

# “FROM “MINI” TO “MICRO” AND THE EVOLUTION TO “NANO” UP TO THE LATEST “ESC” ENERGY SAVING COMPACT MINIMILL: DIFFERENT METHODS TO PRODUCE COMMERCIAL STEEL GRADES IN AN EASY AND ENVIRONMENTAL-FRIENDLY WAY\*

Luca Mottes<sup>1</sup>  
Achille Trisciuzzi<sup>2</sup>  
Andrea Taurino<sup>3</sup>

## Abstract

Since their beginning, Mini-mills had been growing in size to capture the economies of scale and have now reached capacities exceeding 1,000,000 tons per year. However, markets that can serve these volumes are being exhausted. From the early 70's, the mini-mill philosophy has been marked by, low-investment, minimal manning, low-operating cost Mini-mill that can serve specific geographic areas with a good balance of scrap supply and market for finished product. Over the years, the Danieli Group and several customers had worked strictly in order to come up with the right idea to fulfil this vision. The minimills have become a complement to the conventional integrated steel works for the competitiveness they have shown in producing commercial grades in bars, wire rod and spooled bars. In addition, they are the most convenient way to recycle the scrap available in the industrialized countries or to use the raw materials in the developing countries without having to resort to large investments and infrastructures. After eighties and more installations worldwide the evolution, started on 1976 with the first minimill complex realized in Italy, the process goes on through large capacity integrated minimills in Middle and Near East countries to “region-market” Micromills and Nanomills to the recent introduction of ESC environmental-friendly type minimills for bars for commercial grades production.

**Keywords:** Minimill, Micromill, Nanomill, ESC minimill, Compact Mill, Regional mill, Energy saving.

<sup>1</sup> Executive Vice President, Key Account Management , Danieli&C.OfficineMeccanicheSpA, Buttrio, Italy

<sup>2</sup> Sales Manager - Long Products Steel Meltshops, Danieli&C.OfficineMeccanicheSpA, Buttrio, Italy

<sup>3</sup> Senior Product Manager – Long Products Rolling Mills, Danieli&C.OfficineMeccanicheSpA, Buttrio, Italy.

## 1 INTRODUCTION

Since their beginning, Minimills have grown in size to capture the economies of scale and have now reached capacities exceeding 1,000,000 tons per year. However, markets that can absorb these volumes are being exhausted. From the early 70's, the minimill philosophy has been based on low-investment, minimal manning, low-operating cost plants intended for serving specific geographic areas with a good balance between scrap supply and finished product market. Over the years, the Danieli Group and several of its customers have worked closely together in order to come up with the right idea to fulfill this vision. Minimills have become a complement to the conventional integrated steel production complexes for the competitiveness they have shown in producing commercial grades in bars, wire rod and spooled bars. In addition, they are the most convenient way to recycle the scrap available in industrialized countries or to use raw materials in developing countries without having to resort to large investments and infrastructures. After the 80's and more installations supplied worldwide, the minimill evolution, which started in 1976 with the first complex built in Italy, has seen large capacity integrated minimills in the Middle East countries, "region-market" Micromills and Nanomills, and the recent introduction of the ESC environmental-friendly type minimills for commercial grade bars.

The kick-off was in mid 2004 when Danieli approached CMC with a design concept that eventually led to the construction of the mill in Arizona. The design capitalizes on CMC's management and motivational philosophies and is based on the Danieli Endless Casting Rolling (ECR) process where melting, casting and rolling are carried out in one continuous and uninterrupted production process from scrap to finished product. This eliminates the need for a conventional reheating furnace with all the associated entry/exit equipment, auxiliaries and warehouse, which results in significant savings in terms of initial investment, utility consumption and running costs. The design also includes the "Direct Rolling & Bundling System" (DRB) enabling the cut to final commercial length directly off the last finishing stand. The result is a very compact arrangement of the whole cooling bed/bundle forming and tying station, with significant savings in both initial investment and production costs. The mill also features a Bar Quenching and Tempering System (QTB) allowing to produce low-cost billets in the meltshop by using fewer alloys and therefore reducing conversion costs.

In late 2009, the first heat was poured in the new DanieliMicromill at Commercial Metals Co. - CMC Steel Arizona in Mesa, Arizona. The new steel complex, the first of its kind worldwide, is based on the "regional-mill/product-focused" concept designed to serve a regional market concentrating on a specific product range and making extensive use of local scrap.

## 2 Mi.Da. - MAIN DESIGN DATA

The original idea was to develop a CMC Arizona vision for a mill with a design capacity of 300,000 short tons (272,000 metric) per year of finished product with a meltshop intended to work with 100% scrap-based and 35 short ton nominal heats. The rolling mill produces sizes ranging from #4 to #11 (12 to 36 mm) rebar.

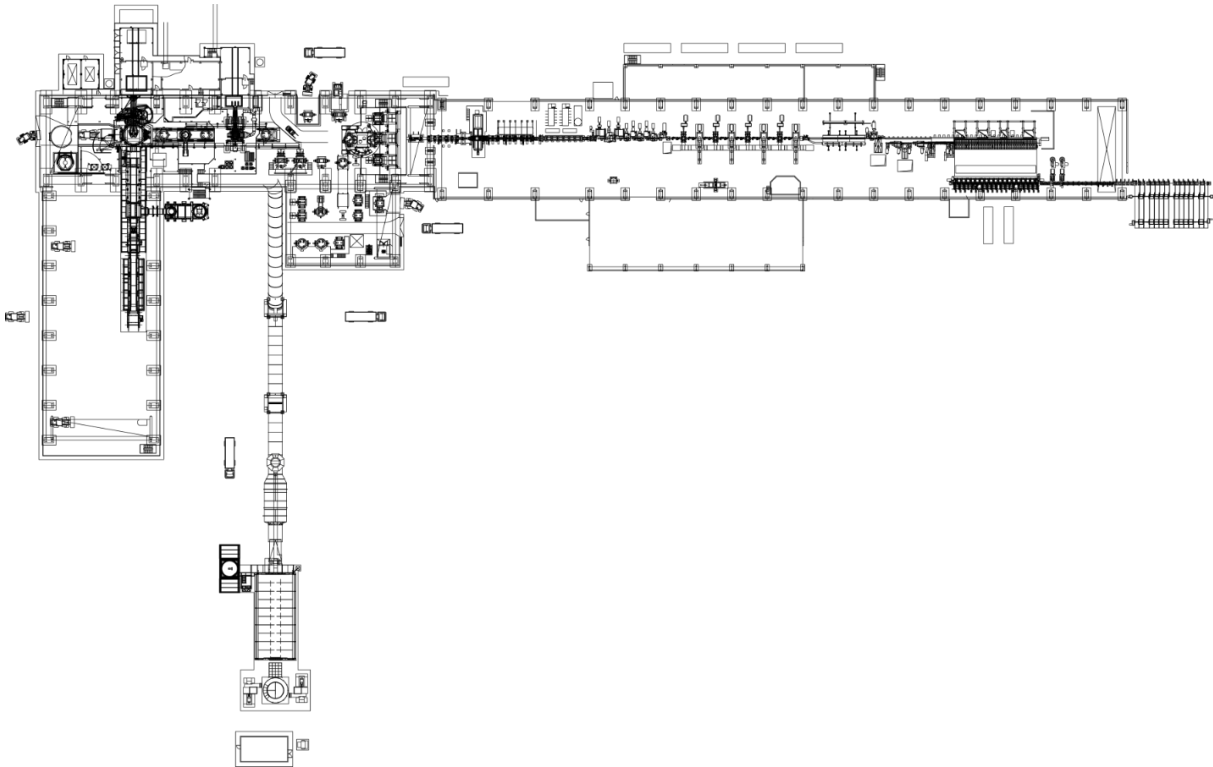


Figure 1. The CMC Arizona Mi.Da. layout

## 2.1 Steel meltshop

The very efficient plant layout features a continuous scrap feeding system that feeds the scrap into the 50-ton total capacity compact EAF (avg. 35 sh/tons of tapped steel). The system was supplied to work at 23MW active power to achieve the design TTT of 45 min. The performances reached so far clearly prove the soundness of the selected design and technical solution. Thanks to an innovative in-line ladle lifting system located underneath the ladle Furnace, the full ladle can be transferred from the tapping car to the LF car for subsequent treatment with no need of crane lifting. The Ladle Furnace is essentially used to achieve the correct chemistry and guarantee proper temperature control, which are both essential for the downstream ultra-high speed casting process.

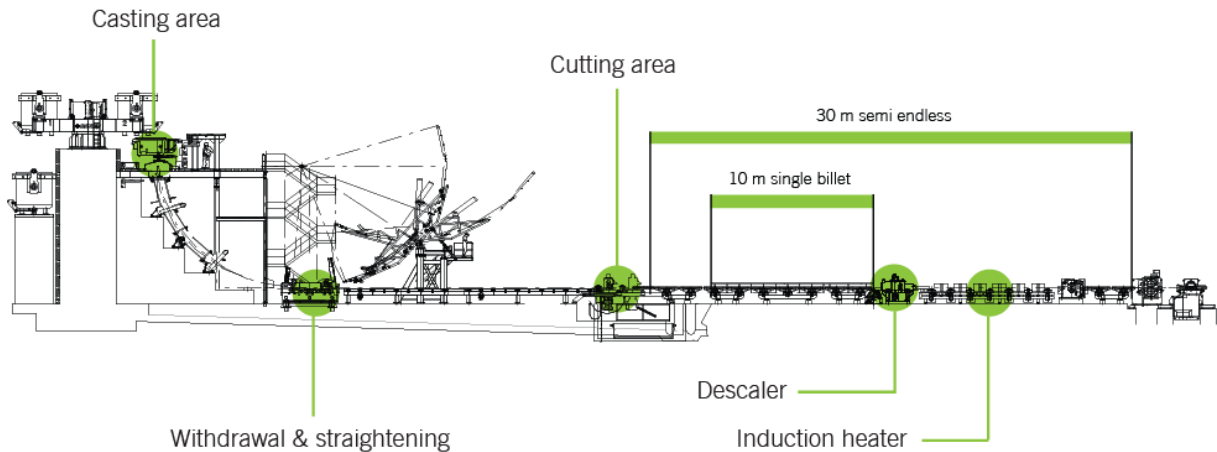
The single strand 9-m nominal radius continuous casting machine features a unique set of tools for unprecedented performances on the market worldwide, **allowing to achieve casting speeds for the 130 mm square billet of up to 6.3 m/min**. In addition to a properly designed and extended multi-zone system for secondary cooling, it includes a revolutionary all-in-one compact mould oscillator: the Fast-Cast-Cube (FCC).

This 1 cubic meter unit includes:

- > A maintenance-free oscillator (bearing-less design), for high performances and 50% extended working limits;
- > An extremely limited oscillating mass and inertia resulting in very sensitive control of mould friction for both process tuning and breakout prediction, to ensure the highest utilization factor (steel in mould);
- > A revolutionary cartridge type mould with top performing alignment-free copper tubes (POWERMOULD). This system does not require water jacket assembly and complicated alignment procedures. In addition, it shows extra stiffness and taper

stability due to enhanced heat exchange performances and controlled cooling of the corners;

- > A radio frequency automatic tracking and monitoring system (RFID) to record any event and critical data for the mould equipment directly stored by the automation system, with no need of human intervention.



**Figure 2.** Longitudinal section of caster and link with rolling mill

A hydraulic shear is located between the caster and the induction heaters essentially for cropping, emergencies and very seldom non-continuous operation.

## 2.2 Rolling mill area

An induction furnace is located between the caster and the rolling mill for temperature equalization prior to entering the first stand. The rolling mill consists of sixteen stands arranged in H/V configuration. The roughing mill consists of eight cantilever type stands. The eight intermediate and finishing stands are housingless type and are equipped with quick change car that enables the whole mill to be changed over in less than 15 minutes. HiWEIGHT gauges are properly located along the mill for on-line measurement of the weight of the stock going through the mill and for monitoring the groove wear. The intermediate and finishing stands have on-load roll gap adjustment capability working in closed-loop with the HiWEIGHT gauges. A Bar Quenching and Tempering system (QTB) is located at the rolling mill delivery side.





**Figure 3.**The CMC rolling mill

The finishing end of the mill incorporates the Direct Rolling and Bundling (DRB) system that enables the cutting to final commercial length of high-tensile rebars directly off the last finishing stand. The result is a very compact arrangement of the whole cooling bed/bundle forming and tying station, with significant savings in the initial investment and production costs. After bundling, the bars are run through two wire-tying machines and then collected onto a chain transfer for final removal by fork lift truck.

### **2.3 Process control**

An ambitious process demands a powerful set of control tools. The automation system provided by Danieli for the CMC mill in Arizona has been a key factor to guarantee the success of the MIDA process. In order to further enhance the capability to monitor, trend and improve the process, Danieli has also developed an innovative set of tools for data collection called MORE Intelligence. Based on Windows Explorer™, MORE Intelligence is a Multi-dimensional Database Analysis system that transforms the significant amount of production and process data gathered by the automation systems into tangible information for decision-making and improved process knowledge. Virtually, the system can be configured in any form (or dimension), and the various reporting structures can be easily customized in a very lean and user-friendly way.

Dashboard type reports, as an example, are preconfigured and ready-to-use with a single click, assessing the actual status of the shop with useful KPIs and gauges that show the salient parameters of each heat. Dynamic reports are the advanced display tool that brings the trends, correlations and cause-and-effect relationships, which are not evident from traditional reports, directly to your desktop. With the increasing number of variables recorded every second (and milliseconds), the need of special software tools has already become unavoidable in order to carry out an effective analysis of significance. MORE Intelligence is the answer to these needs and was

developed and implemented by a team of professionals exclusively dedicated to the steel business.

### 3 NANOMILL - MAIN CONCEPTS AND DESIGN DATA

A NANOMILL (as per the MiDa original concept) is a regional-product focused mill which exploits the availability of scrap or iron-ore from a particular area, as well as the market for the finished product, and converts raw materials into finished products in the most efficient way and with extremely low transport costs.

The NANOMILL concept supports the development of areas around the world where no one had ever before thought of building a steel-making plant at all and where now the construction of a NANOMILL becomes very feasible. As a consequence, the NANOMILL acts as a magnet for other businesses and industries which are established around the NANOMILL for its operation.

Some good reasons to invest in a NANOMILL: - Scrap or Iron Ore fed from local sources - design for local demand! - shorter and cheaper transport! - Scrap quality is getting worse! - Energy sources are limited and become more expensive! - Available landscape is restricted! - Environmental requirements are getting stricter every year! - Investment cost should be as low as possible! - Operating costs should be as low as possible! - less equipment, smaller buildings at a lower price and faster to build and to startup.

#### 3.1 Scrap preparation and melting area

The use of a Shredder as main scrap preparation system has proved to be the most efficient method to guarantee a high-quality and high-yield raw material feed to the NANOMILL. The outcome of the Shredder ensures operational and transformation cost savings, good melting process yield, high productivity and proper control of metallurgical analysis.



Figure 4.A recent Danieli Lynx shredder in operation

In addition to the shredder machines, other scrap preparation systems, like e.g. scrap shears and pre-shredders, are used to fully cover all scrap preparation activities and logistics.

Melting can take place in the DanieliNanoEAF which has been especially developed for being used in NANOMILLS and mainly consists of two sizes which cover the tapping range of 5t to 15t: the NANO2 and NANO3 for 15t to 35t capacity. They are available as full or half platform design and with EBT or Spout tapping. The electrical design of the NANO EAF can be AC or DC depending on individual requirements.

As an alternative primary melting system, the Induction Furnace (IF) technology has been applied to NANOMILLS in those areas where only a limited electrical power is available and the production is limited to commodity steel like rebars.

The Mini Blast Furnace (MBF) is a very flexible and competitive equipment for the hot metal production in the range of 65,000 to 300,000 tpy. Its flexibility allows the burdening from 100% lump ore to any blend of lump ore, sinter or pellets in the burden composition. It can be designed to use charcoal (environmental friendly) or coke as reducer. MBFs are the ideal solution for NANOMILLS in those areas where iron ore and Charcoal / Coke are available but the electrical network has an insufficient capacity for the operation of an EAF or IF System. The hot metal is processed into a BOF or EAF after tapping where, by blowing oxygen, it is transformed into steel suitable for both basic and foundry grades.

The need for a secondary metallurgical treatment facility is a must in a modern NANOMILL and is covered by a small size ladle furnace which guarantees proper chemical composition of the melt and operates as a production buffer between primary melting systems and downstream production facilities. In case of induction furnace as primary melting unit, the implementation of an additional Oxygen Blowing Stand (O.B.S) in front of the LF is necessary for decarburization and de-phosphorization purposes. After the secondary treatment of the steel, the ladle is transferred to a conventional 1-2 strand 7m radius Continuous Casting Machine. The billet sizes produced here are in the range of 100x100mm to 160x160mm square and lengths between 4-12m, which means full flexibility to fulfill market requirements.

### **3.2 Rolling mill**

The RM ensures full flexibility in its technical configuration to fulfill also requirements for the production of wire rod or light sections. The main rebar dimensions depend on local requirements and cover the full finished product range between 8 – 40 mm. It can be configured as a semi-continuous or as a fully-continuous rolling mill, depending on the required production capacity.

### **4THE ESC ENERGY SAVING COMPACT MINIMILL CONCEPT – THE EVOLUTION OF Mi.Da.**

Given the unexpected success of the first Mi.Da. and of the following plants, as well as of the NanoMills with the latest acquisitions, Danieli thought to streamline the process and make it more commercially attractive and above all environmentally friendly. Considering the constant costs increase of raw materials and of the energy required to turn it into high-quality, highly saleable finished products, and thanks to the experience acquired over the years and to our customers' continuous



requirements, we decided to completely rethink both the Mi.Da. and the NanoMill concept and optimize both CapEx and OpEx. In what way? First of all we streamlined the continuous scrap charging process through the use of the HOTWIND system, we automated the EAF melting process with the innovative Q-MELT Automatic Furnace, as well as the system solutions by reducing and rationalizing the use of materials in the structures of buildings, in piping and on the foundations. We simplified the cable, conduit routings and the design of the machines themselves, then the same we did for the technological areas and the various warehouses. This resulted in the creation of a standard for the plants that make commercial products in bars, sections and wire rod with a production capacity ranging from 300 kt/y to 1Mt/y using both endless and semi-endless solutions.

In making and defining these plants, we were helped by the experience acquired in the management of such processes as ECR Luna in Italy and Mi.Da. at CMC Steel in Arizona - USA, which were at the base of the new ESC process. With satisfaction today we can offer our present and potential customers a varied range of products based on the ESC process, tailor-made and regional-market oriented, fully complying with the most stringent safety and environment protection protocols and ensuring steel production under the “Danieli Green Steel” brand for the next ten years.

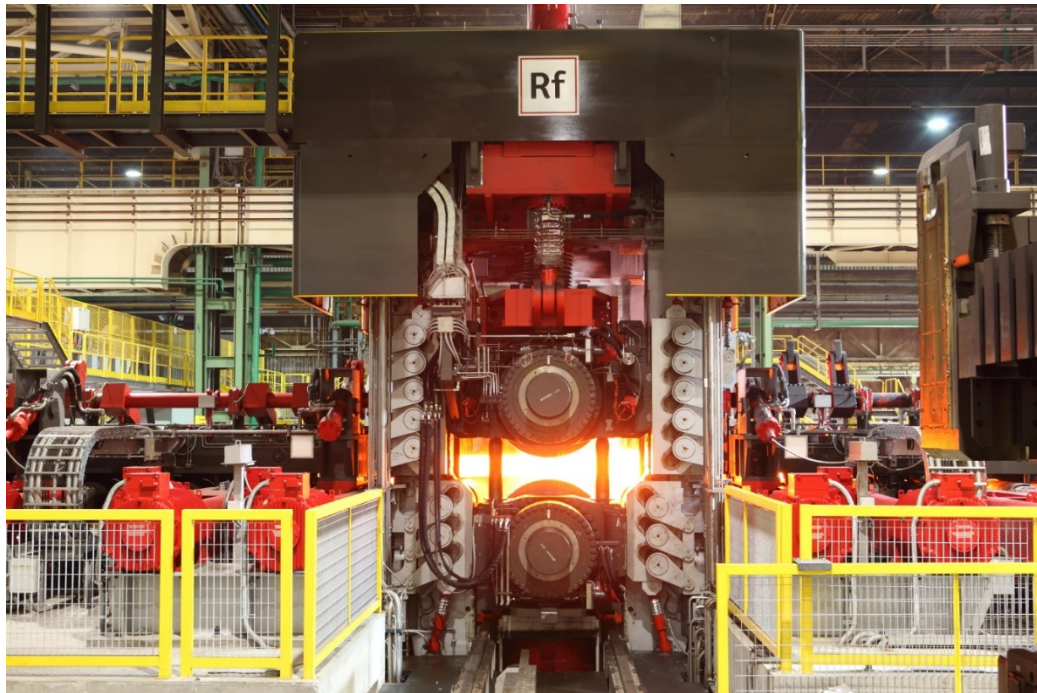
## 5 CONCLUSIONS

In its evolution, the typical electric steel-making production has expanded from 595 Mtons in 1960 to 1,606 Mtons in 2013, with an increase in percentage of 370% of the total steel produced. A minimill based on this technology has increased its output from 50,000 t/y to 3.0 Mt/y to date, and at the same time market requirements for regional production (within 250 km radius) have brought up the concept of endless rolling to achieve a unitary OpEx per ton 300,000 t/y lower than a 1,0 Mt/y steel plant. This is the main “key” point leading to an investment in a Mi.Da. concept based mill. The ECS is a combination of these aspects. CapEx and OpEx values have been optimized over the years and reduced to a minimum to help customers choose micro/nanomills solutions.

Through these experiences and over the years, Danieli has strengthened its leading position in the supply of mini/micro/nanomill solutions providing the best performances and milestones in the history of electric Steel Plants, such as:

- > The biggest EAF ever built at Tokyo Steel – Japan (DC EAF 300 t)
- > The biggest bloom casters for round blooms up to 850 mm/dia. ever built in Laiwu P.R. of China and at ABS, Italy
- > The fastest bar mill with the highest speed on cooling bed of a 8 mm dia. deformed bar at 50 m/s with 96 m bar length at SN Longos - Portugal
- > The fastest wire rod mill with the highest operating speed of 115 m/s with 5.5 mm dia. at JanjingXingchen in P.R. of China.
- > Rotoforged for high-quality bars with 850-mm dia blooms at ABS Italy





**Figure 5.1,800 mm roll dia ROTOFORGE Plant installed at ABS – Italy**