QUALITY STRIP PRODUCTION VIA THIN SLAB CASTER AND HOT ROLLING [1]

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Abstract
The fTSR (flexible thin slab rolling) represents the Danieli advance solutions for high quality, high flexibility and high production level in the field of thin slab rolling technology. Besides the production of light gauges down to 1 mm strip thickness (0,8 mm with semiendeless technology) the equipment will allow to significantly extend the range of today's minimill products to high added value steels, such as API 5L X65 and X70 to be used at temperatures down to –60 C and aggressive atmosphere.This paper describes the main features of the plant lay out and the specific characteristics of the caster in order to cope with production needs.
Key words: Thin slab caster; Hot strip mill; Caster coupled to hot rolling mill.

PRODUÇÃO DE TIRAS DE QUALIDADE ATRAVÉS DE LINGOTAMENTO CONTÍNUO DE PLACA FINA ACOPLADO A LAMINAÇÃO DE TIRAS A QUENTE

Resumo
O conceito fTSR (flexible thin slab rolling – laminação flexível de placa fina) representa uma solução avançada Danieli para produção de bobina a quente de alta qualidade, com alta flexibilidade no mix e alto nível de produção no campo da tecnologia de laminação de placa fina. Paralelamente a produção de tiras de espessuras abaixo de 1mm o equipamento permite um significante aumento na abrangência de produtos que podem ser produzidos nas plantas "minimill" de hoje em dia tais como aços de alto valor agregado API 5L X65 e X70 que são usados em temperaturas abaixo que -60º C e em atmosferas agressivas. Este trabalho descreve as caracteríistias principais de layouts e características específicas do lingtamento para alcançar as necessidades de produção.
Palavras-chave: Lingotamento contínuo de placa fina; Laminador de tiras a quente; Lingotamento contínuo acoplado a laminador de tiras a quente.

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1 INTRODUCTION

Plant Layout concept

The Danieli fTSR plant is composed by the following technological units:

- Thin Slab Continuous Caster
- Tunnel Furnace
- Vertical Edger
- Two 4-high Roughing Mills R1/R2
- Four/Five 4-high Finishing Mills F1-F5

Figure 1 – Thin Slab Caster Last Segment.

2 MATERIALS AND METHODS

2.1 Single or multilple strands Danieli fTSC (flexible thin slab caster)

Able to cast slabs a wide range of slab thickness, adopting Dynamic soft reduction process.
Special attention in caster design features selection (namely slab thickness selection, dynamic soft reduction strategy, secondary cooling design) has been paid in order to cope with the product mix.
This caster is designed embodying all technological experiences developed by Danieli in the cast of hi demanding grades at high casting speeds.
The main metallurgical challenges can be summarised as follows:
Mould section of Danieli H2 mould at meniscus level is also significatelly larger compared to other designs: this guarantees an high meniscus stability and optimised fluid dynamics, hence overcomes the risks of transverse and longitudinal cracks.
Also the distance between SEN and copper plate is higher: hence risk of centreline longitudinal cracks is minimised.
Mould Lubrication is also a key factor in ensuring quality.
The Soft Reduction is the only possible method capable to minimise the segregation in slabs.

In order to be effective in ALL casting conditions, Soft Reduction process parameters (position of thickness reduction, total reduction and reduction rate) must be adapted and optimised to the variable casting conditions.
For these reasons the process MUST be Dynamically controlled.
The Danieli Dynamic Soft Reduction process based on the Liquid Pool Control System can optimise the internal quality of the slab throughout the whole casting speed range.
By the dynamic soft reduction it also possible to slightly reduce the grain size in the slab, aside the strong improvement in centreline segregation.
The possible residual porosity can be easier eliminated thanks to the high reduction rate between slab and strip.

In-line high-pressure descaler integrated in caster.
This device, integrated with the withdrawal unit of the Thin Slab Caster, is composed by a rotary descaler that removes the scale, using high pressure – low flow rate sprays, before the slab enters the tunnel furnace.
Through this design is possible to achieve a high descaling efficiency with low temperature losses (about 5℃).
The slab is then scale-free and comes to the tunnel furnace. This avoids any damage to the furnace rollers and providing the possibility of controlling scale growth in the tunnel furnace as far as scale layer thickness and composition are concerned. Scale thickness and composition will be more uniform on the slab surface.

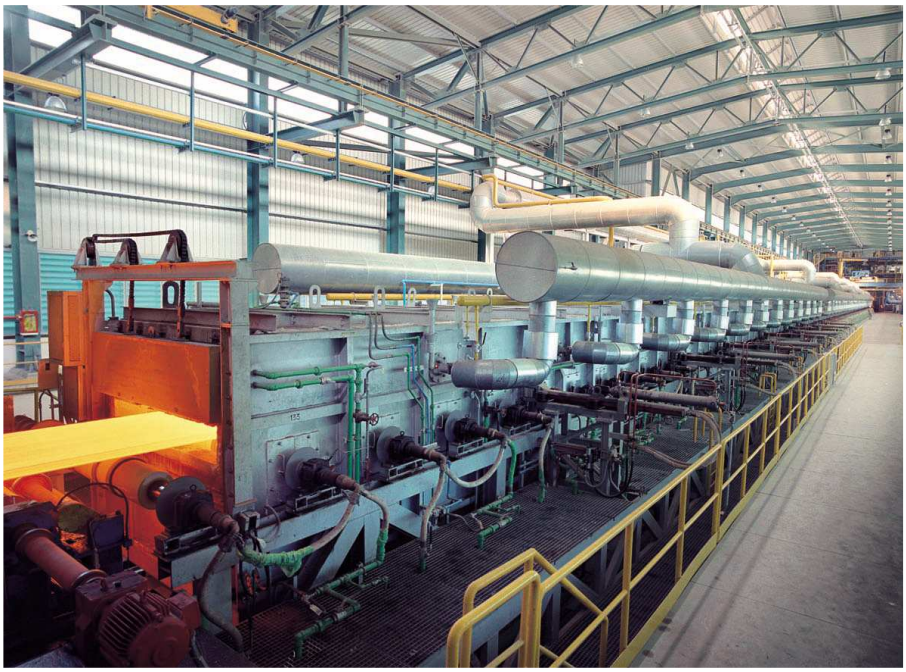

Figure 2 – Tunnel Furnace.

2.2 Tunnel Furnace

The rolling mill is connected with the CCM by means of a tunnel furnace roller type.
The tunnel furnace is designed with a length up to 240 m. The furnace has the capability to hold up to 4 slabs having the maximum length up to 48 m.

The resulting buffer capacity makes it possible to continue casting operations even during mill stoppages due to work roll change or automation default, without affecting the Continuous Casting Machine operating conditions.

2.3 Rolling mill

Equipment includes after the tunnel furnace:

2.3.1 Header descaler No. 2

High pressure descaler unit No. 2 (conventional header type) is located at the tunnel furnace exit. It is designed to keep the slab surface as clean as possible and to remove the scale, which is formed during slab heating in the tunnel furnace, from the surface of the slab.

2.3.2 Vertical edger E1

A vertical edger is located at the inlet of the roughing stand group. It is designed to reduce the slab side faces both to keep its width within the set tolerance value and to improve the edge quality.

2.3.3 Two 4-Hi roughing stands R1 and R2

Integrated into continuous roughing group with the unit for interstand cooling. The inter-stand cooling device installed between roughing stands R1 and R2 provides the required temperature of finishing of rolling in the roughing stand group. The pyrometers installed on the entry side of the roughing stand R1 and exit side of roughing stand R2, give the input of data to the system of control of this inter-stand cooling device.

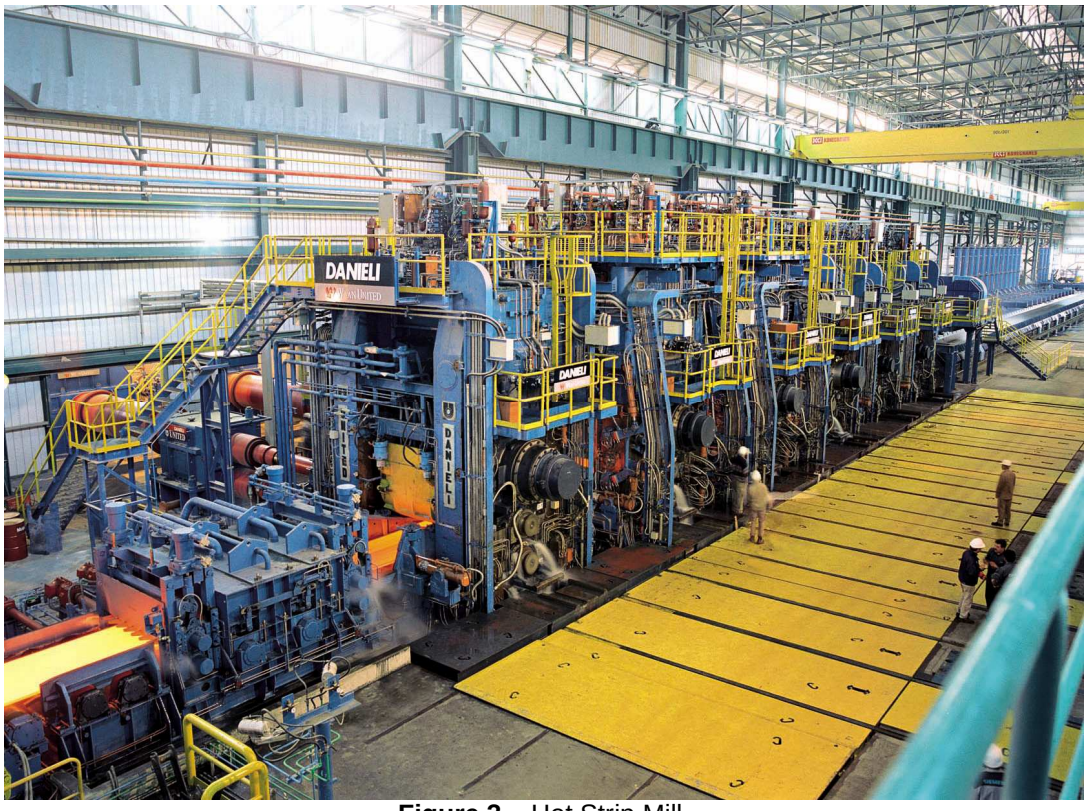

Figure 3 – Hot Strip Mill.

2.3.4 - Intermediate Area between RM and FM

The intermediate table between Roughing mill and Finishing mill gives the space for intallation of additional equipment necessary for strip quality control.
After the high reduction obtained of the first two Roughing stands the shape of head and tail of the transfer bar is affected and must be squared for particular rolling condition . The crop shear installed at the entry side of finishing mill allows to optimes the shape of the head end according to the final thickness to be produced on the finishning mill avoiding the risk of cobble for light gauge strip production. Coupled with cut system control is used only when required to optimes also the total plant yield.
For superior surface quality the plant is equipped with a third descaler unit installed before finishing mill. It is possible to clean again the transfer bar surface after Roughing mill to avoid any scale imprinting during the last phase of the rolling process and to assure a perfect quality also for high demanding requirement for special application when external and surface quality is a mandatory. The insyallation of three descaling points along the plant line is a plus that only fTSR technology can assure.
As optional equipment a strip cooling system, dedicated for ferritic rolling, installed to reduce the temperature at the beginning of deformation in the finishing stand group.
The lenght of intermediate table is in any case very limited to maintain a compact configuration in which Roughing mill and finishing mill work in tandem.
This compact configuration is mandatory when semiendless rolling is required and the long slab is rolled for a long time and an accurate strip end tension control is required on the mill.

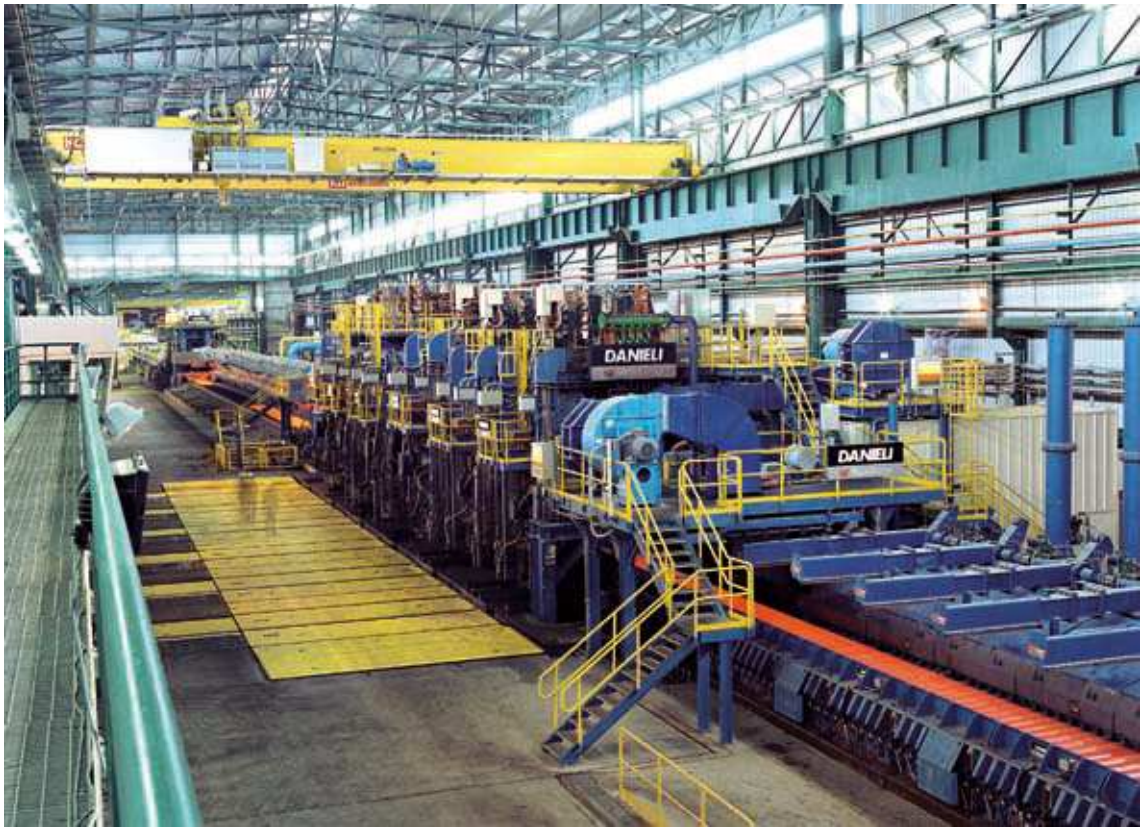

Figure 4 – Hot Strip Mill and Laminar Cooling.

2.3.5 Four/Five Stand finishing Mill

Four or Five finishing stands (according to the final strip thickness 6equirements) with adequate rolling force and rolling torque grant the annual production with maximum flexibility and required final quality.

An inter-stand cooling system grants the required finishing exit rolling temperature of the strip. A set of pyrometers on the entry side and on the exit side of the finishing stand group checks the incoming and outgoing material temperature for optimal regulation of the inter-stand cooling system and consequent regulation of the laminar cooling device at the run-out table.

The chosen equipment for the finishing stands represents the Danieli complete solution to control strip profile and flatness and to enable schedule free rolling. In fact the proposed system is capable of obtaining top level performances without any interference among the rolling mill controls and without any maintenance overload, while considering all the effects influencing the final dimensional tolerances of the strip as per the following scheme:

Strip thickness control	Long stroke hydraulic automatic thickness regulation (AGC) in all stands
Strip crown and flatness control	Work roll heavy bending in all stands (both positive and negative bending) and shaper roll techniology on work roll.
Roll bite lubrication system	To lubricate the work roll bite on stands F1, F2 and F3 to reduce frictions coefficient and therefore to reduce separating force and limit roll wear.
Work roll wear control	Work roll axial shifting in all stands
Work roll thermal crown control	RTC system on stands F1 to F4 and selective cooling on stand F5-F6

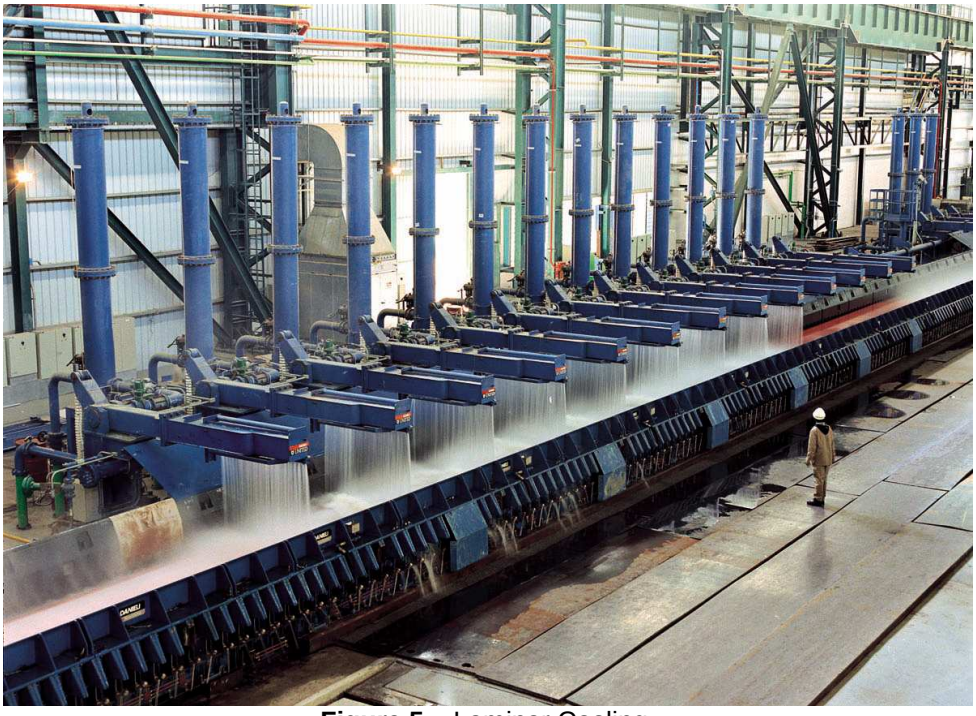

Figure 5 – Laminar Cooling.

2.3.6 Runout table with unit for laminar cooling of the strip

At the run-out table, the installed laminar cooling system is composed by waterwall type headers of which the last group is dedicated for the trimming (fine tuning) of coiling strip temperature. The laminar cooling provides strip cooling in the required temperature range, needed to achieve metallurgical and mechanical properties and strip winding at down coiler equipment.
The solutions chosen for the runout table and towards solving the problem of safe threading of thin strips and of the most uniform and controllable strip cooling.
The strip cooling area allows to obtain the strip characteristics requested by the product mix and to feed the coilers with the provided temperature. Special design and additional units are provided for Dual phase and trip steel.

Figure 6 – Coiling Area.

2.3.7 Coiling area

The down coilers installed at the end point of the line can be shiftable type for easy maintenece operation during the line shutdown. They are completely hudraulically operated type for high tension coiling, required for high strength steel produced on the plant. It si also equipped with special valve for jumping control system.
In case of seminendeless technology in which a series of coil are produced from a long slab special Danieli has designed dedicated machines:
High speed shear able to cut at a maximum speed up to 20 m/s and strip thickness from 3,0 mm down to 0,8 mm;
Threading device to feed the strip head after cutting to the entry side of pinch roll;
Down coiler with four wrapper rolls design for accurate guiding of the strip in the first phase of coiling and to gurantee the right tension and telescopicity also for extreme light guge production.
After the downcoiler the coil handling system is installed equipped with circumferential and radial strapping machine, marking machine, weighing system and off-line coil inspection.
Besides that there is a storage area for the hot rolled products.

fTSR ADDITIONAL FEATURES AND IMPLEMENTATION

A special implementation of fTSR plant so called QSP (Quality Strip Production) can be installed to satisfy special requirements in terms of production level, special steel grade production, thermomechanical and controlled rolling technology
The main difference with the standard configuration are the followings:
The 4-Hi roughing stands are designed to accept an incoming slab up to 90-100 mm thickness. This fact allows to increase the pant production level that can be reach up to two millions tpy withy only one strand caster.
The roughing stand are located at a long distance from Finishing mill and work indipendenltly. Between roughing mill area and finishing mill a long transfer table is installed.
On it an intermediate cooling and a Heated Transfer Table is located.
The intermediate strip cooling system, dedicated for rolling of API grades (especially X70 arctic steel grade), installed to reduce the temperature at the beginning of deformation in the finishing stand group.
The heated transfer table, heated with natural gas, is installed in order to:

- keep the temperature constant through the transfer bar section;
- minimise the temperature difference between head and tail ends of the transfer bar at the inlet of the finishing group, during rolling at the finishing group.

The intermediate cooling on the exit side of roughing stand is dedicated especially for arctic steel grades production that requires temperature at beginning of finishing rolling of about 830-860℃.
The intermediate cooling area, dedicated for rolling of API steel grades (in particularly for X70 arctic steel grade), is located close to roughing stand R2 exit side in order to achieve the best transfer bar cooling results.
A pyrometer at the exit side of the intermediate cooling checks the actual material temperature giving the feedback for an optimal regulation of the cooling system operation.
The heat transfer table, after intermediate cooling, is 100 m long and allows the temperature equalisation of all the steel grades with the proper temperature set point. In this way the cooled transfer bar, passing from the roughing area to the finishing area, through the HTT can equalise itself along the thickness and the length.
Moreover the distance between roughing and finishing mill increases considerably the overall flexibility of the plant because:

- Roughing and finishing stand groups do not roll the same transfer bar at the same time so that it is possible to roll at roughing stand group with higher speed, without using hydrostatic unit for oil film bearings.
- Fast rolling on the roughing stand group prevents local overheating of the work rolls thus reducing their wearing.
- In case cobble occurs in finishing group the transfer bar can be removed from the line of the heated transfer table, not stopping continuos casting.

3 RESULTS AND DISCUSSION

Configuration comparison

The fTSR is a compact configuration with limited investment dedicated to produce in flexible way a wide range of product mix including ultra light gauge that match the most common market requirements. The plant is very flexible and can be implemented in subsequent stages with a possibility to increase the production by installing additional stand and second and third slab caster on the plant line with a high production level that make the investement very profitable.
The QSP is a configuration that implies a longer layout (around 60 m) and additional furnace and stand installed on ther plant. It is suggested when a massive production of high value products and special steel grades production (with special regards to metallurgical properties and surface quality) are the guiding requirement from the customer. The possibility to roll starting from a thicker slab gives the additional advantage to have a elevated production of high value product with only one strand caster and a fast return of investment serving also niche markets.

Figure 7 – HSM Operation Pulpit.

4 CONCLUSIONS

The fTSR and its evolution to QSP after positive experiences, proves the capability of Danieli equipment to successfully produce all the steel grades required by market including API grades in agreement with the tough specifications imposed by Arctic applications, demonstrated the possibility to further extend the range of steels that can be produced with thin slab process route.
It extends to this market segment the benefits implied by this process route in plant investment, transformation cost and cash cost compared to traditional thick slab process route.
fTSR and QSP is the proper answer to the high demanding requirments in terms of Production level, Internal quality, Surface quality, Steel grade and high value product mix that must be produced in a moder new generation Hot Rolling mill.