Danieli’s new generation of thin slab rolling plants

Danieli’s portfolio of thin slab casting/rolling plant layouts provide a range of options for customers to meet the great variety and combination of output, quality, steel grades and strip gauge in today’s markets, including high added value, technically complex products – and at an optimised cost. Thanks to ultra-high casting speed technology, productivity of 4Mt/y is possible.

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The direct rolling process for hot strip production, where the thin slab caster is connected directly to the mill, has gained market share rapidly because of its advantages in terms of energy savings and investment costs over conventional hot strip mills. However, the advantages of these first-generation applications also entail significant limitations both in productivity and the steel grades that can be produced. In order to overcome these limitations Danieli has developed its own concept of thin slab casting and rolling, both in terms of layout and equipment used.

Danieli has developed a portfolio of plant layouts adopting thin slab casting and rolling technologies, each tailored to optimising capital and operating costs for customers’ specific product and output requirements. Three variants of the Thin Slab Casting and Rolling concept are: QSP (Quality Strip Production), fTSR (flexible Thin Slab Rolling) and ETR (Extra Thin Rolling).

With this diversified approach, appropriate solutions can be provided to suit specific needs, an approach that has allowed Danieli plants to exceed production of 3Mt/y, expanding the product mix to include virtually all the steel grades used for flat product applications. This includes the most demanding ones, such as peritectic, micro-alloyed, and silicon steels, for the most sophisticated applications, such as automotive and pipe manufacturing, including...
arctic applications, and extend the range of final strip thicknesses to include ultra-thin gauges.

**DESIGN APPROACH**

Soon after the first pioneering applications of thin slab casting and rolling technologies in the late 1980s, Danieli recognised the necessity to develop its own design concept to overcome the limitations in terms of quality and productivity of first generation plants. The areas in which Danieli introduced its innovative and comprehensive approach are:

**Thin slab caster** A vertical curved design has been adopted, including a patented dynamic soft reduction process (see Figure 1). This provides both superior slab quality and the maximum flexibility in selecting the slab thickness, according to both productivity and quality requested by the mill.

**Configuration of the mill** The first flexible thin rolling plants had all the rolling stands arranged in a single mill (see Figure 2). Danieli identified several mill stand arrangements with separation of roughing stands and finishing stands, in order to apply advanced rolling practices, such as ferritic rolling and thermo-mechanical rolling, typically adopted in conventional hot strip mills. The number of stands is selected according to slab thickness and final coil gauge target. These concepts are applied in QSP and fTSR plants. The ETR concept features an extremely compact layout where caster and mill stands can operate also in full endless mode, taking advantage of the high casting speeds available.

**QSP CONCEPT**

The QSP concept can be realised through several layouts that are tailor-made to specific market requirements, but always aiming for unbeatable productivity (in excess of 3Mt/y) and outstanding surface, internal and dimensional strip quality. The layout is designed for customers who want to produce the top range of commercial steel grades, and uses thicker slabs (up to 100mm), which makes it possible to achieve 2Mt/y with only one casting strand.
and the highest range of grades using ‘two-step rolling’ and thermo-mechanical rolling (see Figure 3).

The use of 100mm slabs and superior temperature control means that eight rolling stands can be installed (2RM + 6FM) to produce a complete range of products, including light gauge strip down to a thickness of 0.95mm in batch rolling mode. The QSP process consists of:

- Thin slab casting in a high productivity FTSC vertical curved caster installed in-line with the rolling mill, including the patented Danieli H2 mould and SEN, mould hydro-dynamic oscillation and dynamic soft reduction for excellent internal and surface quality with virtually no centreline segregation and a fine-grained product
- Cutting and rotary descaling of slabs at caster exit
- Heating the slab through a tunnel furnace, linking the caster to the mill
- Roughing mill comprising a high-pressure descaler, top driven vertical edger, and one or two roughing stands (see Figure 4)
- Transferring the rolled bar from the exit side of the roughing mill to the entry side of the finishing mill via a heated transfer table (HTT) and, if necessary, an intermediate cooling system, for a thermo-mechanical rolling process
- Finishing mill comprising a drum crop shear, high-pressure descaler and five or six 4-high finishing stands provided with state-of-the-art actuators conceived to operate below one quarter of the ASTM standard dimensional tolerances for most products (see Figure 5)
- Vertical edger attached to the roughing mill and, if necessary, to the finishing mill, for accurate strip width control
- Conveying the final strip through strip cooling equipment (WaterWall) to control the final temperature for control of metallurgical properties
- Coiling the strip on one or more coilers, comprising a set of centring side guides, deflecting pinch rolls and a downcoiler with three wrapper rolls drum crop shear at FM entry for safe and stable threading during thin and ultra-thin gauge rolling
- Possibility of installing an intermediate cooling system before the HTT when API grades and ferritic rolling are required
- Transferring coils from the downcoiler to the coil storage bays via a walking-beam system, which includes strapping and marking machines, weighing station and in-line coil inspection station

A more detailed explanation of the main advantages of QSP in the hot rolling mill area is given below.

**Separation of the RM from the FM** The division of the mill into independent RM and FM units as well as the distance between the roughing and finishing area considerably increases the overall flexibility of the plant. This ‘two-step’ rolling means that the transfer bar is not rolled in the RM and FM at the same time and makes it possible to roll the bar at a higher speed in the RM, resulting in less heat loss and scale formation.

Faster rolling in the roughing stand prevents local overheating of the work rolls, thus reducing roll wear, leading to increased rolling stability, longer roll life and improved final strip quality. Because the time that elapses between the first passes is the main factor in the recrystallisation of the internal structure, there is consistent microstructural refinement due to complete recrystallisation before the finishing rolling passes. The distance between the roughing and finishing areas, combined with the effects of the HTT and intermediate cooling between RM and FM, guarantees a homogeneous internal structure with small, refined grains, resulting in a final strip with improved mechanical properties.

**Vertical edger attached to the RM** The vertical edger provides accurate strip width control through effective slab edge rolling. It also creates superior edge quality due to the edge rolling that leads to edge grain recrystallisation, thus improving the mechanical properties of the edges. In addition, in the vertical rolling stand the tapered slabs produced in the caster during slab width changes can be recovered, thus increasing total plant yield. It also contributes to increasing rolling stability in the RM through better slab threading by working as a centring guide.

**Heated transfer table between RM and FM** The main role of the HTT is to keep the temperature constant throughout the entire transfer bar section and minimise the temperature difference between transfer bar head and tail ends, to ensure stable rolling conditions in the finishing mill. Moreover, it makes the plant considerably more flexible such that, for instance, in the case of an emergency, a portion or even the whole furnace roof can be lifted by means of the hydraulic cylinders installed on each section and the slab/transfer bar can be removed from the rolling line by means of a pusher device installed beside the line, without stopping casting operations, thus drastically reducing time losses due to cobble evacuation.

**Intermediate cooling system before HTT** When thermo-mechanical and/or ferritic rolling are necessary (eg, for API grades or ultra-low carbon steels), an intermediate strip cooling system is installed between the RM and the HTT in order to cool the transfer bar at RM exit, which is then rolled in the FM at the proper target temperature, >
with the following advantages:

- Very accurate strip temperature control thanks to the combined action of intermediate cooling and the pyrometer installed upstream the HTT
- Transfer bar is thermally homogenised
- A very fine grained metallurgical structure in the final product because there is no grain growth after rolling and no transient transformation from austenite to ferrite in the finishing mill
- Very stable rolling conditions

The three high pressure descalers installed at the caster exit (caster scale), RM entry (primary scale) and FM entry (secondary scale), give optimised descaling, according to the specific properties of the scale. This gives extremely efficient descaling and, thus, better strip surface quality.

**Drum crop shear at FM entry** A rotary drum crop shear is located in front of the finishing mill to optimise the shape of the strip head and tail ends, in particular during rolling of thin and ultra-thin gauges. A square strip head means good threading in the FM stands, while a square strip tail reduces strip chew-up on the work rolls. As such, the shear contributes to improving rolling stability, reducing the cobble ratio and consequently increasing both roll life and productivity.

**Runout table with laminar cooling unit** The laminar cooling system comprises WaterWall type headers, with the last group dedicated to fine-tuning of strip coiling temperature. Laminar cooling provides fine regulation of the water flow rate in the range of 40-100%, since each single unit (top and bottom) has its own proportional valves, enabling it to select the proper cooling pattern needed to achieve the required metallurgical and mechanical properties of the strip. A longer run out table with additional units could be supplied to fulfil the additional requirements needed to achieve stable production of dual-phase steel and trip steel, providing a powered cooling area when a high cooling rate is required.

**FLEXIBLE THIN SLAB ROLLING (fTSR)**

A more compact version of QSP is the fTSR configuration with reduced investment cost and production capability. The plant (see Figures 6 & 7) is shorter than the QSP as there is no HTT, and it has the RM and FM coupled to work in tandem. The fTSR has most of the advantages of the QSP in a more compact layout. The product mix can be considered in the medium-high quality range and can cover most market requirements, including soft API grades. The absence of two-step rolling only creates a limitation in special grades requiring a true thermo-mechanical process, such as pipeline grades like API X70-X80 for arctic applications.

The achievable production output depends strictly on the product mix, but is slightly lower than that of QSP due to the fact that nominal slab thickness is usually 70mm (with the possibility of reaching 85mm) rather than 90-100mm, based on the same product mix.

On the other hand, the compact configuration and the tandem rolling of RM and FM make the plant suitable for semi-endless rolling to produce ultra-light gauge down to 0.8mm on seven stands (2RM + 5FM), with the addition of a high-speed shear, threading device and high-speed coilers equipped with four wrapper rolls. This is a very attractive configuration due to the fact that you can start with a limited investment and only one casting strand, and then easily expand it at a later stage by installing a second casting strand in order to double production.
EXTRA THIN ROLLING (ETR)
This extremely compact configuration makes the plant suitable for a fully endless rolling process to produce thin and ultra-thin gauges down to 0.8mm. The configuration is very attractive due to the sophisticated process involved, but cannot be expanded at a later stage by installing a second strand caster. In order to obtain the most compact layout (see Figure 8) by directly linking the mill facilities to the caster line, the following equipment flow has been devised:

- Roll grinding workshop
- Motor rooms and electrical rooms
- Hydraulic and lubrication rooms

Two rolling processes can be performed with the proposed layout:

**Batch rolling** In this mode, the roughers always work continuously linked to the caster and the slab is endlessly reduced to the desired transfer bar thickness. The bar is heated via the induction heating system and then coiled in the mandrel box. During coiling, it is separated from the next transfer bar by a crank shear and, to create a gap between the two transfer bars, since the casting speed cannot be changed, the tail of the downstream bar is accelerated. Simultaneously, the mandrel where the coiling is being completed is moved from coiling to uncoiling position.

Two operations are performed: First, the other mandrel (the empty one) is placed in coiling position in order to thread the subsequent transfer bar for coiling. Second, the mandrel where the transfer bar has been coiled is already in the uncoiling position and the bar can be threaded into the finishing mill without wasting any time. Transfer bar head and tail shapes are then optimised by means of crop shear, descaled at the second high-pressure water descaler and then rolled to the final target strip. WaterWall laminar cooling ensures optimum target coiling temperature; coiling is carried out on the downcoiler.

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**Fig 7** ftSR layout

**Fig 8** ETR layout
The plant is designed to guarantee the highest flexibility during both caster start and caster stop. During the start sequence, the dummy bar is removed in front of the roughing mill high pressure water descaler. The head enters the three roughing stands. In each stand, just after biting, the roll gap closing procedure begins in order to obtain the target thickness, allowing a dynamic reduction of roll gap and decreasing the bar thickness.

The initial length of the transfer bar (tapered due to dynamic reduction) is cut by the shears (pendulum or crank type, depending on cutting thickness) and the plates are removed off-line by the piler system. Once the correct casting speed and the proper transfer bar thickness have been achieved, the material is ready to be sent to the induction heater to complete its route. Likewise, at the end of the sequence, transfer bar thickness is dynamically increased by the opening of the roughing mill stands in order to obtain cast slab thickness. Tapered sections are cut and removed by the plate piler. The achievable production level strictly depends on the product mix.

If we consider a slab thickness of 80mm and a high casting speed of ~7m/min, production can exceed 2Mt/y of hot rolled coils. On the other hand, the extremely compact configuration also makes the plant suitable for a fully endless rolling process to produce thin and ultra-thin gauges down to 0.8mm. The configuration is very attractive due to the sophisticated process involved, but cannot be expanded at a later stage by installing a second caster strand.

CONCLUSIONS
The QSP, fTSR, and ETR layouts provide a range of options for customers to meet the great variety and combination of output, quality, steel grades and strip gauge in today's markets. Each one of these plant configurations can be selected based on an optimised capital and operating cost approach to the specific needs of the market that our customers intend to target.

Based on positive experiences, Danieli thin slab casting and rolling technologies have proved capable of producing not only commercial grades, but also strip for high added-value market niches. Thanks to Danieli ultra-high casting speed technology, productivity of 4Mt/y is possible.

These results indicate that the gap between thin slab casting and rolling plants and conventional thick slab-coil mills is almost closed, with virtually all market segments benefitting from lower plant investment and conversion costs associated with thin slab technology.

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