In order to extend the range of steel grades and increase production capacity, Nucor has contracted Danieli to upgrade its hot strip plant in Ghent, KY.

The new plant configuration - from compact thin slab casting and rolling plant to ultra-modern QSP® (Quality Strip Production) - will allow Nucor Steel Gallatin to improve thermomechanical rolling capabilities, therefore expanding production of AHSS grades, API line pipe steel grades and a number of other added-value grades. This is the first time that a classical compact thin slab casting and rolling plant is fully reconfigured into an ultra-modern QSP®.

The revamped plant will include a new meltshop comprised of a high-performance DC EAF featuring the Q-Melt package, twin ladle furnace and provision for a vacuum degasser in the future.

Both Nucor and Danieli teams are committed to set a new benchmark in casting and rolling technology.

“This investment is another major component of our strategy for long-term profitable growth,” explained Ladd Hall, EVP of Flat-Rolled Products at Nucor. This expansion increases our presence in the Midwest market, specifically in the automotive, agriculture, heavy equipment, and energy pipe and tube sectors.”

Re-engineering Nucor Steel Gallatin with QSP®

In the spirit of full partnership, the Nucor and Danieli team of specialists agreed to re-engineer the plant by changing the original concept into an advanced QSP® plant having improved thermomechanical rolling capabilities, thereby expanding production of AHSS grades, API line pipe steel grades and a number of other added-value grades.
“For more than 20 years my work has been dedicated to thin slab casting and rolling and I personally visited the Nucor Steel Gallatin Plant the first time back in 2002. Looking at the new plant concept, I am very proud that Nucor and Danieli teams together will convert the existing concept into a new generation of thin slab casting and rolling plants,” said Christian Bilgen, EVP Rolling Technologies, Danieli. “The possible product portfolio will be significantly widened, including thick API line pipe steels, and the product quality will be considerably increased.”

The revamped plant will include a high-performance DC EAF and Twin LMF, with provision for vacuum degassing in the future. Being equipped with state-of-the-art technology, the new meltshop will make use of the most recent process management tools. One of these will be the new Q-MELT technological package, which is a key function for optimizing the transformation costs.

“The new meltshop shall be the most modern one in the USA, where plant operations are surrounded by the latest steelmaking technologies,” explained Paulo da Costa, Meltshop technical sales manager for Danieli. “Industry 4.0 is a key aspect in the process control, either by applying adaptive process control for the 188-sht DC EAF, where Q-MELT dynamically will alter the EAF profiles for the best practice, or by using mechatronic technologies that make it possible to conduct majority of the operations remotely from the main pulpts. Safety and productivity are the pillars that will guarantee the success of this project.”

If for the meltshop the project foresees doubling production by installing a new production unit, the design vision changes for the casting and rolling plant. After the upgrade, the complete production will be delivered by a single-strand vertical curved caster having a total capacity of up to 3.0 million shtpy.

The new caster represents the fifth generation of Danieli high-production slab casting machines. The slab will be delivered to the rolling mill by a new tunnel furnace via a swivel-type ferry system. The new layout will allow for the installation of the new caster and first portion of the tunnel furnace and swivel system without affecting the mill’s production. Furthermore, two new roughing mills will be added to expand rolling capabilities.

The independent high-speed roughing, intermediate transfer bar cooling and final finishing rolling introduces the ability to perform a thermomechanical rolling process, as is typical for conventional hot strip mills.

This will lead to a complete replacement of the existing tunnel furnace, widening of the finishing mill equipment, new run-out table with advanced combined intensive and laminar cooling and two new downcoilers with coil handling.

The vertical-curved caster will be equipped with a complete suite of advanced technological packages, including Danieli’s latest design of multi-mode electromagnetic brake (MM-EMB) to ensure the control of fluid dynamics within the mould, enabling high throughput of quality thin slabs.

Higher-quality, wider strip by Danieli QSP® at Nucor Steel Gallatin

The six-stands finishing mill will be retained but it will be widened and upgraded with new interstand guides, loopers and a new bending and shifting system. This will
allow Nucor Steel Gallatin to roll strips as wide as 1,870 mm (73.5 in). To further enhance the performance of the finishing mill, the first three rolling stands will be reinforced to withstand higher rolling forces.

Two new powerful roughing stands and a vertical edger will be installed ahead of the finishing mill. With its total draft of 100 mm, the powerful edger allows the full recrystallization of the slab edges and makes it possible to expand the capacity of the plant when producing narrow products.

**Optimizing implementation, operation**

The complete process control from melting to finished hot-rolled coils will be developed by Danieli Automation. The challenge is to optimize the operation between the existing and the new meltshop, while controlling the quality of the caster and QSP®. As part of the implementation strategy, the new automation system will shadow and parallel the current automation systems to allow seamless switchover to the new automation. The automation system will be designed for integrating the industry 4.0 concept.

The project will be implemented over a sequence of three carefully planned mill shutdowns after 9, 15 and 23 month. The strategy will take maximum advantage of the annual maintenance outages already planned by the plant.

During the last shutdown the complete roughing mill group, previously preassembled off-line, will be moved in line via a lift-shift system. The foundations of the mills will be prepared under the existing tunnel furnace without interfering with the production.

With this project to convert a compact mill into a QSP® plant at Nucor Steel Gallatin, together with a high-performance meltshop, the Nucor and Danieli teams are determined to establish a new benchmark casting and rolling plant throughout the world.

**Danieli QSP® Technology / Concept, history and evolution**

Over the last 25 years the thin slab casting and rolling (TSCR) process has been gaining a major market share in the production of hot rolled strip, progressively decreasing the exclusive advantages of conventional mills. Danieli has developed a complete portfolio of plant layouts adopting TSCR technologies, each of these conceived to guarantee the optimal CapEx and OpEx parameters in line with market requirements:

> Exceeding production of 3.0 million tons per year.

> Expanding the product mix to include virtually all the steel grades used for flat product applications, including the most demanding ones, such as advanced high strength steels, micro-alloyed, silicon steels for the most sophisticated applications, such as automotive and pipe manufacturing, including Arctic applications.

> Extending the range of final strip thicknesses to include ultra-thin gauges below 1.0 mm.

The separation of the roughing stands from the finishing stands and the use of a vertical curved caster with thicker slabs is the distinctive concept of Danieli’s QSP®. It is the result of more than 25 years of experience and R&D.

The first plant ever installed with this configuration was the North Star BlueScope QSP® in operation at Delta (OH) since 1997. It was followed by Algoma Steel (Canada) in that same year, and later by Ezz Flat Steel (Egypt), OMK (Russia), MMK (Turkey), NMDC (India), SGJT (China) and Hoa Phat
Different plant configurations for HRC production

The Danieli Wean United QSP® (Quality Strip Production) is a technology for thin slab casting and rolling plants designed according to the specific needs of the product mix and production capacity.

Soon after the first pioneering applications of thin slab casting and rolling technologies in the late 1980s, Danieli recognized the necessity to develop its own design concept to overcome the limitations of “first generation” plants in terms of quality and productivity. The two main areas on which Danieli introduced its innovative and comprehensive approach are the thin slab caster design and the configuration of the rolling mill.

Since its first pioneering applications in 1985, the vertical curved caster design has been adopted, with application of the patented dynamic soft reduction process. This design allows both superior slab quality and maximum flexibility in selecting the slab thickness, according to both productivity and quality requested by the mill.

Compared with other rolling mill configurations, where all rolling stands are arranged together and operate as a single Finishing Mill, Danieli identified several mill-stand arrangements with separate roughing stands and finishing stands in order to apply advanced rolling practices typically adopted in conventional Hot Strip Mills, such as thermomechanical rolling. The number of stands is selected according to targeted slab thickness and final coil gauge.

The QSP® layout is recommended for very demanding customers who want to produce the top range of commercial steel grades. QSP® is designed to work with thicker slabs (up to 130 mm) than other thin slab technologies. This makes it possible to increase production levels up to 2.0 Mt/y with only one casting strand, and to produce the highest range of grades using the controlled metallurgical technology with “two-step rolling”, thermomechanical rolling in particular, due to the special layout features exclusively installed in this plant configuration.

The thicker slabs and the superior temperature control of the QSP® layout mean that eight rolling stands can be installed (2 RM + 6 FM) to produce a complete range of products, including light gauge strip down to a thickness of 1.0 mm in coilot-coil rolling mode. The investment required to implement the QSP® configuration is fully repaid by the possibility of mass producing products with high added value, which means that the plant is very profitable even with only one casting strand, without the need for future expansion.

The QSP® layout provides several advantages that lead to superior strip quality:

- Vertical edger attached to the roughing mill for accurate strip width control.
- Separated roughing mill and finishing mill to increase the overall flexibility of the plant and the steel grade production range.
- Transfer bar furnace (TBF) to homogenize transfer bar temperature, with consistent benefits in terms of rolling stability in the finishing mill.
- Possibility of installing...
an intermediate cooling system before the TBF when API grades are produced.

> Three high-pressure descalers positioned throughout the mill to ensure a superior quality strip surface.

> Drum crop shear at FM entry for safe and stable threading during thin and ultra-thin gauge rolling.

An alternative QSP® layout is recognized by the marked being a perfect compromise between investment cost and production capability. This QSP® layout is shorter, due to the fact that there is no TBF. This makes the layout very compact with the RM and the FM coupled to work in tandem. The configuration has most of the advantages of the QSP® (e.g., three descaling points, vertical edger at RM, crop shear before FM, intermediate cooling and advanced run out table cooling system) in a shorter layout.

The product mix can cover most market requirements. The absence of “two-step rolling” (thus a long intermediate table and related TBF) only creates a limitation in special grades to be produced with true thermo-mechanical processes, such as thicker pipeline grades API X70-X80 for Arctic applications. The nominal slab thickness in this configuration is usually 70 mm (with the possibility to reach 85 mm).

The compact layout and the tandem rolling of RM and FM make the plant suitable for semi-endless rolling technology to produce ultra-light gauges below 1.0 mm on seven stands (2 RM + 5 FM), with the addition of special machines such as a high-speed shear, threading device and high-speed coilers equipped with four wrapper rolls.

**Danieli Universal Endless DUE® for no production and market limitations**

Danieli, together with its customers, has progressively developed a new generation thin-slab casting and rolling layout, marking a new phase in the evolution of the QSP® process. The innovative features of the process are embodied in the acronym DUE®, which stands for Danieli Universal Endless.

What makes the DUE® concept different is the ability to adopt “universal” rolling modes resulting in the fact that now, within a single plant, it is possible to perform endless and coil-to-coil rolling. This new approach can be seen as the natural evolution of the original QSP® design.

What makes the DUE® concept different is the ability to adopt “universal” rolling modes

**Flexible mill design.**

Danieli concepts that marked the progress of the thin-slab route, namely the application of the vertical-curved design thin-slab caster, and the separation of the rolling stands into high-reduction units and finishing units.

The market recognizes significant extra margins for advanced high-strength products compared to mass production of soft grades with lower revenues. At the same time, thin and ultra-thin gauge products are generating significant profits. The DUE® technology ensures the success for the complete steel grade portfolio.

Danieli Universal Endless constitutes a universal tool able to reach all the production requirements of the flat products market by applying the process that is best suited to each steel grade and product. Endless and coil-to-coil process modes, thermo-mechanical rolling and multi-phase grades, ultrathin and thick products all are now possible in a single production line.

The ability to provide the mill with a thicker slab (110 mm), compared to the traditional thin-slab approach, is reflected in the remarkable increment in the reduction ratio from slab to strip, which in turn allows the production of ultra-thin gauges down to 0.8 mm and wall-thickness strips up to...
25 mm, in widths from 900 mm up to about 2000 mm.

Slab-width change during casting is an incorporated function of the technology, thus further increasing plant flexibility. Thanks to the combination of slab thickness (110 mm) and casting speed (over 6 m/min). Due to this the production rates up to 3 Mtpy are possible on a single casting strand, making the CapEx investment per ton extremely attractive.

The DUE® unique vertical-curved caster features a 5.5 m main radius, designed to operate with a single slab thickness of 110 mm after dynamic soft reduction (130 mm at mould exit), with a casting speed in excess of 6 m/min, depending on the steel grade. Such an unprecedented combination of slab thickness and speed makes it possible to easily reach the mass flow conditions required by the full endless production mode, necessary for effective production of ultra-thin gauge.

The tunnel furnace, which is developed in-house by Danieli Centro Combustion, is approximately 80 m long and provides a fundamental buffer function that increases plant flexibility. It allows the work roll change to be performed as a background task, without affecting the operation of caster and meltshop, “switching” from endless to coil-to-coil operating mode during roll changes, which in any case does not reduce plant productivity.

The DUE® hot rolling mill features a well-known and already successfully proven configuration with separation of the mill stands into high reduction units and finishing units, in order to perform the dual step rolling. The transfer bar area includes:

> A drum crop shear for cutting head and tail ends, achieving most stable rolling conditions in coil-to-coil production mode and for automated emergency strategies in endless rolling.

> An induction heating system designed and manufactured in-house by Danieli Automation, for consistent production of thin and ultra-thin gauges in endless mode, which can be retracted off-line when not in use (i.e., during coil-to-coil production mode).

> A dedicated high-pressure descaling unit at the finishing mill entry (in addition to the one at high reduction stand entry), to eliminate imprinting scale phenomena on the final strip.

> An intensive cooling system, incorporated into the descaler box at finishing mill entry, used when producing TMR and/or API grades in order to guarantee the correct bar temperature profile and to achieve proper control of grain growth, which are essential features of the thermo-mechanical rolling process.

The mill stands, designed to guarantee superb geometrical and mechanical properties of the...
final product, are equipped with all the state-of-the-art features for exceptional strip crown and profile control, bearing in mind that these control functions also have to be operational under-load conditions as required by the endless rolling process. The line is completed with the laminar cooling system, consisting of a combination of power and normal units for outstanding strip cooling strategies, followed by the coiling area, made up of a high-speed shear for cutting coils to length when working in endless mode, pinch rolls and downcoilers.

**Danieli QSP® plant performances**

OMK Vyksa is a Danieli single-strand QSP® plant with a plant layout similar the one planned for Nucor Gallatin. It starts with a casting machine producing 90 mm slabs, a 200 m tunnel furnace, two powerful high-reduction stands, a transfer bar area with intermediate transfer bar cooling and TBF that is followed by six finishing stands. Due to this flexible plant layout, OMK is able to cover a wide range of products from thin gauges of 1.0 mm up to 12.7 mm of API grades for special application in an overall width range of 800 to 1,800 mm.

In 2015 the product mix consisted of more than 50 percent API grades (up to API X80) and in general of products with an excellent surface quality (98.6 % prime rated coils). Today OMK operates the mill constantly above the rated capacity of 1.2 Mtpy and will achieve a new production record this year close to 1.3 Mtpy.

Talking about productivity, Tangshan Iron & Steel in China was the first thin slab plant in the world to exceed 3.0 Mtpy after adopting the thin slab casting and rolling process in 2005.

The installation of a new intensive cooling unit in the ROT cooling section will help OMK to increase the mechanical properties of the produced steel grades (strength and impact toughness) and opens up the possibility to decrease high-cost alloying elements, such as manganese, silicon and niobium.

**QSP® final products**

The mentioned QSP® plant of OMK in Vyksa is one of the world’s powerful thin slab plants for pipe grade production. In 2017 99 % of the products were used for pipe applications, with approximately 50 % falling under API or similar specification.

OMK is using those pipe grades in their own pipe shops to produce final products for the oil and gas pipe market.

In 1997 Essar Steel Algoma in Canada became the first thin slab casting and rolling plant in the world to produce peritectic steel grades, as well as HSLA grades like DSPC 700 with a yield strength exceeding 700 MPa, which are used for example in the automotive sector. Customers to whom Essar Steel Algoma regularly supplies these grades include all of the major North American OEMs, primary suppliers to the auto industry, major service centers in the Midwest, as well as Tier 1 manufacturers (among whom are the largest car manufacturers in North America).

Looking into the market of electrical applications, like the laminations for the cores of transformers and the stators and rotors of motors, Benxi Iron & Steel (China) is a pioneer in the production of silicon steel using its thin slab casting technology to produce electrical steel with a Si content of up to 3.2 % with more than 4.0 m/min casting speed.