ADVANCED TECHNOLOGY IN CONTICASTING OF QUALITY & SPECIAL STEEL BLOOMS[1]
LATEST RESULTS, ACHIEVEMENTS AND DEVELOPMENTS

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1 INTRODUCTION

The latest generation Danieli continuous casting machines feature a broad range of advanced technological tools, focused on production of high-quality large, medium and small-size special steel blooms.
In relation to blooms size or type of steel, different Technological Packages are made available, all with the common goal of obtaining top final product quality and best CCM machine performances.
This article introduces the operative results in the field of special steels like free-cutting steels, micro-alloyed steels for automotive industries, bearing steels.
More specifically, reported data refers to following casters:

- 2-strand special steel caster for large-size blooms completely re-constructed by Danieli at SeAH Besteel, Korea. The machine casts 390x510-mm blooms of special steels, as spring steel, bearing steel, free cutting steel, boron steel, high tensile strength steel, alloy and carbon steels for machine and structural use. It features, among other, Dynamic Soft Reduction system and Quench Box system. With a speed up to 0.66 m/min, the machine is capable to reach almost 100000 tons per month.
- 5-strand special steel caster for small-size blooms successfully started up in early 2005 at Corus Engineering Steels' Aldwarke Steel Works in Rotherham, UK The 10-m-radius machine, with a casting speed of 1.9 m/min for 180sq. and 1.4 m/min for 210sq. grants a 140-tph output based on:
  - Low carbon and low carbon free cutting steels (with or without Lead) on 180sq;
  - Alloyed steel as Medium and High Carbon steels, Medium Carbon Free Cutting Steel (with or Without Lead) and Cr CrMo CrMoV steels on 210sq.

2 SEAH BESTEEL BLOOM CASTER: QUALITY RESULTS

Automotive industries is very exigent in terms of surface and internal quality on casted bloom. Thus because of high demanding mechanical requirement on the final product has to be overcame. Some examples of results achieved in SeAH Besteel are here reported, regarding MnCrMo, Bearing steel and low Carbon B/Nb steel grades.

2.1 Internal Quality when Applying Soft Reduction

Internal quality is the first item in medium and high carbon steel grades. Transversal sections show internal structure free from cracks and big porosity (Figure 1).
Use of soft reduction is a great help in order to reduce center and V-shape carbon segregation and center porosity especially in bearing steel. Detailed data are reported in the following pictures (Figure 2 and 3).
SR is able to reduce center segregation more then 15%, reaching average values of 1.05 (Figure 4).

Figure 1. SAE4137HM MnCrMo steel grade, casting speed 0.57 m/min, tundish SH +30°C

Figure 2. STB 2 bearing steel 0.52 m/min, tundish SH +30°C, height reduction 7 mm applied with 5 rolls.

Figure 3. STB 2 bearing steel 0.52 m/min, tundish SH +30°C. Comparison of longitudinal section between soft reduction condition (left) with height reduction 7 mm applied with 5 rolls and NO-soft reduction (right). Is evident the reduction of V-segregation and center porosity.

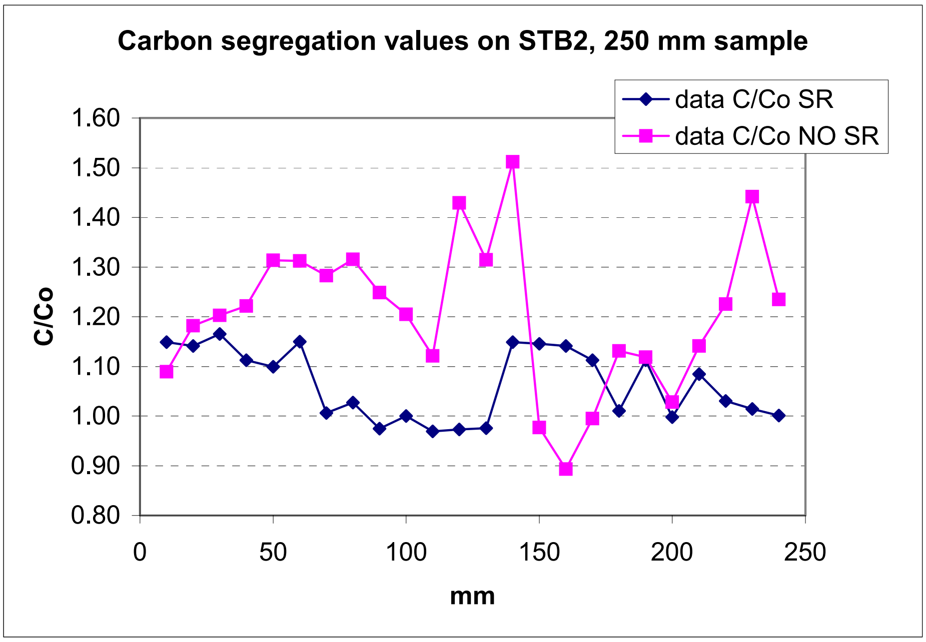

Figure 4. Values of C/Co measured on a longitudinal sample with a length of 250 mm (C = carbon content measured on the center of the bloom: Co = carbon content measured in tundish). Soft reduction is able to reduce the deviation of values, keeping more uniform the carbon distribution in the center of the bloom.

Casting speed 0.52 m/min, tundish SH <+40°, height reduction 8 mm applied with 7 rolls.

2.2 Dynamic Soft Reduction

Soft reduction is a technique for gradually reducing bloom thickness during last stage of solidification. The squeezing effect is applied in order to compensate the shrinkage during the solidification of the end of liquid cone, reducing center porosity, V-shape segregation and center carbon segregation.

A mathematical solidification model calculates the liquid core length in real time according casting parameters; soft reduction system will consequently squeeze the bloom in the area near the end of liquid core, focusing on 60% of solid part position. The withdrawal and straightening units, arranged as 10 independent modules with 1000 mm roll pitch, are positioned by a pressure control (normal casting condition) or by position control (soft reduction condition). New Level 1 and 2 automation system govern the behavior of each roll (**See figure 5),** with an accuracy of ±0.1 mm when position control is applied. The high number of W/S rolls leads to a very flexible system that can work in a wide range of casting condition (casting speed, steel grade).

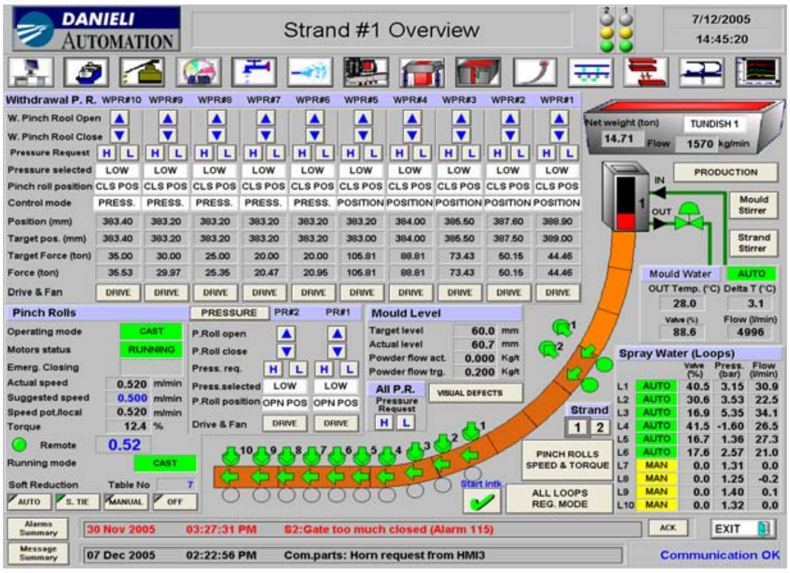

Figure 5. overview page of soft reduction rolls control condition, working pressure and working position.

2.3 Surface Quality when Applying Quench Box

Surface quality on rolled products is a big item on alloyed low carbon steel grades with Boron/Niobium/Nitrogen content, as SCR420HB or KSG4120H steel grades.
In particular, quench box is used when bloom hot charging in the rolling mill is foreseen. In this case a not appropriate bloom cooling can affect rolled products quality, especially for Al-killed low carbon steels ($Al \geq 0.020\%$) which tend to form surface defects as intergranular cracks caused by low ductility. This behavior is associated with precipitation of Aluminum Nitride or Vanadium/Niobium/Boron carbonitride on the edge of the austenite grain. Precipitation temperature range is approximately 600 – 900 °C. If strong cooling is performed before reheating furnace, the bloom surface crosses the critical range very quickly, preventing nitride agglomeration. The cooling effect is evident when measuring the surface temperature after Quench box (see Figure 6 and 7).
In order to avoid distortions of bloom geometry, subsurface cracks due to thermal shock and in order to reach the most homogeneous quench condition, the water flow have to be balanced on the four sides.
An example of quenching effect is shown in Figure 8.

Figure 6. visual effect when using Quench box; bloom surface became completely black after.

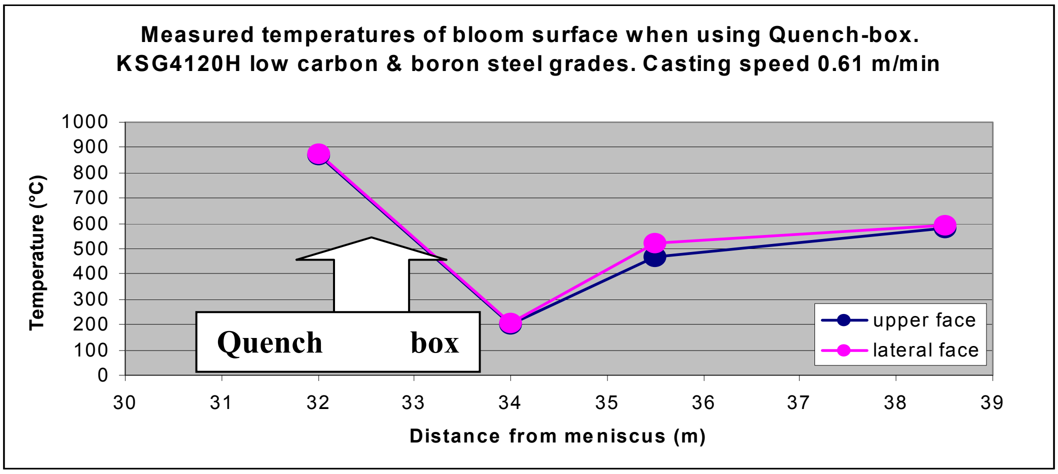

Figure 7. surface temperature before and after quench box. Casting parameters: steel grade KSG4120H low carbon boron steel grade, casting speed 0.61 m/min, quenching water 1100 L/min.

Figure 8. transversal section on KSG4120H – low carbon Niobium steel grade, casting speed 0.61 m/min , Quench box water flow 1100 L/min. It is evident the effect of quenching on the entire perimeter with a quenched deep 15-20 mm.

3 CORUS ALDWARKE SMALL BLOOM CASTER: QUALITY RESULTS

As in SeAH bloom caster, the product mix of Corus Aldwarke is focused on steel grades for automotive industries. Consequently the required quality for cast products is high for all steel grades.

3.1 Geometrical Quality

Thanks to the strong containment (1000 mm mould, 3 rows of foot rolls and ATR device) the performance tests regarding geometrical quality have been successfully overcome. High control of billet section geometry were obtained as the mean value of rhomboidity (0.56% and 0.38 %, 210 and 180 respectively) and bulging (0.92 and 0.87 mm, 210 and 180 respectively) underline.

3.2 Internal Quality

Internal examination through Baumann Prints or Metallographic analysis revealed a structure with no internal cracks neither centreline porosity, for all steel grades (Figure 9, 10).
Moreover the measured equiaxial zone was largely higher than required (average 54%, max 70%).
The statistical data on internal cleanness (Table 1) are the effective results of the use of protected steel flow, correct tundish design and mould stirring. In order to check the billet internal quality, tests according ASTM E45-D method have been done.
Good results have been achieved also on 100Cr6 bearing steel (Figure 11), even if this steel grade was out of contract.

Table 1. Cleaness according ASTM E45-D: severity level mean values

Number of samples :151								
	Sulphur (A type)		Aluminises (B type)		Silicates (C type)		Oxides (D types)	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
Mean values	1.9	0.0	0.7	0.0	0.0	0.0	0.2	0.0

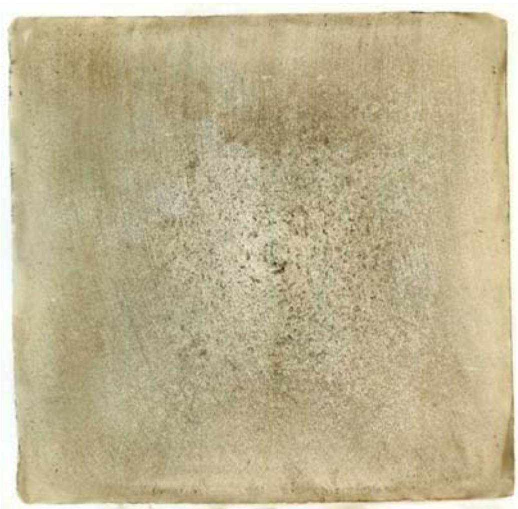

Figure 9. high internal quality as shown by sulfur print of 7MnSPb4-32, 180mm billet.

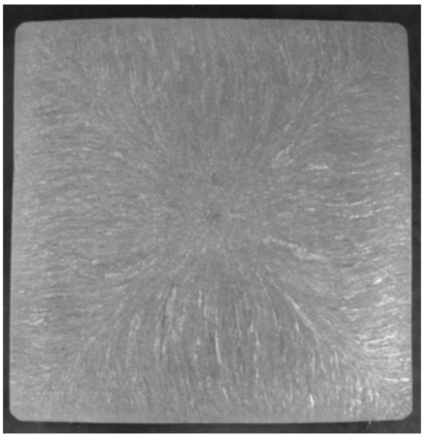

Figure 10. high internal quality as shown by macrography of 7MnSPb4-32, 180mm billet.

Figure 11. high internal quality as shown by sulfur print of 100Cr6, 210mm billet

Most interesting technologies used to reach the requested quality are the following:

3.3 Tundish Design

The tundish is a basic factor that influences the internal quality of the casted billets. For this reason Finite Elements Models can be used to optimize residence time, flow pattern, particles floatation, temperature distribution (Figure 12).
In the Corus Aldwarke new CCM the tundish has a delta shape and a working capacity of 25.5 tons.

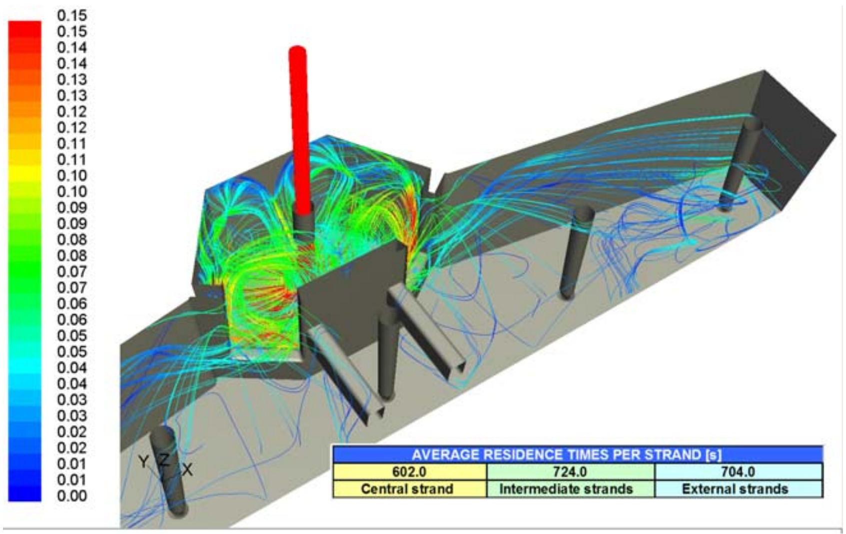

Figure 12. FEM simulation of particles behaviour during steel residence in the tundish.

3.4 Mould Powder Measuring Device (MPMD) and Automatic Mould Powder Feeder

Higher is the process control in mould zone higher will be the final surface quality of the billet. One big step is to keep under control the heat flow into the mould and optimize the lubrication between billet skin and copper tube. This can be finalized with an automatic management of mould lubricant powder consumption.
The Mould Powder Measuring Device is a new system for the control of the thickness of mould powder through a magnetic sensor installed inside the mould body. Coupling the measurement with that one from the radioactive mould level control device, time by time the thickness of the powder over the meniscus zone is measured. According this measure the pneumatic valve that control the powder feeder is activated in order to fill the mould with new powder (see Figure 13).

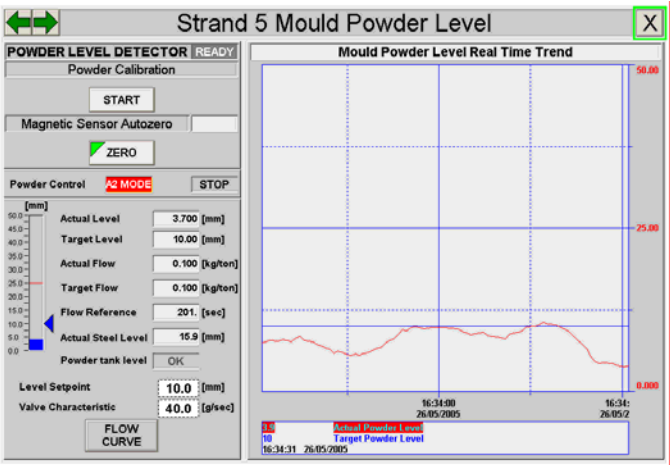

Figure 13. HMI strand page for the control of mould powder level; the level real time trend is recognizable as the red line on the right, while – on the left – the numeric values for the powder flow.

3.5 1000-mm mould and new designed supporting zone;

In order to reach restricted tolerances in billet geometry, a high containment, able to reduce face bulging and deformation of billet skin, has to be foreseen. Finite element simulation shows that the geometrical deformation of the billet due to a non uniform shell growth can worse during the water cooling (Figure 14).
For this reason, a new "Anti Torsion" Device (ATR) has been provided. It consists in two side guiding rolls positioned, in agreement with theoretical studies, between movable and fixed cooling sector in order to reach strict side and diagonal geometrical tolerance (Figure 15).

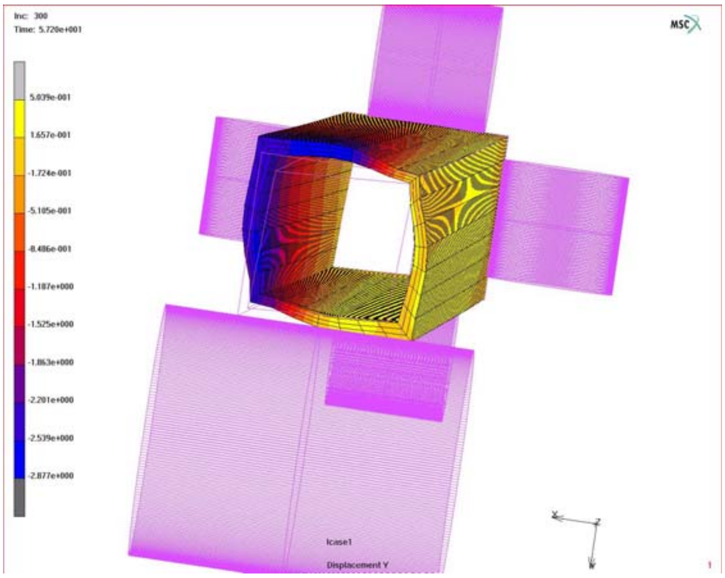

Figure 14. FEM simulation of billet deformation during secondary cooling.

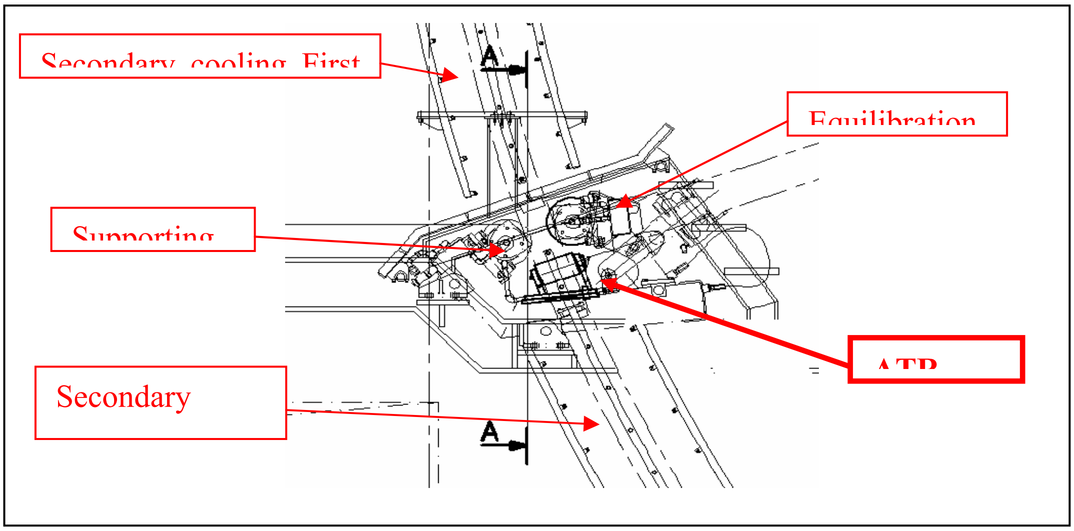

Figure 15. drawing of ATR device.

3.6 Final Cooling Destination

During cooling of high alloyed steels, there is risks of create cracks due to cooling induced thermal stresses. One way to minimize this risk is to perform slow cooling for a selection of steel grades, for example according Carbon Equivalent content (CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni) / 15).
Great care has to be done in dimensioning of CCM Run out area in order to keep billet temperature over 700°C at the exit of slow cooling. Successively hot billets can be stored into isolated boxes where billets are naturally slow cooled.
The Corus Aldwarke caster is provided with two outlets to perform the best final cooling practice according to steel grade sensitivity: walking beam cooling bed or lateral transfer roller table for slow cooling. The final destination is governed automatically by Level 2 and consequently visualized on HMI (Figure 16).

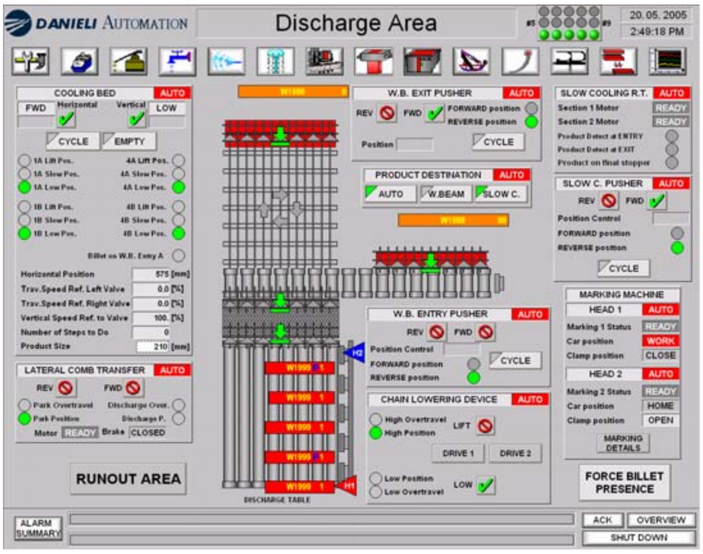

Figure 16. discharge area control page on HMI. In the middle is visible the "Product destination" in AUTO mode**.**

4 CORUS – SCUNTHORPE: THE LAST PROJECT

All the significant technologies highlights discussed up to now will converge in a new caster, presently under construction, for Corus Steel Scunthorpe Works, UK.
The caster, 6 strands, 12 meter bending radius, will produce single bloom size 230x283 mm and have a capacity of 1.25 Mtpy when high speed casting with a maximum productivity of 250 tph. The produced product mix will be: high strength, tyre cord, free cutting, cold-heading, spring and bearing steels.
The design concept includes: protected steel stream, 1000 mm bath level tundish, stopper rods, mould powder measuring device and automatic mould powder feeder, 1000-mm mould and supporting zone, external mould EMS, air mist secondary cooling. The CCM will feature Dynamic Soft Reduction system consisting of 6 withdrawal/straightener units.
According contract it is foreseen to start the operation in 2007.