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DANIELI GROUP LEADERSHIP AND INNOVACTION IN LARGE SBQ MILL TECHNOLOGY[1]

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Abstract

The state-of-the-art process and design for the large SBQ mills are the key factors that have contributed to maintaining Danieli's leadership in this long product field worldwide. In the past few years, a large number of Big Bar Mills for the production of high added-value products have been successfully supplied and put into operation in different countries, and the recent orders in the P.R. of China and India have confirmed once again the market's trust in Danieli's technology. These rolling mills are basically made up of a reversing Break-Down Mill stand followed by a continuous finishing mill with Star Housingless Stands (SHS) in H and V configuration. Particular attention has been paid to enhancing plant efficiency, lowering transformation costs by means of in-line treatments and controlling final product quality. This article introduces the market trends and the latest technological solutions developed by Danieli for the large SBQ mills.
Key words: SBQ; Big bar mills; Technology; Innovation.

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1 MARKET REQUIREMENTS

Big rolled bars are used in all cases where the mechanical, metallurgical and dimensional properties of products coming directly from the conticaster are inadequate to fulfill market demands.
The replacement of these products with rolled products has obviously led to larger equipment size requirements and the need to adapt the process (for example, there is an ever growing demand for rounds with diameters greater than 300 mm).
These products are used in a wide range of applications: automotive, oil and gas, wind farms, mechanical and metalworking fabrication in general. Table 1 shows the steel grades typically rolled in a large SBQ mill.

Table 1: Typical steel grades and final applications

Steel grade	*Final application*
Hardening & tempering steel	*Crankshafts, piston rods, bushes, flanges, cylinders*
Surface hardening steel	*Axles, shafts, gears*
Case hardening steel (nitriding steel)	*Pinions, gears*
Bearing steel	*Bearing rings, rollers*
Microalloyed steel (boron steel, vanadium/niobium steels)	*Shafts, pressure vessels, chains*
Free cutting steel	*High speed machining*
Cold heading steel	*Bolts*
Creep resistant steel	*Pipes, tubes*
Stainless steel	*Valves*

All this has induced Danieli to continuously invest in research and development so that our process fully complies with market quality requirements, while ensuring low transformation costs and high flexibility.

2 STEEL QUALITY

There are two commonly used processes for making steel suitable for big bars: steel obtained by melting scrap or directly from iron ore.
The process with the Electric Arc Furnace (EAF) cycle is characterized by lower plant costs, greater flexibility, lower running costs and reduced environmental impact compared to the “integrated cycle”, which includes other complex plants.
Whether it comes from a converter or an EAF, the steel is tapped into a ladle and then sent to the Ladle Furnace (LF) where ferroalloys are added.
There are countless alloying elements used in specialty steel bar production, and deciding which ones to use obviously depends on the mechanical, chemical and other properties that the final steel must have.
For certain types of steel, the ladle is placed in a vacuum tank for removal of undesired elements like hydrogen, oxygen, nitrogen, etc. by intensive gas stirring at low pressure.
Three types of feedstock are generally used in big bar manufacturing, namely:

- *Rectangular and square blooms* from continuous casting for greater flexibility (they can be used for a wide range of products and may be outsourced)
- *Round blooms* from continuous casting with a more uniform metallurgical structure and less defects typical of blooms such as cracks on the edges and internal segregation.

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- *Ingots* in various sizes and shapes (rectangular, polygonal, etc.) from ingot casting, used for high-alloyed steels and when a strong reduction between the feedstock and the final product is required.

Since it was introduced, the curved continuous casting machine has gradually supplanted the old ingot casting process. In industrialized countries, the percentage of continuously cast steel has now reached 90-95%.
The advantages of the continuous casting process as opposed to solidification in ingots are basically:

- Better liquid to solid yield due to the absence of sprues.
- Higher plant productivity thanks to the possibility of sequence casting the contents of several ladles on the same caster.
- Possibility of applying a high level of automation.

Another advantage is the possibility of carrying out a combined casting-rolling process referred to as “hot charging”, which consists of charging semi-products that have not cooled down completely, thus saving considerable energy.
Given the growing demand for final products even larger than the 300-mm-dia. rounds and reduction ratios higher than 4:1 (typical of quality carbon steels) it is clear that larger and larger cast products are required.
In 2007 Danieli built the largest round bloom caster for high-quality steel grades at Acciaierie Bertoli Safau (Italy). It was the world’s first 750-mm-dia machine able to produce a wide range of products typical of the ingot casting production route.
This machine features excellent bloom surface quality even for products with critical carbon content of 0.15-0.20%, low internal segregation on the whole product mix, up to 1% carbon content.

Fig. 1: Large cast round bloom

3 ROLLING PROCESS

Today’s quality demands in large SBQ mills require a continuous analysis of processes and equipment. To reduce risks, time and costs related to big projects, good analysis tools are required.
Danieli has an international team of experienced Process Engineers and Roll Pass Designers to develop roll pass designs for a wide range of processes and mill layouts. New techniques have been developed to ensure Danieli remains a front runner in World’s Best Practice.

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One of the techniques used to design large SBQ mills is the WICON rolling library, which is a Danieli collection of programs used to carry out the necessary calculations and simulations of the rolling mill process parameters.
This includes roll pass design, evaluating changes to process conditions, evaluating new products or process routes as well as evaluating new design proposals.
The library covers different mill layouts with consecutive symmetrical groove shapes and rolling sequences, which can occur when rolling finished rounds, squares, hexagons and flats.
The usual configuration of a large SBQ mill is a reversing BreakDown Mill (BDM) stand followed by a continuous finishing mill having a certain number of stands in H and V configuration, depending on the final product size.
A typical pass schedule for big specialty steel rounds and squares is shown in Figure 2. Box grooves are typically used in the BDM stand. First passes can also be flat. Several passes are performed in the BDM stand to prepare the leader pass for the finisher. Center segregation porosity is improved by making significant reductions (50-60 mm at each pass). In the finishing mill, box-oval/round sequences are used to manufacture round bars while round-cornered squares are rolled with the bar oriented at 45° using common box-oval/round sequences. The reduction of area varies according to the steel grade and final product application and is 4-to-1 as a minimum. Roller guides are used in the finishing mill also at the entrance of box-oval passes.

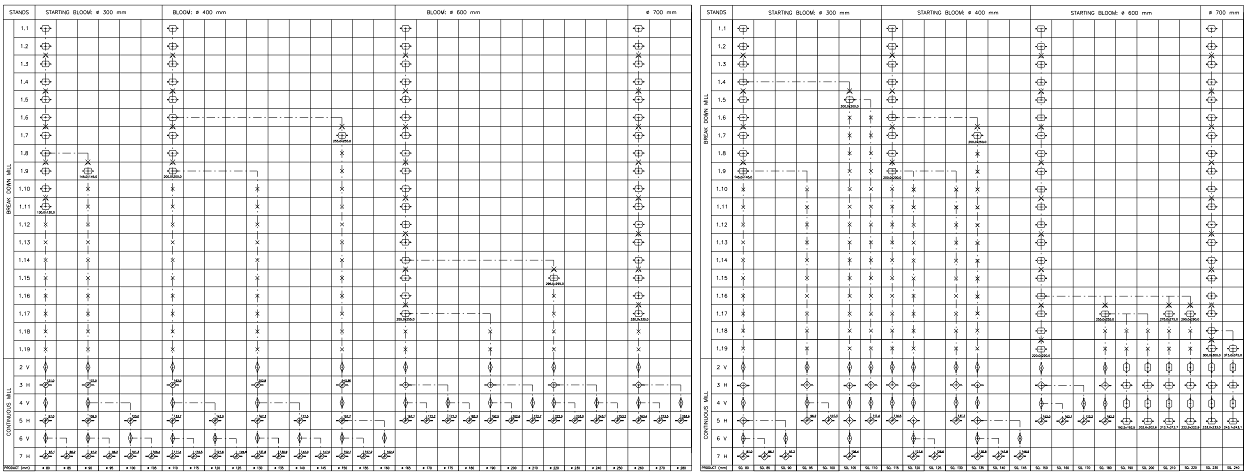

Fig. 2: Typical pass schedule for a large SBQ mill

4 MODERN LARGE SBQ MILL LAYOUT

The rolling mill usually lies in a building orthogonal to the casting bay. The conticaster is connected to the reheating furnace for hot charging.
The mill is arranged in a compact U-shaped layout.

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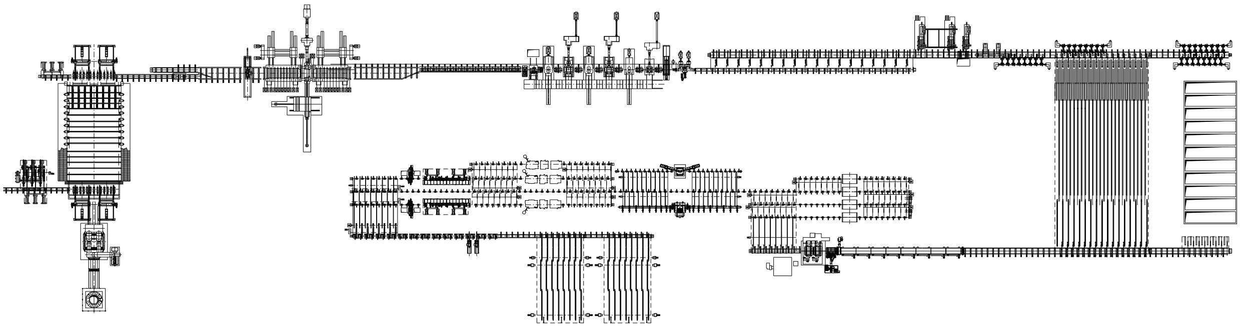

Fig. 3: Modern Large SBQ Mill Layout

In specialty steel mills, walking beam type reheating furnaces are used.
A unique rider profile allows large round and square/rectangular blooms to be charged into the furnace. Square/rectangular blooms are loaded onto the flat surface of the rider and rounds are loaded onto the curved surface.
External rolls and kick-in / off machine arms are also designed to handle different feedstocks.
The furnace is equipped with ultra-low NOx emission (less than 50 ppm) Multi Air and Radiant Flameless technology burners distributed among several independently controlled heating zones to provide the required thermal output.
Radiant burners are usually roof-mounted in the discharging area.
Flameless burners are also designed to operate in flame mode when the zone temperature is below self-ignition temperature.
The lateral fired zones of the furnace are designed to operate with PHL (Proportional High Low) technology to enhance temperature distribution, through a digital on-off firing logic. In order to implement PHL, zones are outfitted with proportional flow control valves, and each burner has both air and gas shut-off valves. As a result of PHL firing, the burners always work at nominal power, thus guaranteeing optimal flame length and uniform heating across the entire width of the furnace.

Fig. 4: Walking beam type Re-Heating Furnace.

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A multi-layer finite difference model is applied to evaluate the bulk temperature and uniformity of each product. A dynamic heat balance model is adopted to simulate furnace chamber temperature. The features are entered into a predictive control mathematical model (MPC), which uses a feed-forward strategy to estimate furnace behavior as compared to actual conditions and to evaluate the proper set-points to minimize the difference between the mean product temperature and the heating practice temperature and to save fuel.
Danieli reheating technology and practice ensure temperature uniformity, with a temperature difference of less than 10°C on sections, and less than 30°C on lengths.
At RHF exit side a 250-bar pressure water descaler ensures that the primary scale is removed before the feedstock is rolled.
A breakdown mill (BDM) stand reduces the feedstock into the proper leader pass for the finishing mill.
The BDM stand is equipped with entry and exit working roller tables, side-wall manipulators driven by electric geared motors and provided with hydraulically operated tilting fingers, and grip-type bar turners for automatic rolling operations.
Roll gap is adjusted quickly by moving the top roll with an electrically driven screwdown system.
Bottom roll position is fixed by means of shims added in the workshop.
The BDM stand is provided with an un-jamming device that opens the gap in case of overload.
The breakdown mill features a system that automatically changes the chock pack in less than 30 minutes.

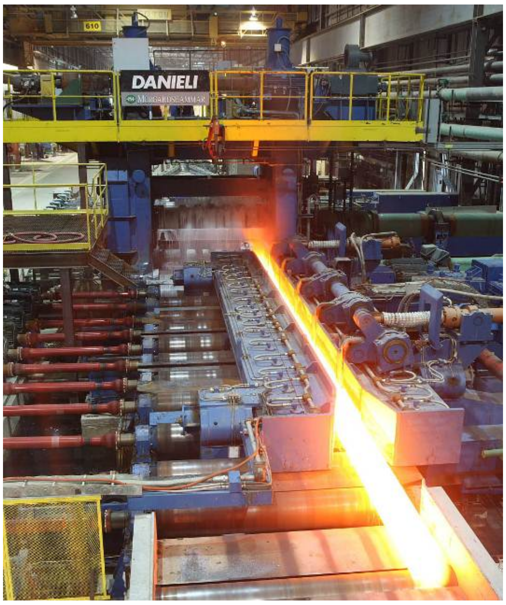

Fig. 5: Breakdown mill stand (reversible rougher)

Located at the entry side of the finishing mill is a hydraulic shear for head (and sometimes tail) cropping to prevent opening of the bar nose during the subsequent rolling operation and to prevent damaging the rolls of the finishing mill stands.

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Finishing rolling is performed with the latest generation Star Housingless Stands (SHS) arranged alternatively in horizontal and vertical configuration for no-twist rolling.

The most important characteristics of the SHS stands are summarized below:

- Compact design and sturdy construction for outstanding radial and axial stiffness;
- Large diameter mill screws located close to the radial bearings for minimized stand deflection;
- Floating spherical joint inside the chock to eliminate axial loads on the mill screws, lengthen bearing life and do away with edge loading on bearings;
- Mechanical counterbalancing system featuring no backlash between chocks and mill screw threads and no hydraulic pressure during rolling;
- Symmetrical gap setting around the pass line.

Fig. 6: Continuous finishing mill with SHS stands in H/V arrangement

If the rolling schedule so requires, the stands can be moved off line and replaced with new ones or with by-pass tables in less than 20 minutes by means of an automatic changing car.
Thanks to the way the SHS stands are built and the use of roller guides, half of the size tolerances stated in the standard can be achieved.
Installed at finishing mill exit side is the HiGauge for in-line contactless measurement of bar size.
Disc saws with steel blades are used for cutting to final length in hot conditions.
Different saw layout arrangements are available, depending on final length range and required throughput: usually two or more disc saws in stationary or moveable arrangement.
The final length is adjusted by movable stoppers.

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Fig. 7: Disc saws for cut to final length

In order to keep up with mill production, cutting to length is performed on a layer of bars that are formed by a transfer system located at finishing mill exit side.
This is a walking beam cooling bed, where the bar rotates at each step to give it the required straightness, avoiding damages to the product surface.
It is usually sized so that the bar exit temperature is less than 300 °C.
The beams are shaped and the pitch is designed to suit the product size mix.
Chains are provided at exit side to prepare the layers of bars that are then deposited onto the runout roller table by means of lifting trolleys.
Thanks to this Danieli design a bar straightness tolerance of 2 mm/m is possible.
The bars that require slow cooling (alloyed grades with delayed phase transformation to minimize internal tensions) are not moved to the cooling bed but are off-loaded in saddles in their final lengths. The bars are put in the slow cooling pits at a temperature of about 600 °C and are kept inside the pits for one or more days. When the process is over, the bars are put back on line at the exit side of the cooling bed for the subsequent processes.
Since the temperature of the bars to be treated must be under 80°C, a water spray box is installed at cooling bed exit side to cool the bar layers down to the required temperature before they enter the shotblasting machine.
The spray box is generally equipped with top and bottom sprayers, operated separately.
Before entering the downstream shotblasting machine any water on the bars is removed by a drying system.

Fig. 8: Spray Box at Shotblaster Entry Side

The shotblasting machine operates a mechanical removal of the ferric-oxide layer located on the surface of the hot rolled steel bars. This widely known process is

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centrifugal shot blasting, which uses as a descaling method the centrifugation of steel balls (by means of a centrifugal wheel) hitting the surfaces to be cleaned at high speed.
The kinetic energy of the centrifugal shots thus produces the desired result: scale breaking and removal, roughness modification of the processed surface according to the size of balls chosen and their centrifugal speed.
The machine performs a cross shotblasting on the layer of bars.
With the shotblaster the bars can be delivered with a finishing degree of SA 3 and a roughness of less than Ra 10.
The shotblaster is totally enclosed in a cabin provided with an air cleaning system.
To eliminate any possible burrs left on the bar ends after cutting to length, the bars are processed in the chamfering station. The operation is performed on both ends of each single bar.
The chamfering station consists of a singling device, a lining-up roller table, a clamping unit and a chamfering head which processes the bar radially. Angle and bevel depth can be adjusted.
This operation is needed to prevent damages to the heads of the Non-Destructive Testing center and facilitate the subsequent peeling process. In fact, chamfering lengthens peeling tool life because its operation is softer and consequently produces less wear.


Fig. 9: Chamfering Station

In the same station a label is applied to each bar to identify it unequivocally during the rolling process. It usually includes information such as heat number, strand number, bloom number, bar number, bar shape, bar size, steel grade, bar length.
After chamfering, the bars are conveyed to the Non-Destructive Test (NDT) center to detect the presence of surface and internal defects.
Surface inspection is by Eddy Current technology on round bars as well as square bars including corners.
Testing for internal defects is done by ultrasonic technology with conventional probes in longitudinal wave mode immersed in a tank with a floating probe holder. Both round and square bars are inspected by changing the probe holder cassettes.
Defect location is revealed by means of an ink spray marker.

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The NDT station is situated on a line parallel to the main one, so the bars can be diverted into the station or can bypass it and continue to the final preparation area.
At the exit side of the NDT station the bars can be rejected or transferred to the repairing station for manual spot grinding or for manual cutting with carbide disc saws.

Fig. 10: Non-Destructive Testing (NDT) center

Stacking of SBQ bars is performed with a non-magnetic system, fitted with a series of lances that pick up the layer of bars from the feeding chain transfer and deposit it into the forming pockets. The pockets are equipped with gradually lowering arms that descend step-by-step as each layer is deposited. Pocket width is automatically adjusted according to stack size.
After formation, stacks are automatically weighed, tied and conveyed to the final collecting station.
A tag is produced with the order information and is applied automatically to the stack.

Fig. 11: Stacking, Tying and Collecting Stations

This type of mill is intended for extremely high quality sale orders that require specialized software to ensure enhanced operation.
The main functions performed by the automation control system are:

- Complete, fully automatic rolling process management from the feedstock yard to the storage area;
- Production program management;
- Rolling process simulation;

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- Re-heating furnace thermal model and optimization algorithm for proper material re-heating and energy consumption reduction;
- Material tracking, production and quality-relevant data logging;
- Roll management, equipment life tracking;
- Quality control system.

5 LATEST INSTALLATIONS AND NEW ORDERS

- **Jiangyin Xingcheng Special Steel Co. Ltd. (Jiangsu Province, P.R. of China)**

This mill, which has been in operation since Dec. 2006, is able to produce finished rounds from 120 to 250 mm in dia. and squares from 100 to 180 mm, from rectangular blooms.
A second SBQ mill to manufacture smaller bar sizes has also been supplied by Danieli.

- **Jiangsu Huaigang Group Co. Ltd. (Jiangsu Province, P.R. of China)**

This mill, commissioned in January 2008, has an annual nameplate capacity of 800,000 tonnes and produces finished rounds from 70 to 250 mm in dia. and 150-mm semi-finished squares starting from round blooms.

- **Nucor Steel Memphis Inc. (Tennessee, USA)**

This mill for 750,000 short tons per year (680,000 tonnes/y), part of a complete minimill supplied by Danieli, was started up in February 2009.
The rolling mill produces 2-¼” (57.9 mm) to 9” (231.6 mm) diameter finished rounds and 2” (51.5 mm) to 6-½” (167.3 mm) round-cornered squares as well as 12” (305 mm) and 8” (203 mm) semi-finished squares for re-rolling, starting from 13-½” (343 mm) and 20-⅛” (511 mm) conticast round blooms.

- **Latest Orders**

In 2011, Danieli was awarded four orders for greenfield SBQ mills to manufacture large size bars, three of which are to be installed in the P.R. of China and one in India.

5 CONCLUSIONS

With the know-how acquired from field experience and strong design and manufacturing capabilities, Danieli has developed innovative processes and technologies for large-size specialty steel bars.
This enables our customers to operate state-of-the art rolling mill plants featuring:

- *Wide product range in terms of both product sizes and steel grades*

Both round and round-cornered squares can be manufactured in a wide size range and in different engineering steel grades with a proper pass design schedule and process.

- *High production performances at low transformation costs*

After cooling, a series of operations that are normally performed off-line are included in the process line without the additional costs for product handling and intermediate storage.
In-line shot blasting, chamfering and non-destructive testing give a high added value to the final product.

- *Maximum plant efficiency and operation flexibility*

The layout is studied to provide the needed flexibility and the possible future installation of additional equipment.

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Plant efficiency is guaranteed by the pass design schedule split into a small number of families to reduce the number of changes and by the quick product changing systems along the mill.

- *High, consistent final product quality*

Final product quality is ensured not only by the equipment designed to carefully handle the stock until delivery but also thanks to the advanced automation system for process and equipment control.