FLEXIBLE SLAB CASTER TECHNOLOGY: WHERE OPERATIONAL AGILITY MEETS PRIME SLAB QUALITY PRODUCTION*

Andrea Carboni[1]
Gianpiero Brunetti[2]

Abstract
The modern caster design are operational flexibility, reduction of OPEX and energy saving. Danieli has developed a suite of "3Q" technologies to address three critical principles: delivering the highest product Quality, in the required Quantity, with Quickness of response required for today's casting machines. Ever increasing market demands for productivity and slab quality necessitate the latest advances/improvements in equipment design, process technology, and control software for all types of slab casters.
Keywords: EMB, mold fluid dynamics, mold width adjustment, dynamic soft reduction, solidification control, surface cooling control, dry casting.

[1] *Vice President – Danieli Davy Distington, Danieli & C. Officine Meccaniche SpA, Buttrio, Italy.*
[2] *Vice President, Information Technology B.U. Steel Making, Danieli Automation SpA, Buttrio, Italy.*

1 INTRODUCTION

The main requirements for a modern slab caster design are operational flexibility, reduced OpEx, and energy savings.
Danieli has developed a suite of "3Q-Quality-Quantity-Quickness" technological packages to achieve these targets.

2 DISCUSSION

2.1 Q-MM-EMS - Controlling the fluid dynamics in the mold

The Multi-Mode Electromagnetic is a family of devices designed to control the fluid dynamics in the mold, for both thin and thick slabs, by means of the interaction between the liquid steel and an imposed magnetic field.
The purpose is to maintain a smooth liquid steel stream below the meniscus in a range of speeds suitable to avoid mold level fluctuations and waves that lead to poor lubrication, avoid turbulence that generates mold flux entrainment, and guarantee a proper liquid steel flow below the meniscus to avoid freezing and bridging.

The ideal fluid-dynamic pattern is the so-called double roll flow (Figure A). In case of uncontrolled flow, the pattern may develop into a single roll with generation of high waves (B); a too strong double roll (B); a weak double roll (C).
Every configuration depends on casting speed, slab width, SEN immersion, and argon flow rate, that are obviously continuously changing. Danieli Rotelec developed an efficient and flexible technology for mold fluid dynamic control. This is usually simplified as Electromagnetic Braking, but in reality, it is something much more advanced, being a multi-mode (MM) system.

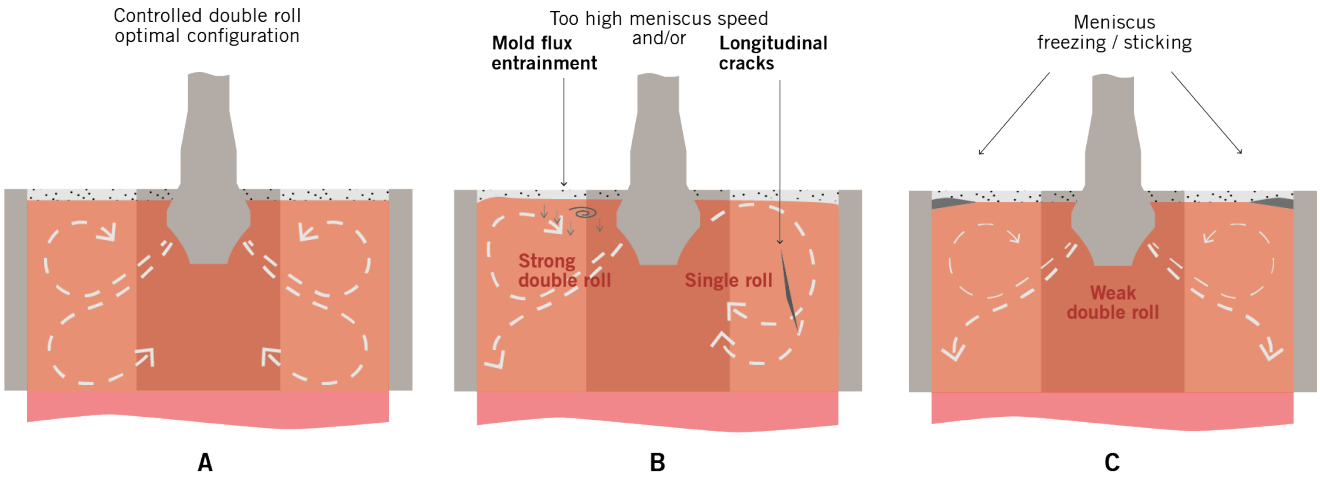

Figure 1. Ideal fluid-dynamic pattern (the so-called double roll flow) (Figure A). In case of uncontrolled flow, the pattern may develop into a single roll with generation of high waves and a too strong double roll (B) or into a weak double roll (C).

2.1.1 Thick slab caster solution MM-EMS

In a slab caster, the possibility of switching from double to single roll is always present.

The countermeasure is therefore not only to brake but also to accelerate the flow out of the SEN.
MM-EMS is able to do these functions thanks to four linear magnetic motors that generate an AC traveling magnetic field with controlled speed and direction.
By adjusting the direction and the intensity of the magnetic force, it is possible to alternate braking/accelerating effects.
As an additional function, by creating a loop of the magnetic field the MM-EMS can work as a stirrer.

2.1.2 Thin slab caster solution MM-EMS

In thin-slab casters the main problems are the meniscus waviness and the bias flow, which means asymmetry of flow left/right.

Generally, the transition double/single roll is not experienced in this case. Then, the solution is a new type of electromagnetic device with five poles. With such a configuration, the flexibility of the system is optimized and gives the chance to operate in a wide range of working conditions.
Mainly, three modes of operation are possible:
— braking, operated mainly with the lower poles by reducing the liquid steel speed as soon as it exits the SEN ports;
— damping, operated only by the upper poles acting as a damper to any vertical movement, including natural waves and local disturbances;
— stabilizing, operated by the central pole working as a divider that forces the flow to distribute symmetrically.

The benefits of such devices are higher quality, fewer breakouts, less scarfing, higher yield and less slab inspection. The ability to control the process in the widest operational parameters range (width, speed, thickness, argon practice, SEN wear, etc.) gives the maximum flexibility in scheduling the production.

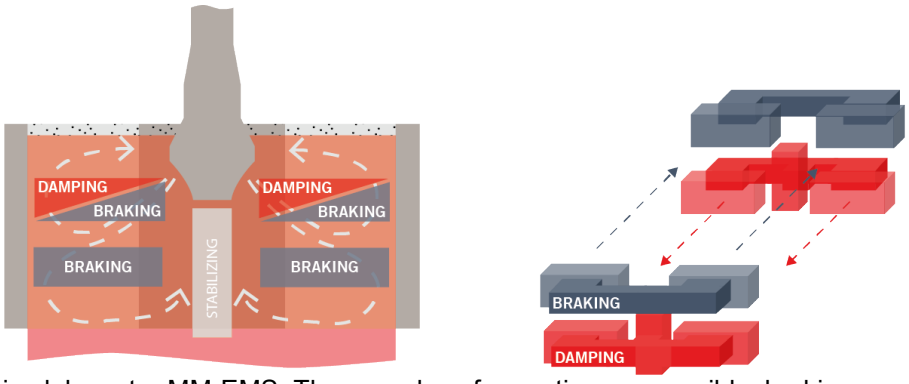

Figure 2. Thin slab caster MM-EMS. Three modes of operation are possible: braking, operated mainly with the lower poles; damping, operated only by the upper poles; stabilizing, operated by the central pole.

2.2 Q-WIDTH - Flexibility to change slab width

Flexibility for changing slab widths according to the order book is a must for modern slab caster design, and it should be done during casting at the maximum speed to minimize the transition bar length and maximize the yield. The Q-WIDTH package

can execute a width change at speeds up to 200 mm/min with no limitation on the maximum variation and casting speed.
During changing, the control software calculates, in real time, the optimum narrow side taper to control the “air gap” according to the steel grade, and also makes it possible to change the casting speed during a width change, to maximize the operational flexibility.
Thanks to Q-Width, it is possible to execute width changes up to 500-600 mm in a short time and with a reduced tapered length. This makes it possible to recover a large part of the tapered slab without penalizing the yield.

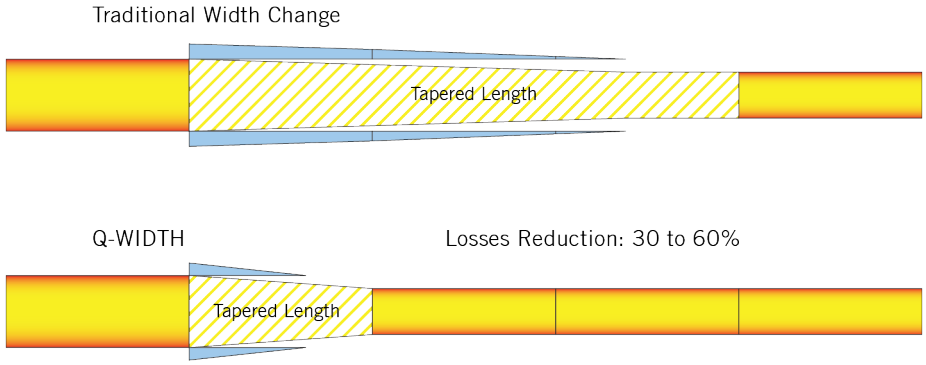

Figure 3. Q-Width package for flexible slab-width changes. Thanks to Q-Width, it is possible to execute width changes up to 500-600 mm in a short time and with a reduced tapered length.

2.3 Q-COOL – Controlling the temperature

Q-COOL is an innovative, 3D temperature control system. The concept has been developed keeping in mind that a step forward in the secondary cooling could be taken with the precise control of the temperature across the slab width. The goal is to maximize the product quality, focusing on the slab edges and corners to avoid surface and subsurface cracks. “Spray width” control is realized by splitting the spray map in different nozzles width bands. Each band flow rate is controlled independently. It is possible to obtain either a high-temperature or a low-temperature slab-edge cooling, according to the metallurgical requirements.
A wide variety of corner/edge cooling strategies are possible, such as: uniform temperature, high temperature and quenching. Temperature optimization makes it possible to maximize the slab temperature for the hot charging practice, reducing the requirement of reheat energy.
Q-Cool is a tool that boosts the flexibility of the operation with no quality downgrade.

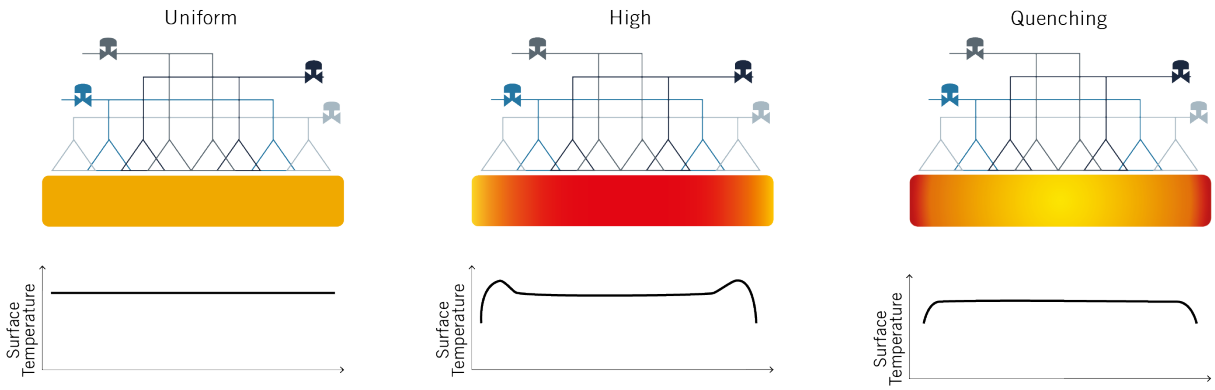

Figure 4. Through the Q-COOL package a wide variety of corner/edge cooling strategies are possible: uniform temperature, high temperature, and quenching.

2.4 Q-ROLL and DRY CASTING – Adding cooling capabilities

Rolls have to be considered an additional cooling system to be used in parallel and/or in substitution to the spray nozzle external cooling. Namely, the so called “Dry Casting” is used when more than 80 % of the overall heat extraction is done through the rolls in order to operate an extremely soft cooling for crack sensitive grades. Danieli has recently added the spiral roll cooling to the Q-Roll family to cover the full range of operation from hard cooling to soft “Dry” cooling.

2.5 Q-CORE & Q-PULSE – Controlling the dynamic soft reduction

Q-CORE is the mathematical tool that controls the dynamic soft reduction. The solidification profile is controlled by Q-COOL and the proper thickness reduction is set according to the metallurgical length.
Q-PULSE (Patent Pending) detects with maximum precision the position of the liquid pool end. The tool preforms automatically a test on the segment close to the solidification pool end. The test consists of a light oscillation of the segment upper frame that generates a pressure wave in the liquid pool. The wave propagates along the liquid pool to the mold. Here, the mold level control, through a FFT analysis, detects the frequency and assesses whether or not a liquid core is present.
Q-PULSE does not require any additional equipment beyond the soft reduction packages.
Together with the overall improvements of internal quality, Q-PULSE has succeeded in opening the possibility to produce heavier plates without the high CapEx needed to increase the slab thickness.

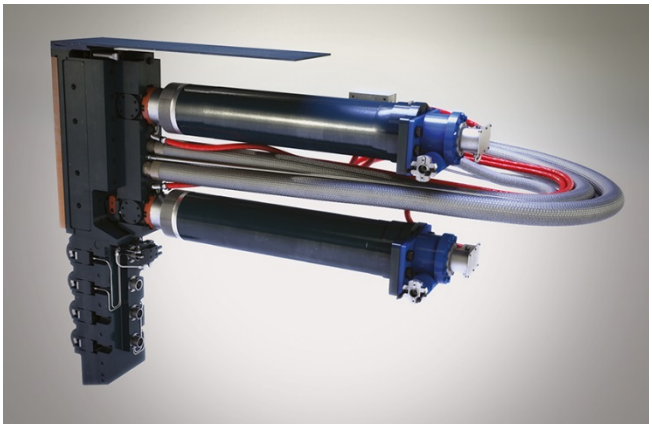

Figure 5. 3D render of a typicalQ-WIDTH assembly.

3 CONCLUSIONS

The main goals presented by modern slab caster operation are fully reachable through the Q3 technological packages.
In fact, operational flexibility and product quality are possible thanks to the widest range of casting speeds achievable with the MM-Ems; Q-COOL provides an optimized surface quality in the full range of widths; a constant internal quality in

ensured by Q-CORE / Q-PULSE, with no limitation in product size or steel grades. Q-COOL and Dry Casting improve product quality and generate energy savings by reducing water consumption and emissions.