OMK FTSR PLANT
THE FIRST THIN SLAB CASTING AND ROLLING PLANT IN THE WORLD FOR API GRADES, ARCTIC APPLICATIONS[1]

M. Fornasier [2]
C. Piemonte [3]
A. Pigani [4]

Abstract
On march 9, 2005 the Russian OMK Group and Danieli signed the order for the supply of for the new CRC (Casting Rolling Complex) plant to be constructed in Vyksa, Nizhny Novgorod Region. The plant will produce 1.2 Mtpy HRC hot rolled coils for producing pipes ranging from 21 to 530 mm diameter in the OMK Group production plants in Vyksa and Almetyevsk. The plant will be the first thin slab casting & rolling plant installed in Russia and the first in the world specifically conceived for the production of API grades for arctic applications using thin slab process route. The final choice by OMK of Danieli as technological suppliers was based on the optimum technological level of the equipment proposed by Danieli and on the successful tests made in Danieli reference plant for the production of HR coils according to OMK metallurgical request (refer to the paper describing the test for X 70 grades campaign in Ezz plant, Egypt).
Key words: Slab-casting,

1 *43rd Rolling Seminar – Processes, Rolled and Coated Products, October 17th to 20th, 2006 –Curitiba – PR – Brazil*
2 *Caster Process engineer, Danieli Wean United, Italy*
3 *Director Sales, Danieli Wean United, Italy*
4 *Rolling Process Engineer, Danieli Wean United, Italy*

OMK FTSR PLANT

The whole plant supplied by Danieli includes:

- 174 tons per hour AC EAF
- Twin ladle LF
- Twin tank VD
- Single strand fTSC (flexible Thin slab caster)
- Tunnel type heating and soaking roller furnace
- Two stands Rougher with attached vertical edger
- Intermediate cooling and heating transfer table
- Five finishing stands with vertical edger
- Laminar cooling facilities
- Downcoiler and coil handling facilities

Electric and automation equipment, up to Level 3 is supplied by Danieli Automation for meltshop, caster and mill.
Besides the production of light gauges, (future 1 mm strip thickness is foreseen with the installation of the 6^{th} stand) the equipment for the CRC plant 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.

PLANT LAY-OUT CONCEPTS

The Danieli fTSCR (flexible Thin Slab Casting and Rolling plant) is composed by (Figure ure 1):

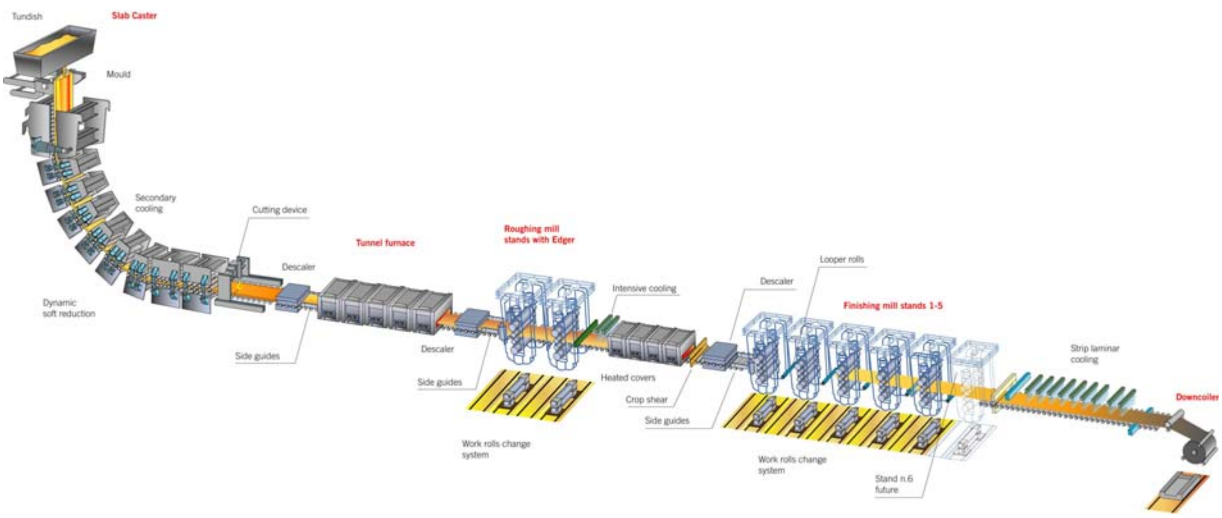

Figure 1. OMK fTSCR plant technological lay out

Single strand Danieli fTSC (flexible thin slab caster) able to cast slabs up to 90 mm in thickness at caster exit, adopting Dynamic soft reduction process.
Special attention in caster design features (namely slab thickness selection, dynamic soft reduction strategy, secondary cooling design) has been paid to cope with the product mix.
In plant design, provision for second strand has been considered for future expansion.

In-line hi-pressure descailer 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.
On the rotating arms are installed 8 nozzles (4 top and 4 bottom nozzles). Making a comparison with a conventional descaler (e.g. the ones installed in front of stands R1 and F1) the number of the nozzles is about 80% less. Through this design is possible to achieve a high descaling efficiency with low temperature losses (about 5°C).
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.
The rolling mill is connected with the CCM by means of a tunnel furnace roller type, forming a unit. The slab enters into the furnace at a temperature of 900-1050 °C depending on the speed (width and steel grade).
The tunnel furnace is designed with a length of 200 m. The furnace has the capability to hold up to 5 slabs having the maximum length of 37.5 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.

Rolling mill equipment includes after the tunnel furnace:

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.

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.

Two 4-Hi roughing stands R1 and R2 integrated into continuous roughing group with the unit for interstand cooling, intermediate runout table with units for intermediate cooling and heating of rolled material.
After that there are:

- **Flying shear** for 45 mm transfer bar
- **Header descaler No. 3**
- **Vertical edger E2**
- Continuous finishing group composed by **5 4-Hi stands, F1 to F5 (F6 for future)**
- Runout table with unit for **laminar cooling** of the strip
- **One hydraulic downcoiler** (second downcoiler for future).

After the downcoiler is foreseen the coil handling system. On this are installed the 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.
The rolling mill (R1 and R2 work roll body length 1950 mm, F1 to F5 work roll body length 2250 mm) for hot rolling begins after the pendulum shear of continuous casting machine (CCM), cutting continuously cast bars into slabs.
All the equipment and its arrangement have been studied to meet the required annual production of the wide range of the steel grades included in the production mix.

Namely,

A) since the continuos caster has to produce peritectic steel grades for the 30% of its production, the 90 mm thickness slab has been chosen as slab thickness at the caster exit to allow an optimal casting of such steel grades.

B) For an incoming 90 mm thickness slab, the two roughing stands solution has been adopted in order to:

- meet productivity requirements.
- give to finishing stand group the required thickness of transfer bar prior to roll.

C) 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.

D) Between the roughing and the finishing stand group, two different devices are provided:

- One 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.
- One heated transfer table, heated with natural gas, foreseen 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°C.

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.

The intermediate cooling device is about 18 m long and is a laminar based system designed to meet the conditions of work according to the rolling speed of roughing stand R2 and considers the maximum heat removal in the interface water/transfer bar.

In this way, quenched areas on transfer bar surface and excessive thermal stresses are avoided: for X70 arctic steel grade a maximum cooling capacity of 8-10°C/s is necessary for incoming transfer bar at an average speed of 1.0 – 1.5 m/s.

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.

E) Five finishing stands 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)
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

F) At the run-out table, the installed laminar cooling system is composed by 20 main waterwall type headers plus other 3 similar ones 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

Caster tecnological requirements and solutions
Special attention in caster design features selection (namely slab thickness selection, dynamic soft reduction strategy, secondary cooling design) has beeb paid in order to cope with the product mix.
This caster has been 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:

- Surface quality is a must because API are crack sensitive grades.
- In thin slab casting process no conditioning can be done:
- This implies that slab surface cracks or depressions must be avoided in casting practice. No repair is possible: only slab downgrade.
- No trace of oscillation marks must remain on the surface
- Internal quality must be at the highest level
- Grain size must be minimised for control of the toughness.
- Segregation in centreline must be at the minimum level

Danieli patented H2 mould and Dynamic Soft Reduction process are the optimum tools to overcome these quality issues.

Slab thickness selection
The caster is designed to produce slabs with a variable final thichness from 90 to 70 mm, starting from 110 (or 90 mm) et the mould exit.
Slab thickness can be chosen according steelgrade and optimal rolling schedule.
Even if the caster is designed to cast at speeds up to 6 meters per min, the selected 90 mm final thickness of the slab allowed by Danieli vertical curved design enables to reach the target plant production of 1,2 Mtpy without the necessity to cast at extremely high casting speeds implied by thinner slabs.
And this is positive: the low casting speed Danieli can adopt reduces the risk of surface cracks and depression, unacceptable for API and peritectic grades.
With reduced casting speeds also the heat transfer in mould can be easily kept below critical values.
An API grade must not have residuals trace of oscillation marks on the surface. Even the small defects can initiate a cracking action at low temperature and in presence of Hydrogen. In a traditional process the oscillation marks are eliminated during the rolling, thanks to high reduction rate. With a 90 mm thick slab it is possible to eliminate during rolling these marks even at the highest strip thickness, because a significant reduction rate is always available for the mill. Moreover, hydraulic oscillation allows the best possible control of oscillating process, minimising oscillation marks "at the source".
Segregation and axial porosity must be completely eliminated. Any cavity or defects in centreline can lead to a cracking effect. This reduces the toughness in cold temperature environment and in presence of Hydrogen.
The application of dynamic soft reduction allows the decrease of the segregation and porosity index in any casting condition. The possible residual porosity can be easier eliminated thanks to the high reduction rate between slab and strip.

H2 Danieli mould (Danieli Patent)
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. Wide surface meniscus available in H2 Danieli mould allows to use high basicity powder (having low melting points, they are "difficult" to melt) that helps to reduce the heat transfer lower than 2500 kw/M2. Below this level it is possible to cast microalloyed steel grades and peritectic steel with no cracking.

Dynamic soft reduction
The Soft Reduction is the only possible method capable to minimise the segregation in slabs. But, 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.
With the Liquid Pool Control, mathematical model, the soft reduction can always be applied in the right position of the liquid pool, i.e. at the position along the strand where the optimum ratio between liquid and solid fraction is optimal. Only in this way the segregation and the axial porosity can be controlled. It the soft reduction is done too early, no improvements of

segregation can be obtained. If it is done too late, internal cracks can be generated (Figure ure 2)

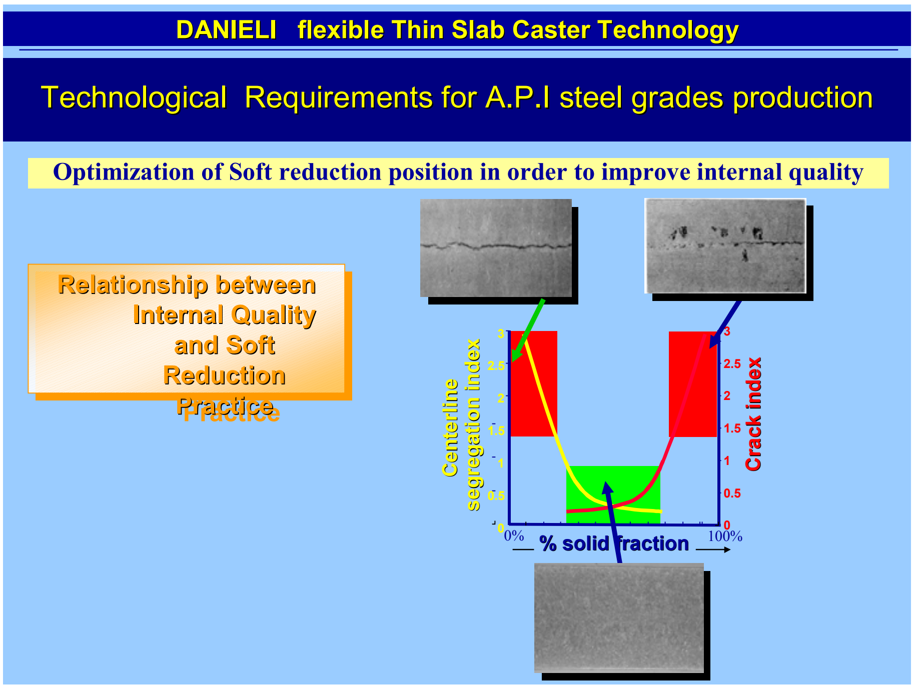

Figure 2. Relation between slab quality and position of Soft Reductionapplication along the strand

Dynamic soft reduction has also a beneficial effect on the grain structure of the slab and ,as a consequence, also on the final strip, the latter important to guarantee the final product toughness and mechanical properties.
As shown by the enclosed pictures in Figure 3, with the dynamic soft reduction it also possible to slightly reduce the grain size in the slab, aside the strong improvement in centerline segregation.

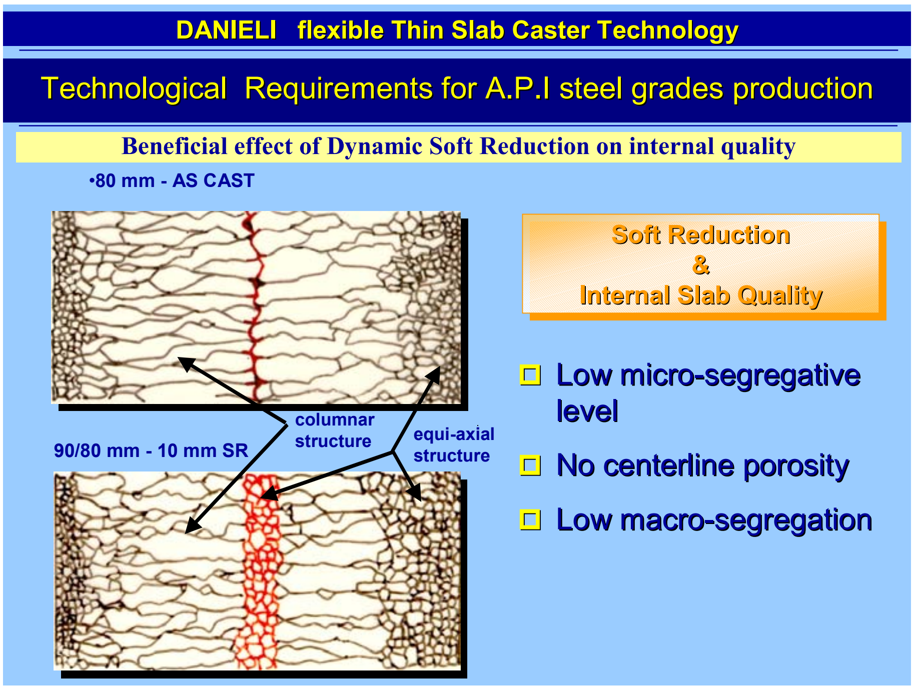

Figure 3. Improvement of slab internal quality thanks to application of Dynamic Soft Reduction.

CONCLUSION

The OMK order, awarded to Danieli after positive prove of the capability of Danieli equipment to successfully produce 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.