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STEEL FLOW CONTROL OF CONTINUOUS CASTED SLABS USING SUBMERGED ENTRY NOZZLE EXCHANGE SYSTEM FOR TUNDISH

Viorel MUNTEANU
“Dunărea de Jos” University of Galati
email: viorel.munteanu@ugal.ro

ABSTRACT

In the steel making process, the continuous casting of molten steel is a very important step which involves hi-tech facilities. The flow control is a very important issue that influences the quality of the final products. The parameters of flow control from the tundish into the mold are achieved by means of stopper, taking into account the casting speed, tundish weight, mould and a new generation of submerged nozzle exchange mechanism developed by Vesuvius – SEM 2085 – along with the chemical behaviour refractory component during steel casting.

KEYWORDS: continuous casting, steel, tube changer, tundish, mould, steel flow control

1. The new generation of tube changers

Development of a new generation of tube changers

In order to develop a new generation of tube changer, it took into consideration new requirements such as robust and simple mechanism (less parts) easy to install, handle and maintain, with air tightness improvement, operating in full automatic mode for casting longer sequences of very high quality steel grades including stainless steel, etc. The introduction of tube changer has an impact on productivity (improving by over 2% as the proportion of time for re-stranding is reduced), yield (primary yield can be improved by 0.85% through the elimination of 1.5 meter crop required to remove the scar on a flying tundish), steel quality, safety and operational conditions.[1]

The tube changer cassette

The core of the system is the „cassette” that holds the refractory and the pressure loading device. (see figures 1 and 2).

There is a cassette for normal size refractory (tube changer bore size ≤ 85mm) and a cassette for extra-large refractory (tube changer bore size >85mm).[2]

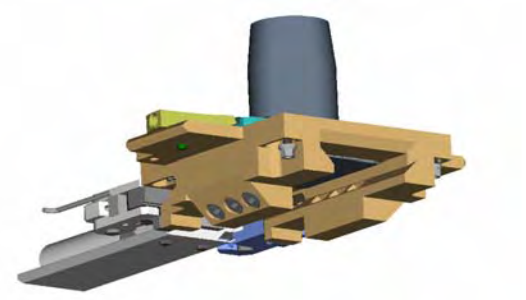

Fig. 1. *Tube changer cassette without submerged entry nozzle plate.*

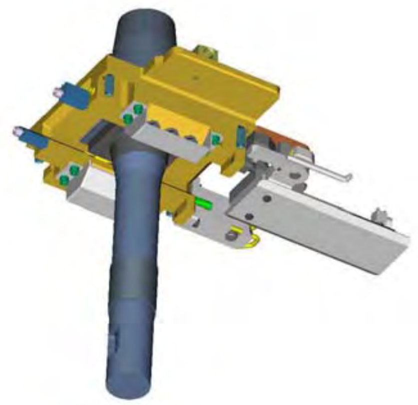

Fig. 2. *Tube changer cassette with submerged entry nozzle plate.*

Monobloc inner nozzle plate clamping device

In order to reach an improved air-tight system, it is important to have a sturdy monobloc inner nozzle plate that can be strongly fixed in the mechanism and reliably connected to the argon supply network. In this regard, a completely new design of canned nozzle plate has been designed with a parallelepipedic flange provided with two 45° tapered faces. (see figure 3 and 6).

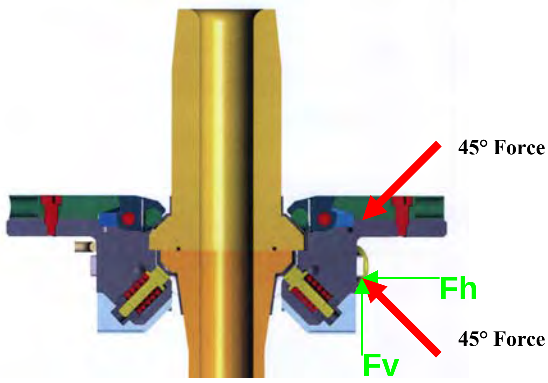

***Fig. 3**. Cassette – Monobloc inner nozzle support and submerged entry nozzle-plate spring-pushers device*

This design is very strong. It also allows to precisely position the refractory in the cassette and to firmly lock the piece by means of 2 rotary wedges pressing 2 rockers. (see figures 4 and 5)

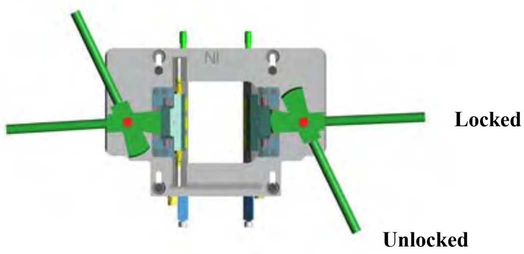

***Fig. 4.** Inner nozzle clamping device rotary wedges pressing rockers in locked and unlocked positions*

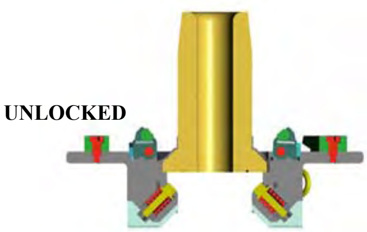

***Fig.5a**. Inner nozzle clamping device in unlocked position*

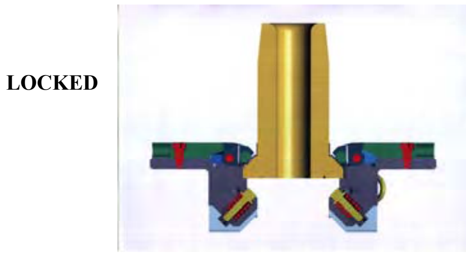

***Fig.5b**. Inner nozzle clamping device in locked position*

The clamping forces are directed in 45° angle towards the center. This unique clamping concept reduces stress peaks and also causes horizontal compression forces acting at the plate sector of the refractory elements. (see figure 3)

Monobloc submerged entry shroud design and support

The new monobloc submerged shroud also has now a flange that looks similar the inner nozzle plate, for the same reasons. (see figure 3 and 6).

It is supported by means of 6 direct acting pushers and 6 high temperature resistant springs. (see figure 3) The direction of the force is 45° inclined towards the center, similar to the inner nozzle. This also generates a combination of vertical and horizontal forces on the flange of the tube leading to reduced stress in the piece.

Inert gas supply

The argon connection is "automatic" when the inner nozzle plate is installed. (see figures 7 and 9) Some of the pushing rockers are provided with argon injection tuyeres. When the rockers are in the pushing position, they provide a reliable argon-tight connection with the argon input holes (with graphite gasket) that are located on one of the tapered faces of the nozzle plate flange.

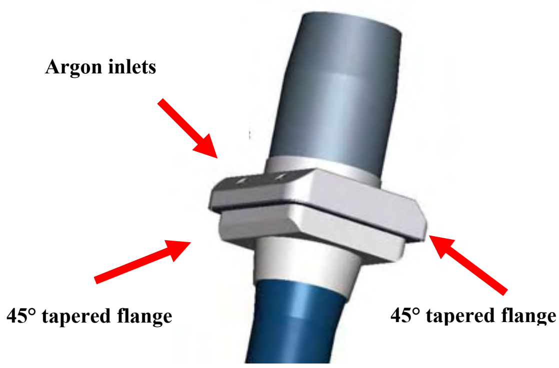

***Fig.6.** Monobloc inner nozzle plate and monobloc submerged entry nozzle design*

Two independent networks can fill argon in the nozzle plate itself (purging) and in a sealing groove located in its sliding surface. It allows a very accurate tuning of the argon flow/pressure in each zone, which is critical for clogging avoidance and steel quality.

Automation

The process can be automated in order to link the casting speed, the mould level and the stopper rod positions for a one-button operation.[4]

Fig. 7. *Tube changer in operation on the slab caster no.1 in Mittal Steel Galati [3]*

Modular concept

Targeting a flexible "Modular Design", the two kinds of cassettes can be combined with different driving mechanisms such as:

a) Pneumatic shifting drive with push-bar and side mounted cylinder: (see figure 8)

It does not need any hydraulic supply. The cylinder is directly attached to the tube changer cassette. It is a simple control system, which allows automated tube change.

b) Hydraulic shifting drive with push-bar and side mounted cylinder: (see figure 9)

The drive is attached to the tube changer cassette but the hydraulic cylinder is detachable. It remains on the tundish car or it remains on the mechanism and is connected with quick couplings. It allows automated tube change.

c) Manual swing arm mounted hydraulic direct shifting drive: (see figure 10)

This is a pivot mounted direct acting hydraulic cylinder with self locking device.

The cylinder is easy to detach and remains on the tundish car.

It is the most simple configuration, but it is not capable of automated tube change

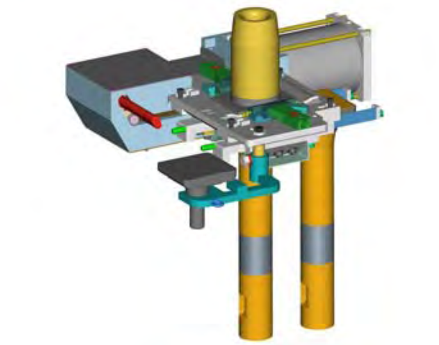

Fig. 8. Push-bar with Pneumatic Drive = "PP" version

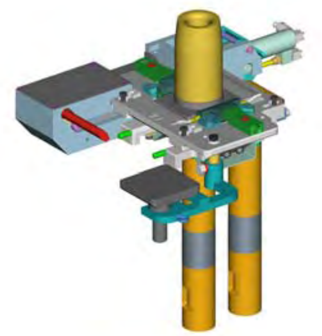

Fig. 9. Push-bar with Hydraulic Drive = "HP" version

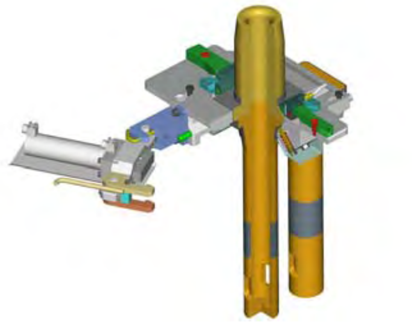

Fig. 10. Manual Swing Arm with Hydraulic Drive = "HM" version

2. Chemical behavior refractory component during steel casting

The classical experimental evaluation of steel corrosion is not enough to determine refractory component. Standard experimentation are conducted with limited amount of steel, while in reality steel is continuously renewed at refractory interface.

The second limitation faced today is that refractory interface is, in reality, controlled by variables like steel dissolved elements and steel inclusions. For instance, the volume of inclusion during continuous casting is comparable to the volume of refractory components used so they have a strong influence on steel refractory reactivity.

So the only possible approach to corrosion is to determine experimentally mass transfer from refractory to steel and to extrapolate to continuous casting conditions.

2.1 Steel and refractory interaction model

To precise the nature of chemical reactions, specific experiments have been conducted:

For the first type of experiment, pure iron is melted in an induction furnace with tailored alloys addition. A rotating refractory sample is place in the melt and steel chemical composition change are determine by steel sampling during the experiment.

A second set of experiment consist to degassing evaluation on refractory samples using a mass spectrometer at increasing temperature.

For the different type of refractory composition used in steel casting the following major reaction have been determined and quantified:

- Carbon dissolution C -> <u>C</u>
- Silica reduction SiO2 + C -> SiO(g) + CO(g)
- Magnesia reduction MgO + C -> Mg(g) + CO(g)
- Zirconia reduction ZrO2 + 3C -> ZrC + 2 CO(g)
- Oxides dissolution MxOy -> x<u>M</u> + y<u>O</u>

The different reaction kinetics have been determined depending on steel grade, refractory composition, microstructure and physical parameters at refractory interface (pressure, temperature)

For example the model for Carbon dissolution is show in Fig 11.

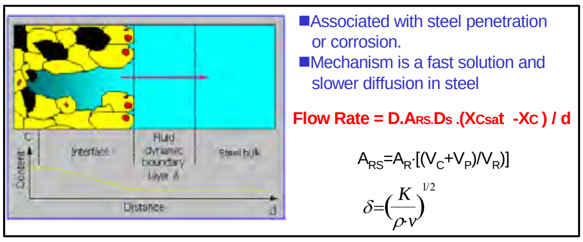

***Fig 11**. Carbon dissolution: carbon flow rate as a function of reactive surface (Ars), carbon content (X) and steel flow.*

The global result is a mathematical program which calculate the flow rate of species passing from the refractory interface to the steel.

3. Steel flow control optimization

In order to better understand steel flow characteristics during casting and steel flow consequences on refractory components, specific fluido-dynamic models have been developed.[5]

The main features investigated are for example:

- Specific meshing refinement at refractory interface to capture physical parameters at refractory interface.
- Thermal exchange between refractory and steel to better evaluate temperature loss in steel as well as thermal gradient in refractory
- Chemical interaction with refractory interface and contamination diffusion in steel flow.

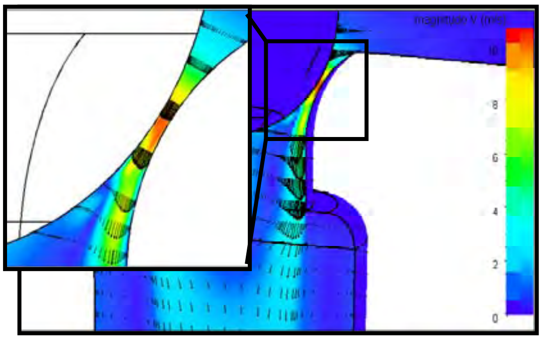

***Fig. 12.** Calculated steel flow at stopper regulation point*

The mesh refinement capability is illustrated in figure 12 representing the steel flow regulation between a tundish stopper and a submerged nozzle.

The noticeable high speed at the regulation area justify the occurrence of severe corrosion phenomena at this location.

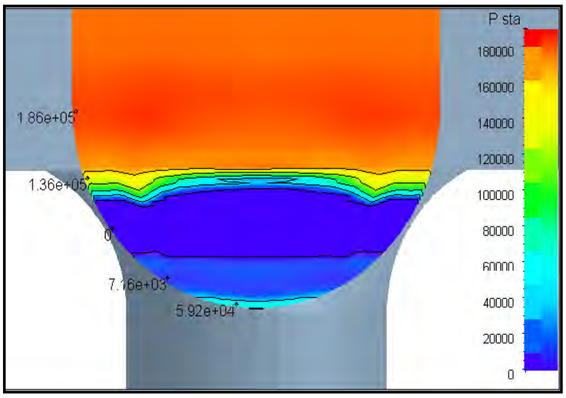

***Fig 13.** Pressure at refractory surface on tundish stopper*

Secondly the extraction from the steel flow results of the pressure at refractory surface (figure 13) explain the strong degassing of refractory observed in this area.

The casting rate is controlled by a stopper or a slide gate, but depends on the ferrostatic head in the tundish and the bore size only. The withdrawal speed of the caster can be adjusted to cope with the flow rate from the tundish and maintain a satifactory steel level in the mold. (fig.14).[1]

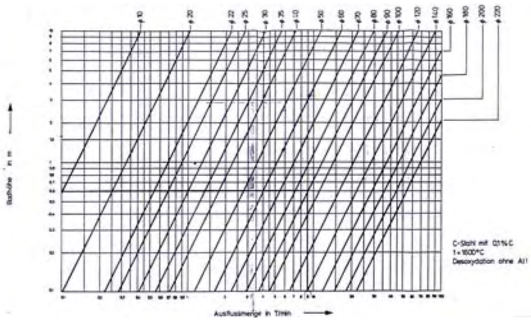

Fig. 14. *Flow Rate Calculation*

4. Conclusions

The continuous casting process of slabs can be automated using submerged nozzle exchange mechanism, flow control of which is achieved by means of a stopper. The tube changer offers : improved caster scheduling, increased caster productivity, increased prime grade slabs, increased yield and reduced operating cost.

In addition to the extension of the tundish service life, there are advantages on improvement of the operation flexibility and security.

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