Mini mills, Micro mills, Nano mills and the Energy Saving Compact Mini mill

World electric steelmaking has increased from 595Mt in 1960 to 1,606Mt in 2013, an increase of 170% and, since their beginnings in the 1970s, a typical mini mill has increased its output from 0.50 to 3.0Mt/yr. At the same time, market requirements for regional production using local raw materials (within 250km radius) have generated the concept of micro and nano mills, with a capacity of 0.2-0.5Mt/yr utilising endless rolling to achieve an operating cost lower than a 1.0Mt/yr steel plant. Danieli, as a plant designer and builder, is at the forefront of this trend.

MINI MILLS
World electric steelmaking has increased from 595Mt in 1960 to 1,606Mt in 2013, an increase of 170%. Since their early beginnings in the 1970s, mini mills have gradually grown in size to capture the economies of scale and have now reached capacities exceeding 1Mt/yr and a typical mini mill has increased its output from 0.50 to 3.0Mt/yr. The mini mill philosophy has been based on low investment, minimal staffing and low operating costs of plants intended to serve specific geographic areas having a good balance between scrap supply and finished product market.

Today, mini mills are not restricted to commercial quality steel grades or the use of simple technology, and Danieli has been at the forefront in the supply of mini mill 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 300t)
- The biggest bloom casters for round blooms up to 850mm/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 an 8mm diameter deformed bar at 50m/s with 96m bar length at SN Longos, Portugal
- The fastest wire rod mill with an operating speed of 115m/s for 5.5mm diameter rod at Janjing Xingchen in P.R. of China
- Rotoforged high quality bars from 850mm dia blooms at ABS Italy (see Figure 1)

However, markets that can absorb these quantities of steel are being exhausted and Danieli Group and several of its customers have worked closely together to come up with the idea of micro mills.

DANIELI MICRO MILLS – MI.DA
Mi.Da, which stands for ‘Micromill Danieli’ mini mills are based on the ‘regional-mill/product-focused’ concept and, with a relatively low production capacity (200-500kt/yr) are designed to serve a specific market (local or regional), focusing on a specific product range and making extensive use of local scrap supply. They have become a complement to the conventional integrated steel production complexes for the competitiveness they have shown in producing commercial steel grades in bars, wire rod and spooled bars. In addition, they are the most convenient way to recycle the scrap available in industrialised countries or to use raw materials in developing countries without resorting to large investment and infrastructure.

MI.DA AT CMC Arizona
The start of Mi.Da as a reality was in mid-2004 when Danieli approached USA steel producer Commercial Metals Company (CMC) with a design concept that eventually led to the construction of the mill in Mesa, Arizona. The design capitalised 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, so results in significant savings in terms of initial investment, utility consumption and running costs.

The design also included the Direct Rolling & Bundling (DRB) System whereby the rolled product is 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) providing the ability to produce leaner chemistry (cheaper) steels without loss of mechanical properties. The first heat was made in late 2009.

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Oklahoma Following the success of the Arizona plant, CMC ordered a second Mi.Da in July 2015, to be located in Durant, Oklahoma. The micro mill has a design capacity of 300,000 short t/yr (272,000 metric) of finished product with a 35 short ton tap weight melt shop intended to work with 100% scrap charge. The plant commenced steelmaking in March 2017. The rolling mill produces sizes ranging from #4 to #11 (12 to 36mm) rebar. The plant layout and section through the plant are shown in Figures 2 and 3.

Meltshop The efficient plant layout features a continuous conveyor scrap feeding system that feeds the scrap into the 50t capacity compact EAF (avg. 35t of tapped steel). The system was supplied to work at 23MW active power to achieve a tap-to-tap time of 45 minutes. The performance reached so far clearly proves the soundness of the selected design and technical solution. Thanks to an innovative in-line ladle lifting system located underneath the ladle furnace (LF), the full ladle can be transferred from the tapping car to the LF car for subsequent treatment without need of crane lifting. The LF 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 9m nominal radius casting machine features a unique set of tools for unprecedented performance on the market worldwide, allowing casting speeds for the 130mm square billet of up to 6.3m/min to be achieved. In addition to a specifically 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 unit includes:
- A maintenance-free oscillator (bearing-less design), for high performance and 50% longer time between maintenance.
- A small oscillating mass and inertia resulting in very sensitive control of mould friction for both process tuning and breakout prediction. This ensures the highest utilisation factor (steel in mould time).
- A revolutionary cartridge-type mould with alignment-free copper tubes (POWERMOULD). This system does not require a water jacket assembly and complicated alignment procedures and has extra stiffness and taper stability due to the enhanced heat exchange 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 for human intervention.
A hydraulic shear is located between the caster and the induction heaters essentially for cropping, emergencies and very seldom non-continuous operation.

**Rolling mill** An induction furnace is located between the caster and the rolling mill for temperature equalisation prior to entering the first stand. The rolling mill consists of 16 stands arranged in H/V configuration (see Figure 4). The roughing mill consists of eight cantilever type stands and the eight intermediate and finishing stands are housingless and equipped with a quick change car that enables the whole mill to be changed in less than 15 minutes. HIWEIGHT gauges are located along the mill for on-line measurement of the weight of the stock going through the mill and for monitoring 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 self-tempering system (QTB) is located at the rolling mill delivery side.

The finishing end of the mill incorporates the Direct Rolling and Bundling (DRB) system that enables 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 on to a chain transfer for final removal by fork lift truck.

**Process control** An ambitious process demands a powerful set of control tools. The automation system 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. It 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. The system can be configured in any form (or dimension), and the various reporting structures can be easily customised 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 a desktop.

With the increasing number of variables recorded every second (and even milliseconds), the need for special software tools has become unavoidable in order to carry out effective data analysis. MORE Intelligence is the answer to these needs and was developed and implemented by a team of professionals exclusively dedicated to the steel business.

THE NANOMILL
A NANOMILL, derived from the original Mi.Da 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 thought of building a steel plant before. As a consequence, the NANOMILL acts as a magnet for other businesses and industries which are established around the plant. The envisaged size for such a mill is 300kt/yr max.

Some good reasons to invest in a NANOMILL are (see also Figure 5):

- Scrap or iron ore fed from local sources
- Designed for local demand, with shorter and cheaper transport
- Scrap quality generally is deteriorating around the world due to increased contamination from coatings and electronics
- Energy sources are limited and becoming more expensive
- Available land 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.

Scrap preparation The use of a shredder such as the one shown in Figure 6 as the main scrap preparation system, has proven the most efficient method to guarantee high quality and high yield raw material feed to the NANOMILL. This leads to operational cost savings, good melting process yield, high productivity and proper control of metallurgical analysis.

In addition to the shredders, other scrap preparation systems such as scrap shears and pre-shredders are used to fully cover all scrap preparation activities and logistics.

Melting Melting takes place in the Danieli NanoEAF which has been specially developed for NANOMILLS and consists mainly of two sizes which cover the tapping range of 5t to 15t with the NANO2 and 15t to 35t for the NANO3. They are available as full or half platform design and with bottom 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, Induction Furnace (IF) technology has been applied to NANOMILLS in those areas where only limited electrical power is available and production is limited to commodity steel like rebars.

Mini blast furnace The mini blast furnace (MBF) is an ideal solution for NANOMILLS in those World regions where iron ore and charcoal/coke are available but the electrical network has an insufficient capacity for the operation of an EAF or IF. The hot metal is processed via BOF or EAF and is transformed into steel suitable for both basic and foundry grades.

The MBF is a very flexible and competitive unit for hot metal production in the range of 65 to 300kt/yr.
increasing cost of raw materials and of the energy required to turn them 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 optimise both CapEx and OpEx.

We created a standard for the plants that make commercial products in bars, sections and wire rod with a production capacity ranging from 300kt/yr to 1Mt/yr using both endless and semi-endless solutions.

- Streamlined the continuous conveyor scrap charging process through use of the HOTWIND system
- Automated the EAF melting process with the innovative Q-MELT system allowing for O/C injection/power input, off-gas monitoring and analysis system
- Reduced and rationalised the use of materials in the structures of buildings, piping and foundations.
- Simplified the cable and conduit routings and the design of the machines

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, USA, which were the basis of the new ESC process. Today we can offer our 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 coming years.

CONCLUSIONS

World electric steelmaking has increased from 595Mt in 1960 to 1,606Mt in 2013, an increase of 170%. A typical minimill has increased its output from 0.50 to 3.0Mt/yr. At the same time, market requirements for regional production (within 250km radius) have generated the concept of endless rolling with a capacity of 0.3Mt/yr to achieve a unitary operating cost lower than a 1.0Mt/yr steel plant. This is the key point leading to an investment in a Mi.Da. concept mini or nano mill.

The ESC-Energy Saving Compact solution is a further variant of these with additional cost (CapEx and OpEx) and environmental benefits.

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