

Danieli Concepts & Experiences in Casting & Rolling HR Coils

Abstract

The thin slab casting and rolling process has been gaining momentum over the last 25 years and winning a significant market share in the production of hot rolled coils, progressively eroding the production areas previously of exclusive domain of conventional hot strip mills. This has resulted, thanks to the economic competitiveness demonstrated over conventional process as well as to the growing capabilities of such technology to cover the large majority of market niches, in crossing well beyond the boundaries of the mere commodity market.

Thin slab casting and rolling has been originally developed as a low cost alternative to conventional casting and rolling process route. However, due to the initial restrictions of this technology, limited quality and productivity goals could be achieved, questioning the further application of this production route to more advanced products.

This paper describes the original contributions Danieli gave to the development of this concept, from first generation plants to present front running applications including production of high-added value grades, flexibility in operating mode (including endless process) and new products (including ultra-thin gauges market), with productivities compared to conventional HSMs.

Since its first pioneering applications in 1984, Danieli developed his own original design and technology, strongly diversified from other available solutions on the market that allowed Danieli plants to largely overcome the original limitations.

- **Sanat K. Bhaumik**, Sr. Vice President (DWU), Danieli India Limited
Matteo Bulfone, Product Manager (DWU), Danieli & C. Spa, Italy
Mike Knights, Sales Director (DDU), Danieli & C. SpA, Italy
Santanu Rudra, General Manager (DWU), Danieli India Limited

QSP Concept

Without any doubt, it can be stated that few other technologies shown in the last 2 decades a comparable booming development from the original targets similar to this one. This process, that for the first time considered the full integration of the casting and rolling processes previously seen as “separate world”, gave a fundamental contribution in the progress of the steel industry.

It is well known that the original idea that generated this concept was to establish a viable economical alternative to conventional process route, with the target to limit both capital investment and operational transformation cost involved by the huge conventional complexes till that time have been the only way to produce hot rolled coils.

This concept has been a winning concept, however, due to technological limitations of what Danieli calls “first generation plants”,

involved also some substantial limitations in his applications, namely :

- A limited range of grades could be produced according to market requirements
- A limited productivity could be reached, mainly due to the limitation in caster productivity, hence limiting to “a regional approach” the market that can be targeted.

Since the first developments of this process route, Danieli clearly identified these as limitations that must be overcome, in order to guarantee investment profitability.

In a nutshell, commercial and regional market could be served by those plants, but with neither the scale economic advantages of mass-production nor high-added value products margins, and without these competitive tools the coil total Opex cannot be economically sustained by present market: commercial grade target and productivity less than 1.5 - 1.6 Mtpy are not economically sustainable at present.

Starting from this early recognized stand points, Danieli has been constantly developing its own approach to the design of thin slab casting and rolling plants, generating a diversified portfolio of layout solutions under the commercial name of QSP, which stands for Quality Strip Production, with a not incidental reference and emphasis to the quality aspects.

The selection of such product name aims to emphasize the clear target to enlarge the application range of this technology and, doing so, strongly diversifying Danieli design from other available solutions, still at present recalling first generation solutions, in reaching the following goals :

- Increase the production level
- Extend the product mix
- Increase the quality of the products
- Introduce new products in the range of hot rolled coils, normally not targeted by conventional mills, such as ultra-thin gauges production.

These are the results that have been progressively reached adopting Danieli technology :

Productivity

A massive progress separates the original 0.8 Mtpy (per casting strand) of first generation plants, from present target productivity already consolidated at 2 Mtpy (per casting strand).

Mix Grades

Product mix impressively evolved over the years; from low and medium carbon grades of first generation plants we have been able to progressively produce in industrial conditions Peritectic, HSLA, API grades for arctic applications and Advanced High Strength Steel, among others. Let's resume, through the world record performances successfully reached in Danieli plants, the state-of-the-art of this process:

Flexibility in Productivity

Tangshan Iron & Steel plant, (P.R. China) has been the first plant in the world able to produce in excess of 3.0 Mtpy of coils adopting thin slab casting and rolling process, since 2005.

Starting from this consolidated result and based on records reached in the Ultra-High Speed Casting machine in Posco (Korea) with over 7m/min in stable conditions, Danieli is in position to propose a thin slab casting and rolling plant targeting 4 Mtpy, with 2 casting strands.

Flexibility in Quality

Essar Algoma Plant (Canada) : The first plant in the world to

produce Peritectic steel grades since 1997, adopting thin slab casting and rolling process. Danieli Thin Slab Casting process is the only technology that ensures the cast of these steel grades. Essar Algoma developed HSLA grades with High strength like DSPC 700 which has a yield strength exceeding 700 MPa, for several applications including automotive, weathering grades, drawing quality.

Fig.1 - Essar Algoma Adopted the Thin Slab Route for the Production of Peritectic Grades



Benxi Iron & Steel plant (P.R. China), pioneering silicon steel production in China using Thin Slab Casting technology, which successfully cast silicon grades with a Si content up to 3.2% at over 4 m/min.

Fig.2 - Benxi Iron & Steel has Successfully Cast Thin Slabs with High Si Content Up to 3.2%



Last but not the least, it is worth to mention the outstanding performances reached at OMK plant (Russia), the first thin slab casting and rolling plant in the world specifically conceived for the production of top quality pipe grades, like API X70 and X80 even for arctic applications.

Environmental Aspects

Environmental issues are not a luxury option for industrial countries only on the contrary “green steel”, “green plants” and “environmental sustainability” are fundamental mantras for all the world steel industry, worldwide. In this thin slab casting and rolling technology can give a substantial contribution to social acceptance of steel plants, with his

Fig.3 : Top Quality Pipe Grades Produced at the First Thin Slab Casting and Rolling Plant in Russia



reduction down to 35% of the carbon dioxide emissions, generated by the absence of intermediate reheating process of the slabs: temperature equalization only is foreseen.

Danieli Approach in QSP Technology

Danieli, since its first pioneering experiences in 1984, developed his own design concepts marking its original approach, market oriented, and based on the following principles:

- Definition of the slab thickness according to quality and productivity requested by the mill
- Definition of mill layouts that allow the application of non-only basic rolling process but also sophisticated ones as in conventional mills for advanced applications.

Due to this approach, Danieli is not marketing a single solution, but a complete portfolio of plants that allow our customers, in a flexible way, to answer to the specific needs of their market, with an eye on the future, with expandable solutions open to market trends.

Two are the areas where Danieli differentiate its product compared to other available solutions :

- Caster design and
- Mill arrangement

Thin Slab Caster (TSC)

Since the first applications Danieli adopted a thin slab caster that strongly differs from other technologies, as summarized in the following comparison :

- Vertical curved design versus vertical design
- H2 long funnel mould versus conventional short funnel mould
- Dynamic soft reduction versus static soft reduction
- Air mist secondary cooling versus water only
- Independent cooling of all rolls and wear sensitive elements versus non cooled elements

All Danieli thin slab casters embody these concepts in casting thin slabs ranging in thickness from 45 up to 110 mm (always with the application of dynamic soft reduction process), selected according to final product quality requirements.

New concepts in roll diagram design as well as in fluid dynamic control in mould allow Danieli to combine these slab geometrical features with unprecedented casting speeds, up to the consolidated world record pick values of 8mpm and daily average speeds in excess of 7mpm reached in Danieli reference plant in POSCO.

Rolling Mill Layout

During the constant evolution process, the following solutions have been developed and installed by Danieli, targeting different market needs, progressively more stringent.

Fig. 4 : Casting Speed Over 7m/min for an 80mm Thin Slab at Posco Gwangyang Works



As starting approach, our first generation of thin slab casting and rolling plant was mainly composed by a 60mm slab caster followed by tunnel furnace and a finishing mill consisting of 6/7 rolling stands in cluster configuration, but we shortly evolved from this basic approach, not any more compatible with present market conditions, to the QSP concepts described below.

In order to introduce the “flexibility” concept, Danieli conceived in this layout a physical separation between roughing and finishing stands to allow the installation of:

- The insertion of a dedicated high-pressure descaling unit at finishing mill entry, to limit imprinting scale phenomena, thus significantly improving the surface quality of the final coil;
- The installation of a crop shear, for transfer bar head and/or tail end cut, in order to have a smoother threading into the finishing mill as well as to reduce tail chew-up;
- The fitting of an intensive cooling system, used when producing API grades in order to guarantee the correct bar temperature profile and proper control of grain growth that are essential feature of the thermo-mechanical rolling process

For some specific applications, a complete separation between roughing and finishing stands can be achieved further increasing the gap between Roughing and Finishing stands up to the length of the transfer bar, and adding a heated transfer table homogenizing the bar temperature over such distance.

Such solution allows to completely uncouple the rolling conditions in roughing and finishing units, both operating at the optimal rolling conditions (in speed and temperature) allowing the real “two step” rolling and replicating the process parameters applied in semi-continuous mills.

Last Reference in India, NMDC Nagarnar Plant

A promising market is also represented by “thin gauges” of 1 mm and below. To materialize this trend, it is worth to mention the most recent order awarded to Danieli concerning this kind of plants. The NMDC new integrated plant in India, including a 2.9mtpy thin slab casting and rolling plant ordered on Danieli led consortium on full turnkey basis and at presently under execution. The product mix targeted by this project is a good example on how diversified the reference market for these plants can at present be, representing a tangible sign of the versatile approach that is necessary to follow when conceiving these new massive

Fig.5 : Separation Between Roughing & Finishing Stands, MMK Metalurgy Turkey



investments, focused to serve a constantly evolving market. Such dramatic versatility embodied in Danieli plants, rely upon two distinguishing features, originally developed since the first pioneering application and identified as the two technological hearts of the plant – (1) The vertical curved thin slab caster, at his 4th generation of development, compared to standard vertical caster considered by other potential suppliers and (2) The dual step mill design, with partition of mill stands in separate roughing and finishing units, compared to a more conventional “Cluster Mill Configuration”, with all stands grouped in a single array.

Endless Process

In recent years, the progressive increase in mass flow (i.e. higher casting speeds) inherited from the last generation of thin slab casters operating at ultra high casting speeds, together with reliable application of induction heating technology, made it possible to develop, test and put in operation a new generation of plants, specifically consecrated to the production of ultra thin gauges.

Such new market segment generated growing interest from market, allowing directly substituting some cold rolled products, or reducing the transformation costs in strip processes downstream.

This was made possible by the development of the endless rolling process (i.e. the direct, uninterrupted connection of casting and rolling) overcoming the obstacles represented by the well known problems of “flying strip head” between the finishing mill exit and the down coilers, when producing coils with final thickness below 1 mm.

Such concepts have been first materialized in the CEM Project in Korea, developed in close cooperation with Posco and in successful operation since 2009, specifically conceived for the production of thin gauges and the application of endless casting and rolling process.

Such extremely compact plant, less those 200 meters in length, features the possibility to operate in coil to coil or in endless mode according to the specific metallurgical needs of the steels to be produced and the optimal rolling conditions of the mill, in order to safely operate in endless mode when producing coil gauges of and below 1 mm. Thanks to the specific features we have developed, including ultra-high speed casting technology (up to 7mpm as standard cruise speed and with a record of 8mpm) the following unprecedented performances have been proven and consolidated. This facility is for sure the most productive single casting line plant in the world.

In this plant productivity is driven by caster: thanks to ultra-high speed casting technology the available mass flow is unprecedented.

Fig. 7 : The Most Productive Minimill in the world at Posco Gwangyang works, South Korea



Evolution

The market is in constant evolution, and considering the multi decennial operating life of these plant, the choice of the layout must keep into account not only present market needs, but must be open to evolution towers more sophisticated grades and applications, already in the horizon of the possible applications.

Such concept is materialized by Danieli by the application of a modular layout concept, which can progressively evolve according to the market needs, reconciling the need of present investment optimization with future evolution.

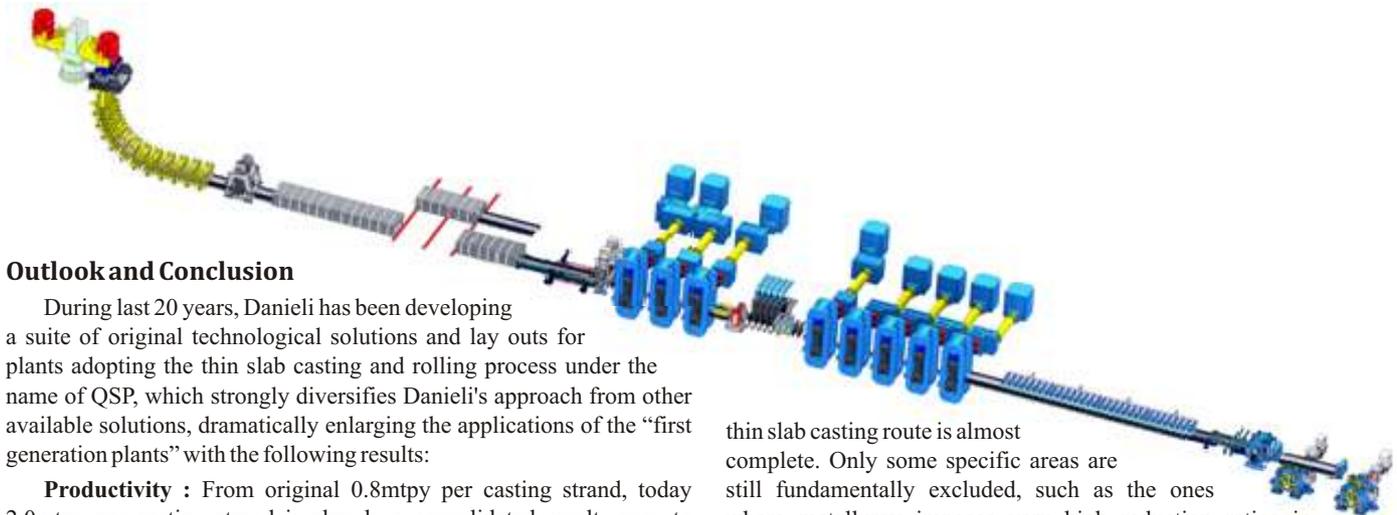
Present this slab mills, aside the conventional operational process in coil to coil, have the target to apply more sophisticated process, such as semi endless and endless for thin gauges or thermo mechanical rolling for the production of advanced API grades for the oil and gas industry.

QSP layout allows the possibility to install the proper equipment in an evolving step by step process, as soon as the market is there to justify the additional investment. For this reason the modularly granted by the QSP layout is a must, having the possibility to progressively install additional equipment from the “base configuration” in order to move the target from commodity market production to much more advanced applications.

In between roughing and finishing mill stands, there is the possibility to insert in line induction heaters, to master strip temperature along the mill in case endless process is applied, and intensive cooling, to guarantee the necessary temperature drop below the not recrystallization temperature before entering the finishing mill as requested by thermo mechanical rolling.

The combination of these features, together with the proper cooling sequence on the run out table allows to closely control along the whole mill both temperature and grain size, in order to reach the final microstructure, including the most sophisticated “engineered” crystallographic matrices of multiphase steels. Going back to the roots of the investment, thanks to his massive productivity, this plant shows also the best transformation cost compared to any other technological solution available on the market.

An optimized layout, fit to the purpose of present market, but allowing the full flexibility of his modular design to evolve to more sophisticated and productive scenarios, as soon as the market allows / requires it. The “full-fledged QSP evolution” that, since the beginning of the investment, allows reaching unprecedented and uncompromised quality and productivity results.



Outlook and Conclusion

During last 20 years, Danieli has been developing a suite of original technological solutions and lay outs for plants adopting the thin slab casting and rolling process under the name of QSP, which strongly diversifies Danieli's approach from other available solutions, dramatically enlarging the applications of the "first generation plants" with the following results:

Productivity : From original 0.8mtpy per casting strand, today 2.0mtpy per casting strand is already a consolidated result, open to further expansion. We can state that, thanks to the experiences of ultra high speed casting, today it is possible to conceive a thin slab casting and rolling plant, with two casting strands with a productivity of 4mtpy, as a classic conventional mill.

Quality: At present the "conquest" of the flat product market by the

thin slab casting route is almost complete. Only some specific areas are still fundamentally excluded, such as the ones where metallurgy imposes very high reduction ratios in rolling, or where process temperatures are not compatible with an uninterrupted process. Niche high-added-value products or mass-production commodities are both markets that can be served by this new single production line, which has enhanced and expanded one of Danieli's cornerstone concepts: "flexibility".



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