

THIN SLAB CASTER AT TANGSHAN IRON & STEEL GROUP, P. R. OF CHINA¹

High speed casting and machine reliability led to a exceeding 277,000 t of rolled coils produced in may 2005, establishing the new world record in thin slab casting performance with a total production exceeding 3 Mtpy produced during 2005

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Abstract

Recently, energy savings has become the most important theme in the steel manufacturing industry for reasons of environmental protection, economic utilization of resources, reducing capital equipment and reducing transformation cost. In the field of new hot strip mills, instead of conventional hot strip mills aimed at mass production, the direct process of hot strip production, in which the mill is directly connected to the thin slab caster, has rapidly gained in popularity because of its remarkable energy savings. This plant structure and philosophy has been applied by Danieli in many reference plants: plant flexibility and slab surface has been confirmed. The Danieli design concept allows to expand original application of thin slab technology (and originally confined to mainly commercial grades) to more sophisticated grades (such as peritectic, stainless and silicon steels) and allows to strongly increase caster output. Only having fulfilled these two points, the process can give the full advantages of transformation cost and target a wide range of market niches. In this paper the successful start up and the main production goals reached by the two strand casting facility applying Danieli technology in Thangshan Iron and Steel is described, up to the record breaking production record of 277.000 tons produced during the month of may 2005 and demonstrating the capability to exceed 3 Mtpy production as successfully done during 2005.

Key words: Thin slab casting; Direct rolling; Energy saving; Record.

O LINGOTAMENTO DE PLACAS FINAS (THIN SLAB) NO GRUPO TANGSHAN IRON & STEEL, CHINA

O Lingotamento a Alta Velocidade e a confiabilidade da Máquina Danieli proporcionou uma produção superior a 277.000 t de bobinas laminadas em maio de 2005, estabelecendo o novo recorde mundial em lingotamento de placas finas (Thin Slab), com uma produção total excedendo 3 Mtpa produzidas em 2005.

Resumo

Recentemente, a economia de energia, tem se tornado o tema mais importante na indústria siderúrgica devido a razões de proteção ambiental, utilização econômica de recursos, redução de equipamentos capitais e redução dos custos de transformação. No campo dos laminadores de tiras a quente, a substituição dos laminadores convencionais, focados apenas na produção em massa, pelos processos diretos de produção de tiras a quente, nos quais o laminador está diretamente conectado a um lingotamento de placas finas (Thin Slab), tem rapidamente ganhado popularidade devido aos expressivos ganhos de energia obtidos. A estrutura desta planta e filosofia tem sido aplicada pela Danieli em muitas plantas de referência: a flexibilidade da planta e qualidade superficial da placa tem sido confirmada. O projeto Danieli permite expandir a aplicação original da tecnologia de placas finas (originalmente confinada principalmente a aços comerciais) para qualidades de aço mais sofisticadas (como os peritéticos, inoxidáveis e aços silício) e permite aumentar fortemente a produção. Apenas quando atendido estes 2 pontos, o processo pode proporcionar as amplas vantagens de custo de transformação e objetivar uma ampla faixa de nichos de mercado. Neste trabalho, o "start up" com sucesso e os principais objetivos de produção alcançados pela máquina de 2 veios utilizando tecnologia Danieli na Thangshan Iron and Steel, China, é descrito, até a quebra do recorde de produção de 277.000 t obtida durante o mês de maio de 2005 e demonstra a capacidade para exceder 3 Mtpa de produção conforme obtido com sucesso durante 2005.

Palavras-chave: Lingotamento de placas finas; Laminação direta; Economia de energia; Recorde

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The evolution of the Thin Slab caster process.

The “thin slab based process” was originally developed with the main goal to reduce the investment and production costs related to “traditional thick slabs process route”.

But, due to design limitations of the “first generation” technologies, the archived target was to serve markets with limited requirements (mainly for “low added value” commercial applications) and with a productivity around 1 Mtpy of HRC or below.

Today, this approach, with strong limitations on the product niche, is not enough to remain competitive anymore.

The Danieli strategy for thin slab technology has been since then to evolve our products in order to propose to our customers flexible plants.

This “flexibility” implies:

Flexibility in steel grades that can be cast:

Flexibility in slab thickness

In SLAB CASTER AREA, this means the capability to consistently produce at high outputs in stable and practical industrial conditions, as necessary for mass production in a wide range of castable steel grades, including sensitive grades as PERITECTIC) with different slab thickness available, according to steel grade and mill requirements.

Large casting size generates superior quality slabs in order to target top market niches normally served through coils produced by traditional thick slab caster process.

To reach these goals, our last generation casters have been designed to have an extremely flexible mix of thickness,

from 70 mm (mainly used to feed the mill when thin and ultra thin gauges are produced) up to 85 mm, starting from about 100 mm at the mould exit.

Higher slab thickness allows also to cast at high production rates, limiting the maximum casting speed, which is beneficial reducing the risk of breakout.

Caster Roll diagram design, Mould design, SEN design and Dynamic Soft Reduction Process allows us to optimize both fluid-dynamics of liquid steel in the mould and solidification process of the slab: this allows to extend the range of steels that can be cast in this slab casters

These leading concepts have already been embodied in our last plants of Third generation for instance in Tangshan (P.R. China) and EFS Ezz Flat steel (Egypt) just to mention two of them.

The quality results experienced in these plants shows that today thin slab casting & rolling process route can practically cover all the steel grades used for flat product applications, including carbon steels, (for instance also in the peritectic range), HSLA micro alloyed, API grades (also for Arctic applications), stainless and Silicon steels.

As far as productivity is concerned, the goal of a thin slab plant exceeding the 3 Mtpy with two strands in operation as already been proven in Tangshan plant.

Tangshan Thin Slab Caster Production Milestones

By the beginning of October 2002, as part of an overall project of the installation of the UTSP Ultra thin strip production plant, the first Danieli FTSC Flexible Thin Slab Caster in China started operating two months ahead of the contract schedule in Tangshan Iron and Steel group.

This was the first of the two casting line foreseen in the project.

With this achievement Danieli demonstrated his capability to successfully cooperate in a project where some important parts of the equipment have been co-manufactured by local suppliers.

This early startup of the caster ensured a tuning period of roughly three months before the coming in operation of the hot strip rolling mill (end of January 2003).

Thanks to the plant high reliability and technological quality it has been possible to change the final slab thickness from 70 mm to 85 mm, ramping up to 61,000 tons of rolled coils in June 2003 (5 months from start), 106,000 tons of rolled coils in December 2003 (10 months from start), 123,000 tons of rolled coils in March 2004 (13 months from start).

In June 2004 the second thin slab caster came in operation, the 85 mm slab thickness was adopted from the very beginning rocketing the rolled coils production to 220,000 tons in August 2004 (two months from 2nd strand start) setting a world record in May 2005 with 277,000 tons of rolled coils.

Therefore the plant demonstrated to reach and overcome the historical milestone of yearly production of 3,000,000 tons, as shown in the attached production trend marking a total production during 2005 of 3.011.230 tons.

Production and Quality results

- Prime quality rate 99.8 %
- 380,000 tons of continuous production without breakout interruptions
- Average heats per day 54 (December 2004) = 8243 tons/day
- Max N of heats per day 65 (December 2004) = 10,000 tons/day

Major technological highlights

To achieve such remarkable performances the Danieli Thin Slab Caster has been equipped with the most up to date technological solutions.

Following now established designs, the main section of the caster has a vertical bending geometry, with a vertical height of 2,290 mm and main radius of 5,000 mm. Roll diameters and pitches have been chosen in order to best support the solidifying shell, even at the high casting speeds reachable in this caster. Progressive multi-point bending and unbending will assure lower stresses in the shell in order to guarantee optimum internal quality in any casting condition.

Each caster is fed by a 150 ton ladle, the liquid steel is poured through a suitable protective tube into the optimized tundish, with flow correction devices to assure an optimum steel homogenization along with the correct residence time and inclusion flotation behavior.

From the tundish, the liquid steel flows into the mould through a dedicated submerged entry nozzle. Enhanced liquid steel fluid dynamics are guaranteed by two different SEN designs for different ranges of slab width; this assures an optimum meniscus behavior and the proper powder performances for the complete range of slab dimensions.

The distinguishing features of the Danieli Thin slab casting technology, marching the difference between Danieli FTSC (flexible Thin Slab Caster) and other solutions can be summarized as follows:

Vertical curved design, with main castes radius of 5 meters (compared to 3 meters in other solutions)

Patented H2 mould (High speed High quality) with long funnel mould extended throughout the complete mould and continuing in the first rolls of top segment (compared with short funnel moulds in other solutions)

Advanced Breakout prevention system, based on complete thermal mapping of the mould.

Patented Dynamic Soft Reduction process based on Liquid pool calculation mathematical model(compared to static soft reduction used in other solutions).

Air mist secondary cooling based on **Dynamic Model** of the cooling process (compared with water only water cooling available in other solutions)

Split type caster rolls a bearing supports **internally cooled** with independent tertiary cooling circuit (compared with non cooled rolls included in other solutions)

Integrated **descaling unit** integrated in caster.

Vertical curved design allows to limit the height of the caster, hence reducing the ferrostatic pressure inside the solidifying slab: this is beneficial for quality.

The mould broad copper plates of the **H2 Mould** incorporate the long funnel design giving additional space for the SEN to guarantee an optimum liquid steel fluid–dynamic behavior: the particular shape of the funnel, down through the foot rolls and finally flatten in the upper part of segment 0, assures a significant surface quality improvement.

In Danieli H2 Long funnel mould, the slab is flattened along a total distance of 2100 mm (compared to 700 mm only in other designs): this ensures a dramatic reduction of the stress on the slab during the transition between funnel and flat shape: hence the quality of the slab is ensured also for crack sensitive grades.

The superior design of the **H2** mould, together with the Patented design of the SEN (Submerged Entry Nozzle) allows an optimized and stable behavior of liquid steel in the mould: this is testified by the fact that the use of Electromagnetic breaks or accelerators in the mould is not necessary.

(Tangshan casters are designed with the provisions of the installation of Electromagnetic brake, but this device has not been installed).

The mould narrow copper plates are designed with the well proven multi-taper profile. This solution is coupled with an automatic control system to continuously adjust the width and the total taper thus applying the proper parameters according to real casting conditions. Furthermore, to follow production schedules, the slab width at the mould exit can be changed during casting, in a complete automatic way and within the entire width range, enhancing machine flexibility.

The mould level control is performed by both radioactive and electromagnetic sensors in order to capture the advantages of both them in terms of flexibility, reliability and precision.

The mould is also fitted with breakout and sticking detection systems that are based on a complete array of thermocouples arranged from top to bottom of the mould, whose signals are collected and elaborated by dedicated software. With these systems, safety of operations and yield of the plant have consistently risen through a reduction in the number of breakouts and the complete recover from sticking without stopping the sequence.

To achieve the best results in lubrication an hydraulically-driven oscillator moves the mould guaranteeing precision and flexibility in the oscillation parameters, a key point to achieve the best surface quality. Frequency, stroke and wave shape can be varied continuously while in operation, assuring the proper lubricating conditions for the entire range of steel grades and casting speeds.

Among the main technological items involved in the fulfillment of internal quality requirements **Dynamic Soft Reduction** has proved to be vital.

All segments, starting from segment 0 down to segment 9 are equipped to perform dynamic soft reduction on the solidifying slab and are kept in position by hydraulic cylinders. The Liquid Pool Control System software, based on the real casting conditions, defines automatically the optimum gap pattern along the caster, sends the signals to the cylinders position transducers and places each segment in the required

position. This technology is crucial to keep under control the center line segregation and porosity, for all steel grades and in any casting condition, even transient ones.

Consistent segment structure has been achieved splitting each roll in three parts thus reducing at the minimum the roll deflection, the final slab geometry proved to be consistent allowing to roll repetitively to the thinner gauges (0.8 mm) during the performance test period.

The air mist slab cooling provides the maximum flexibility to the caster in order to reach the high quality requirements for the different steel grades and casting conditions. Thirteen different loops distribute the secondary cooling water and compressed air on the slab, allowing the possibility of adjusting flow and spray width. Different flows between inner and outer radius can be set as well.

For the maximum ease operation, different functioning modes, from fully to semi automatic, are available to control the secondary cooling system in the fastest and most efficient way.

An internal machine cooling for rolls and bearing supports, separated in different circuits, for the roll and the bearing supports together with separate loops for the scale flushing, guarantees long service life for all the equipment even in case of emergency situations like slab stoppage.

Advanced functions adopted for production of ultra-thin strip and high quality rolled products

The production of very thin gauges for final uses as a substitute for cold rolled products requires very high surface quality. For this reason, caster design has been focused toward the obtainment of the best surface quality.

Hot charging and direct rolling requires defect-free slabs because of the fact that no slab inspection and conditioning is possible.

For the above, the working parameters involved in the formation of the first solidified shell were considered with particular care during the design phase of caster equipment. Mould funnel shape, SEN shape and dimensions, mould level control system, narrow side profile and settings, mould lubrication powder characteristics are all key factors that have been carefully considered for achieving the goal of a top quality ultra-thin strip.

Conclusion

The “state of the art” UTSP line in Tangshan allows the application of the most advanced casting and rolling practices, such as semi-endless rolling, and achieves stable thin strip production at outstanding quality, comparable to what can be reached in a traditional hot strip mill fed by thick slabs.

The two thin slab casters have been designed utilizing Danieli’s well established technological solution for the fulfillment of the highest quality requirements.

The Ultra-thin strip rolling and the Ferritic rolling offers the possibility of a new practice in hot strip rolling.

It is expected that this UTSP plant will expand the market range of hot coils and the ability to supply advanced raw materials to cold rolling.

Design Product grades and sizes in Tangshan plant

Steel grades

Low and extra-low carbon, peritectic, medium carbon, high carbon, microalloyed

Slab thickness

70 mm (1st phase) 85 mm (final phase)

Slab width

850 to 1,680 mm

Final product target Specifications

<u>Production steel grade</u>	Austenitic & Ferritic rolling steel
<u>Thickness</u>	0.8 to 12.7 mm
<u>Width</u>	850 to 1,680 mm
<u>Production capacity</u>	1,500,000 tpy (one strand) 3,000,000 tpy (two strands)

Thin slab caster: main features

CCM type	Vertical – curved
N. of machine	2
N. of strands for machine	1
Main radius	5,000 mm
Casting speed	6.0 m/min max (2.5 m/min for quality grades)
Thin slab thickness	92.5mm(mould exit), 72 & 67mm (caster exit)
Thin slab width	850 to 1,680 mm
Thin slab length	37 m max
Sequence index	13.7(design) 20 (maximum achieved)
SEN type	Danieli design
Mould type	H2 type (Danieli patent)
Narrow faces profile	Multi-taper MT6
Mould thickness	92.5 mm
Mould level control	Berthold and NKK
Breakout & sticking prevention	by thermocouples
Mould thermal map	by thermocouples
Variable width mould	automatic or semi-automatic
Mould lubricant feeding	manual
Containment below mould	foot rolls
Soft reduction	dynamic with LPC (seg 0 to 9)
Oscillating table	Hydraulically actuated
Liquid pool control system	automatic or semi-automatic
Secondary cooling	Water and air-mist type
Machine cooling	Internal via axial bore
Straightening unit	Segment 7
Withdrawal unit	Segment 7, 8, 9 and extraction unit
Pendulum shear	Start-stop type (17,300 kN)
Dummy bar feeding	from bottom with tilting chute
Captions:	



Figure 1. Casting of 85-mm-thick slabs at Tangshan fTSR complex, PR of China. The caster features the latest Danieli Thin slab Casting Technology such as H2 Funnel Mould and Dynamic Soft Reduction Control.

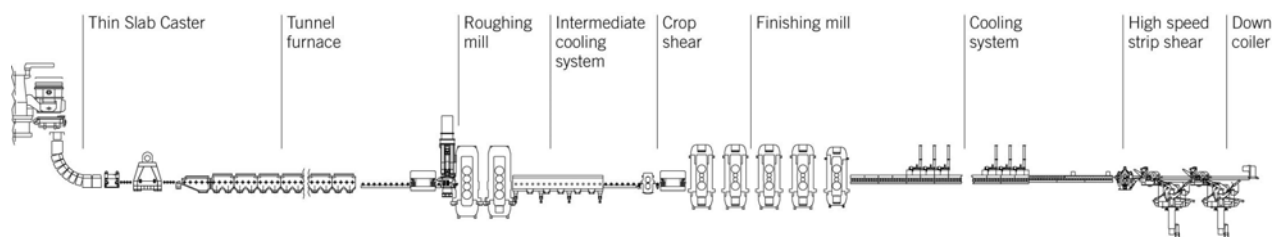


Figure 2. Layout of the Tangshan's plant; it represents the most modern thin slab rolling complex in China for the production of cold substitutes, being able to achieve a final strip thickness as low as 0.8 mm.



Figure 3. Overall view of the casting section at the Tangshan thin slab casting and rolling plant.



Figure 4. Strip exiting the Danieli two-stand roughing mill: the line ensures the production of ultra-thin strip down to 0.8 mm.

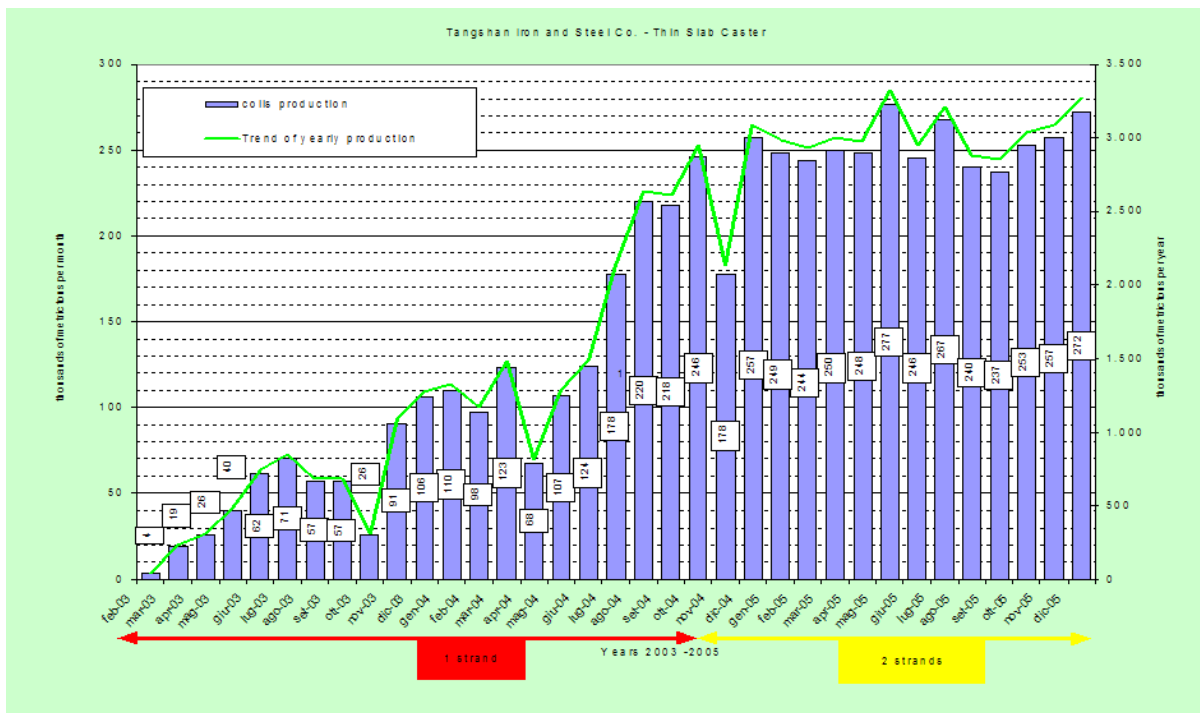


Figure 5. Tangshan Production ramp up.