar is shown in Fig 7. Beside the calculation graph is the relevant process parameter worksheet.



PPW43 01-02-2004 Rev 01
Rolling line: Bar line
Steel group: Bearing steel
Steel grade: GCr15
Process: Thermomechanical rolling
Size: 15 - 50 mm

Setup Reheating furnace
Heating 1: 980 - 1020 °C
Heating 2 : 1180 - 1200 °C
Soaking: 1150 - 1180 °C

Rolling mill temperature
Waterbox system: ON
Waterbox system ID: Setup1 - Setup2
Descaler: ON
Stand #1 entry temperature: 1100 °C
Inductor setup temperature: 970 - 990 °C
RSB entry temperature: 780 - 820 °C
Cooling bed temperature: 720 - 760 °C

Cooling bed
Cycle time: FAST
Slow cooling box: OFF
Cold shear temperature: > 450 °C

Fig 7. GCr15, 50-mm-dia bar. Temperature curve along the mill and process parameter worksheet

Bar-in-coil production

As in the case of straight bar production, all the finishing rolling for the coiled bars is performed at the RSB finishing block. The finishing rolling temperature is controlled by the waterboxes located upstream the RSB, whilst the coiling temperature is selected and controlled by the water boxes located after the RSB. The whole system is PLC controlled and the temperature is regulated by field pyrometers. The temperature regulation system uses 4 pyrometers for feedback and feedforward correction. Thanks to the accuracy of the induction furnace the temperature profile at stand#7 entry side is basically flat with a maximum deviation of 10°C along the billet. After coiling, formed coils can be delivered either directly to the walking beam conveyor or to the rotary furnace depending on steel grade and final requirements.
The following operations are possible on the walking beam conveyor:

- Slow-cooling under heat retaining hoods for cold-heading, carbon-structural and spring steels.

- Fast cooling by fans for bearing and free-cutting steels

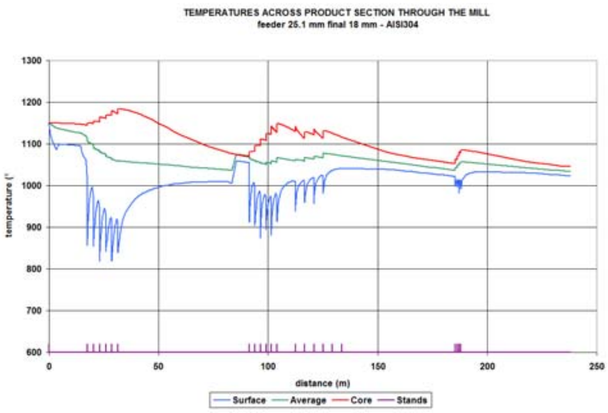
The rotary furnace is used for in-line heat treatment of austenitic stainless steel coils, which then undergo a solution heat-treatment by rapid cooling in a water tank at furnace exit side. Then they are loaded onto the walking beam conveyor and delivered to the coil finishing services.

Fig.8 shows the robot used to load the rolled coils into the rotary furnace, while Fig.9 shows the coils directly discharged onto the walking beam from the coilers.

Fig. 8. Rotary furnace robot for coil charging

Fig. 9. Coil directly charged onto walking beam conveyor

A typical temperature profile from off-line simulation trends across the product section for a 18-mm-dia, 304HC-grade coiled bar is shown in Fig 10. Beside the calculation graph is the corresponding process parameter worksheet.



<u>PPW3 26-03-2004 Rev 01</u>
Rolling line: Bar in coil
Steel group: Austenitic Stainless steel
Steel grade: AISI304 / AISI316 / AISI304HC
Process: Rotary furnace
Size: 18 - 40 mm

<u>Setup Reheating furnace</u>
Heating 1: 100 - 1020 °C
Heating 2 : 1180 - 1200 °C
Soaking: 1180 - 1230 °C

<u>Rolling mill temperature</u>
Waterbox system: OFF
Descaler: OFF
Stand #1 entry temperature: 1150 °C
Inductor setup temperature: 1030 - 1100 °C
RSB entry temperature: 1000 - 1050 °C
Cooling bed temperature: 980 - 1020 °C

<u>Walking beam setup</u>
Walking beam: DISABLED
Fans cooling: OFF
Insulating hoods: -

<u>Rotary hearth furnace setup</u>
Furnace setup ID: Setup 4
Heat treatment: Solubilization
Exit furnace quenching system: ON
Treatment time: 3600 sec
Furnace step time: 120 sec

Fig.10. 8304HC, 18-mm-dia bar. Temperature curve along the mill and process parameter worksheet.

The coiling pipe is equipped with lubricated rollers to avoid scratching during coiling operation of different layers. With this device it is possible to define the density of the coils depending on grade and descaling requirements. The results obtained for some sizes and grades are shown in Fig 11, where the coil specific height (per ton of coiled material) is shown.

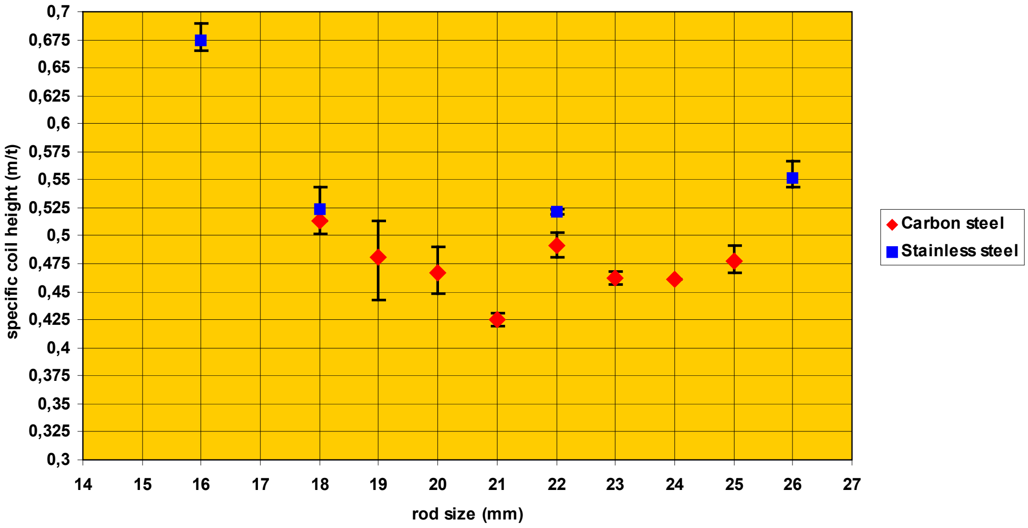


Fig 11- Coil specific height (per ton of coiled material)

Wire rod production

In this case, the RSB acts as prefinisher for the high-speed finishing block. The latest generation loop layer delivers wire rod loops onto the controlled cooling roller conveyor where several different treatments can be performed depending on requirements (see table 5).
To this end the roller conveyor is equipped with a set of specific devices, namely:

- Water-spray system in the first part, before Pit n°1 for austenitic and ferritic stainless grades
- Coil rotary reforming Pit n°1, located in the first part of the roller conveyor, after the loop layer, where hot coils are formed and then delivered to the rotary furnace. Pit n°1 is equipped with mobile sector for pit by-pass when not in operation.
- Set of heat retaining hoods and centrifugal fans for slow and fast cooling, respectively.
- Coil rotary reforming Pit n°2, located at the end of the roller conveyor, for normal coil forming.

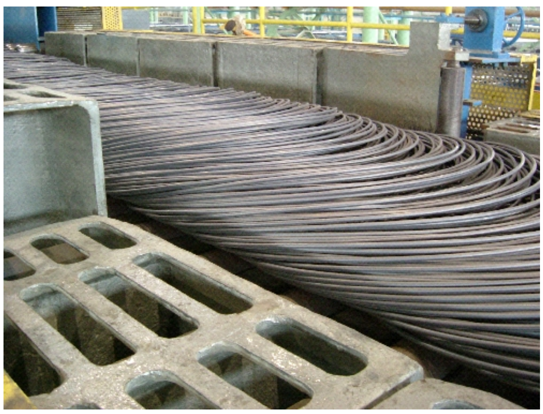


Fig 12. Laying head **at wire rod outlet.**

Fig 13. Compacted coil for slow cooling process.

<u>In line Rotary Furnace</u>

The reason for the installation of a rotary furnace was due to the need for a high-productivity plant for stainless steel, where all storage operations between production and delivery needed to be reduced as much as possible. Considering the size of the furnace it's clear as production lots smaller than the nominal capacity influence the productivity only if a drastic heat treatment cycle change, in terms of temperature profile, has to be done. The main process targets are a uniform structure and a grain size close to ASTM 5.

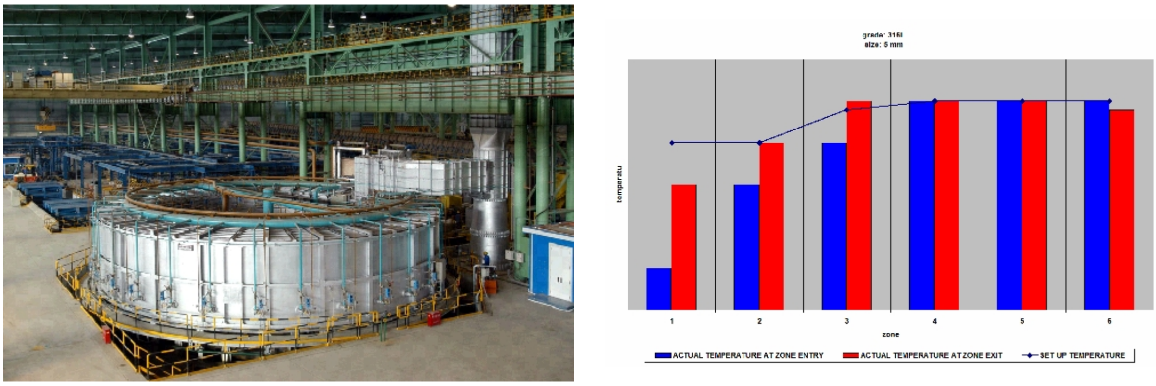


Fig 14. Rotary furnace overview and operating cycle for 316L, 5.0 mm.

<u>DSC waterbox system for stock temperature control</u>

As mentioned in the previous paragraphs the temperature control of the stock feeding the KOCKS finishing block, the cooling bed and the Garret coilers is done by the DSC system. The system is PLC controlled and uses proportional valves to set the proper flow/pressure according to the signals coming from the field pyrometers. The mechanical part consists of two 4 strands waterboxes before the RSB to avoid pipe changes during product changes and one waterbox after the RSB to control the cooling bed discharging temperature and the coiling temperature.

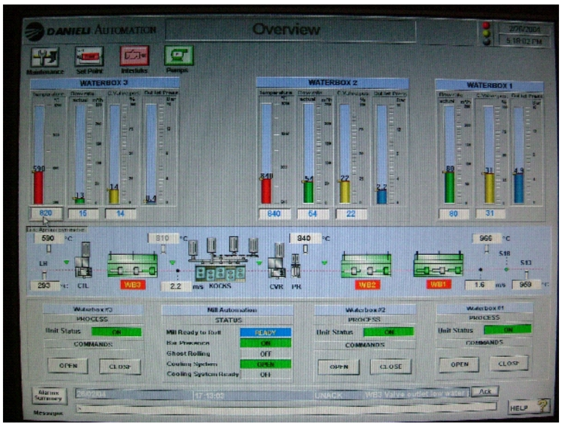


Fig 15. HMI overview page.

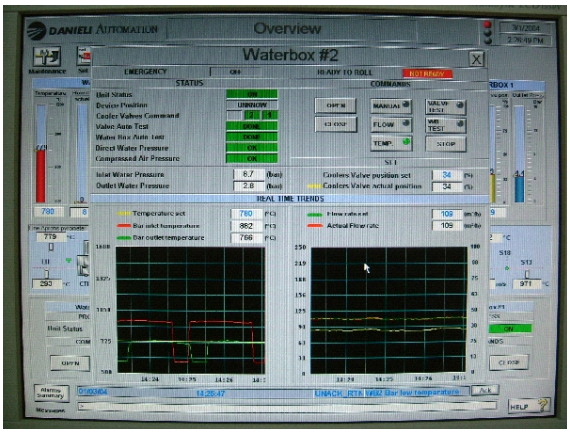


Fig 16. HMI waterbox page.

The HMI allows the main operations to be controlled from the pulpit and provides the possibility of storing the recipes for the various rolled products and grades. The overview page (Fig 15) illustrates the actual settings of the waterboxes such as pressure, flow rate, valve positioning, actual and set temperature, as well as the status of all the devices and alarms. All the pyrometer signals are displayed. The waterbox page (Fig 16) shows the detailed data of the waterbox and the trend values of pressure, flow rate, actual temperature. All these data are continuously recorded by the FDA and can be used as quality control parameters.
The temperature control system uses feedforward and feedback regulations to reach the set temperature. It is important to emphasize that for this specific application, thanks to the temperature equalization carried out in the induction furnace at stand 7 entry side, the billet temperature profile at waterbox #1 entry side was practically flat without any sign of black spots on the head/tail or reheating furnace beam.
In these conditions the KOCKS block can be fed with a deviation of ± 10°C from the set temperature.
The basic waterbox setup data are calculated and entered into the HMI by the operator. In the new DSC system the cooling nozzle is automatically opened/closed by the system, thereby avoiding any precalculations for the different sizes and products requiring different starting setups. The only information is reduced to process parameters such as rolling temperature and waterbox utilization.

RESULTS OBTAINED

During the commissioning and performance test period considerable work was done with the Shanghai #5 team to set up all the process routes required for current production, as well as for the future, considering delivery requirements for microstructure and mechanical properties.
The configuration of the mill and the wide range of in-line and off-line heat treatments available make it possible to test and compare the results obtained for the same grade following different process routes.
Also, considering that in the last period of commissioning the chemical descaling plant was in operation, it was possible to test different final heat treatments to improve performance during the descaling and coating processes.
This paragraph deals with the results on the grades and sizes given in table 3.

Table 3 - Tested grades and sizes summary

Product Identification (ID) Number	GRADE	SIZE(mm)	LINE	PROCESS	BILLET
1	316L	5.0	Wire rod	IFR	CCM SQ. 160
2	304HC	5.5	Wire rod	IFR	CCM SQ. 160
3	430	6.5	Wire rod	DWQ	CCM SQ. 160
4	21-4N	8.0	Wire rod	IFR	BL SQ. 120
5	HNV3	8.0	Wire rod	IFR	CCM SQ. 160
6	304HC	12	Wire rod	IFR	CCM SQ. 160
7	304HC	12	Wire rod	DWQ	CCM SQ. 160
8	304HC	18	Bar in coil	IFR	CCM SQ. 160
9	60Si2CrVAT	42	Straight bar line	LTR	CCM SQ. 160

Code index:
IFR: in line rotary furnace; **CC**: controlled cooling; **DWQ**: water spray cooling; **LTR**: low temperature rolling

The results obtained for different steel grades and product types are summarized in table 4.
Tests on products #1 to 8 are related to Stainless steel grades, while test on product #9 is
related to a Carbon special steel grade.

Considerations on the various tests executed and on the associated procedures.

>>> Product ID #1 - (316 grade)

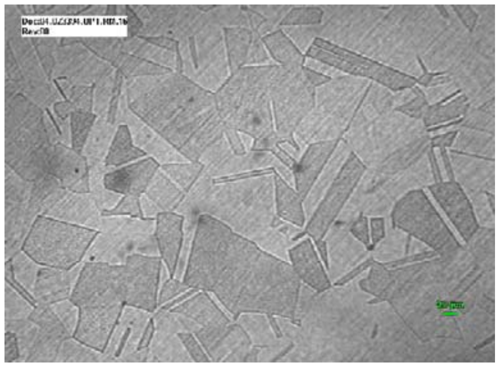


Fig 17. 316 grade

The results for this grade were basically related to the microstructure and mechanical properties in terms of grain uniformity and good formability. The rotary furnace allows heat treatment temperature control in 6 independent zones from the charging zone to the last zone before water quenching. Considering the time (60 minutes) and the maximum working temperature available (1180°C) it is obvious that the better structure can be obtained, considering the possibilities to lower the treatment temperature, maintaining a good final coil shape as well. The uniformity of the mechanical properties was tested to analyze rotary furnace performance also considering the different coil entry temperature in the bottom and upper parts. A standard deviation of 5 MPa on the coil shows how temperature distribution and temperature accuracy control inside the rotary furnace are fully satisfactory. Considering the surface quality for 316L the average defect depth was 0.030 mm during all the product campaigns.

>>> Product ID #2 - (304H grade)

The same observations made for product #1 can be repeated for product # 2. In addition, for this grade, it is interesting to compare a material that was heat treated in the rotary furnace and solution heat-treated in the tank at outlet side and the material that was directly solution heat-treated on the roller conveyor. For the material treated in the rotary furnace the grain size of 7 gives the required formability. When a higher temperature was adopted for the heat treatment, the result was a grain size of ASTM 4, but this was detrimental for scale and coil shape. Considering the material directly quenched on the roller conveyor and considering the process temperature used along the mill it is obvious that it is impossible to obtain a coarse grain structure. In any case the uniformity of the structure was definitely good and indicate the proper distribution of the water by the quenching system. Considering the surface quality for 304HC in 5.5 mm, the average defect depth was less than 0.045 mm during all the product campaigns.

<u>>>> Product ID #3 - (430 grade)</u>

Depending on final customer requirements the 430 grade can be directly quenched or heat treated and quenched. Direct quenching after rolling shows the high grain refinement capacity of this grade, thereby guaranteeing the absence of residual austenite.

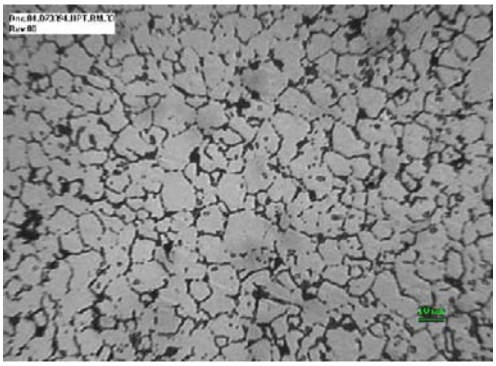


Fig 18. 430 grade

<u>>>> Product ID #4 - (21-4N grade)</u>

From a rolling point of view, the austenitic stainless valve grade is the most critical steel produced. The high-speed roughing mill and inductor head heating cycle solve a lot of problems usually caused by these grades. What the customer required was essentially a uniform structure after solution heat-treatment and grain size in the range of 7–10.

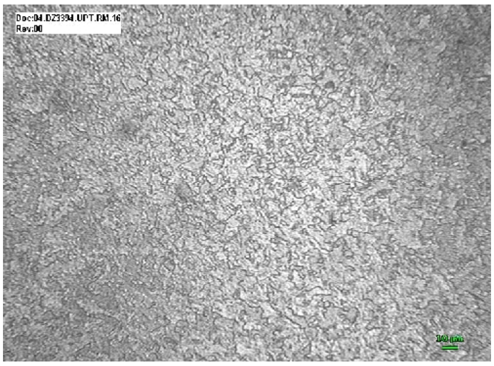


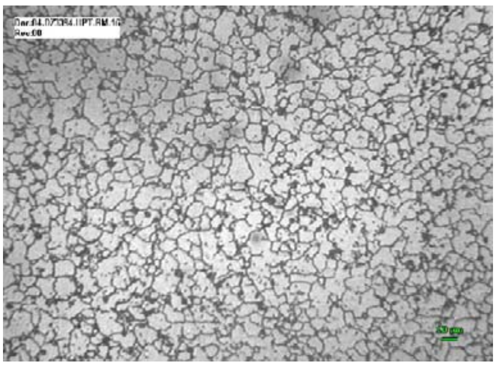
Fig 19. 21-4N grade

<u>>>> Product ID #5 - (HNV3 grade)</u>

These results refer to the as-rolled products and the micros, the material after the off-line heat treatment. This grade could also be in-line heat treated in the rotary furnace because temperature accuracy control was guaranteed, and reached also at 700°C of treatment temperature. In this way, coils do not require intermediate storage, thereby avoiding damages and/or delayed treatment.

<u>>>> Product ID #6 - (304HC grade)</u>

The results for size 5.5 mm for 304HC have already been presented even if for a slightly different chemical composition in terms of carbon content. The same comparison can be made for the 12 mm. The response to the heat treatment was greater than for the 5.5 mm resulting in a grain size of ASTM 5 compared to the 7 of the 5.5 mm. For product sizes larger than 8 mm the possibility of increasing heat treatment temperature without influencing the final coil shape means that the target of grain size 5 can easily be reached.



<u>>>> Product ID #7 - (304HC grade)</u>

Also for the 12 mm, the structure after direct quenching is uniform without any network chromium carbide. As mentioned for the 5.5 mm it

is not possible to obtain a coarse structure directly after rolling even for the larger sizes.
Considering the surface quality for 304HC the average defect depth was 0.055 mm during all the product campaigns. A limit of 0.1 mm was assumed as the maximum threshold but action for pipe changing and equipment adjusting was taken as soon as the defect depth trend start to rise.

>>> Product ID #8 - (304HC grade)
Austenitic stainless steel coils in large sizes were produced on the wire rod line and Garret line. Experience in the new line show how production on the wire rod line, even if possible, implies a certain number of limitations that jeopardize it, and quality needs to be kept under control. Specifically for surface defects, while in the wire rod line it is not easy to keep the scratches below 0.05 mm, in the new coiler it was possible to produce coils without surface scratches.

>>> Product ID #9 - (60Si2CrVAT grade)
The main targets for Si spring steel were reduced decarburisation, fine grain and uniformity on mechanical properties. The process used to roll this grade was LTR considering that reduced decarburisation means a correct reheating furnace practice and the possibility to roll at low temperature in the whole mill.

Table 4 – Summary of the results

Product ID Nr	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Grade	**316L**	**304H**	**430**	**21-4N**	**HNV3**	**304HC**	**304HC**	**304HC**	**60Si2CrVAT**
Size	5.0 mm	5.5 mm	6.5 mm	8.0 mm	8.0 mm	12.0 mm	12.0 mm	18.0 mm	42.0 mm
Rolling Line	WRL	WRL	WRL	WRL	WRL	WRL	WRL	BIC	SBL
Process	**IRF**	**IRF**	**DWQ**	**IRF**	**CC**	**IRF**	**DWQ**	**IRF**	**LTR**
Results									
Grain size (ASTM)	6	7	11	9	10	5	11	5	8
UTS (MPa)	570	590	-	-	-	-	-	-	-
Hardness	-	-	HB220	HV310	HRC60	HB125	HB170	HB140	HB300-
YS (MPa)	270	295	-	-	-	-	-	-	-
Z (%)	66	65	-	-	-	-	-	-	-
A (%)	70	70	-	-	-	-	-	-	-
Chemical composition:									
C	0.02	0.07	0.05	0.46	0.45	0.04	0.05	0.03	0.61
Si	0.25	0.59	0.7	0.18	2.9	0.68	0.52	0.21	1.32
Mn	0.87	0.82	0.77	12.4	0.36	0.77	0.89	0.93	0.55
Cr	17.1	18.5	18.2	21.0	8.6	18.6	17.8	18.2	1.1
Mo	2.21	0.10	0.06	0.14	0.03	0.12	0.10	0.11	0.01
Ni	10.7	8.7	0.23	4.2	0.13	8.65	9.1	8.3	0.07
Cu	0.18	0.16	0.11	-	0.13	2.14	2.28	2.44	0.08

Code index:
WRL: wire rod line; **BIC**: bar-in-coil line; **SBL**: straight bar line
IFR: in line rotary furnace; **CC**: controlled cooling; **DWQ**: water spray cooling; **LTR**: low temperature rolling

Conclusions

The new Baosteel Shanghai Minimill No.5 for stainless and special steels was designed and built on the basis of the most updated and proved technologies presently available in long product production. Plant startup in November 2003 marked the beginning of operation of one of the most modern special steel plants in the PR of China, taking an important step forward in technology and operation flexibility, to be taken as an example in the Country and on the whole Asian continent.

This paper describes some interesting results that are strictly related to the process routes obtained during the commissioning and performance test period. During that period, all the processes for which such a complex mill was designed and built were optimized and put into production. The mill itself is extremely flexible in terms of production routes and processes that can be related and optimized to the actual product requirements coming from the market.