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Short Communication

Reduction of slivers by the use of an electromagnetic actuator

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Abstract – The submeniscus velocity has a big influence on the surface quality of slabs. Slabs casted with a low casting speed result in a low submeniscus velocity and suffer more from Al-inclusions, while slabs casted with a higher casting speed have a higher submeniscus velocity and suffer more from mould powder inclusions. If the submeniscus velocity can be controlled, the amount of slivers has to be reduced. ArcelorMittal Ghent decided to install an ElectroMagnetic Actuator (EMA) to control this submeniscus velocity. This topic shows what the impact of the EMA can be on slivers.

Slivers occurrence [1] is still a major cause of quality problems in steelmaking industry. Inclusions elimination is getting more and more important to obtain clean steel, particularly in Continuous Casting (CC) mould, which is the last reactor where steel remains liquid. Industrial quality results show that steel surface defects observed on hot and cold rolled products are intimately linked to the casting conditions during the CC process and as a consequence to the flow behaviour in the CC machine [2, 3]. Controlling the flows in mould with the use of electromagnetic technology [4–6] is an important working axis for quality improvement.

A Multi-Mode Electro-Magnetic Stirring technology delivered by Danieli Rotelec Company [4] has been implemented in ArcelorMittal Gent CC2 machine. This solution is able to control the liquid steel flows in CC mould by braking, accelerating or stirring it through the use of 3 different modes: EMLS, EMLA and EMRS respectively.

In order to better understand those fluid flow phenomena and optimize the working of the electromagnetic actuator, ArcelorMittal Gent, in collaboration with ArcelorMittal Maizières R&D, has used different approaches:

- Industrial measurements with Submeniscus Velocity Control device [7, 8]. This system gives access to the meniscus velocity measurement directly in the mould, a key parameter to characterize fluid flow pattern and stability.
- CFD/MHD calculations [9, 10]. Many research teams work on the development of numerical tools to predict flow behaviour in CC mould. Interactions of liquid steel flow with electromagnetic forces generated by an actuator can be taken into account [11, 12]. This kind of calculations is very useful to highlight configurations affecting steel cleanliness and to propose/optimize settings for electromagnetic actuator or modifications of casting conditions.

This paper presents the methodology applied in order to optimize the working of this electromagnetic technology for improving the quality of products in terms of slivers defects. Some quality results are also presented and prove the real efficiency of this technology. However, they show that the control of the actuator is not so easy and that the model used for this control has to be adapted for each grade type individually.

1 Installation of the EMA in Ghent

In July 2007, Danieli/Rotelec delivered and installed a MM-EMS technology in ArcelorMittal Gent CC2 machine. First, only strand No. 4 was equipped with 2 sets of stirrers. In April 2011, the second strand No. 3 was also equipped and 5 sets of stirrers were available for a complete CC2 production in February 2012.

The main objectives of the ElectroMagnetic Actuator (EMA) were:

- Reduction of surface defects by creating an optimal flow pattern in the mould.
- Keeping a good surface quality at very high casting speeds and being able to increase the casting speed.
- Increasing the casting flexibility of ULC en low C-grades without having a degradation on the quality.

2 Determination of the EMA model

2.1 Working modes of the EMA

The EMA technology offers different possibilities to control the flow in the mould:

- EMLS–mode (Electro-Magnetic Level Stabilizer) for braking the flow under higher casting speeds.
- EMLA-mode (Electro-Magnetic Level Accelerator) for accelerating the flow under lower casting speeds.
- EMRS-mode (Electro-Magnetic Rotative Stirring) for creating a rotative flow in the mould. The EMRS-mode can be used in a symmetrical way, in which all the coils produce the same current, or in an asymmetrical way, in which the current of the coils have a different value. The more asymmetric the currents are defined, the more suitable they are for higher speeds. When a EMRS-mode with a low asymmetric factor is used under a higher casting speed, the flow in the mould would become more and more unstable, leading to more defects. This means that the symmetrical EMRS-mode is only suitable for lower speeds. Asymmetrical EMRS-modes can be used with a wider range of casting speeds.

2.2 Calibration of the EMA

Before selecting the working mode, measurements of the submeniscus velocity have to be done. These are done by inserting special refractory probes in the mould. These probes offer a way to measure the flow in the mould. The combination of these measurements with numerical simulations offer a way to determine when which working mode has to be used.

This leads to a EMA-model where the EMLS-mode has to be combined with EMRS (symmetric) of EMLA. The EMRS asymmetric mode can be used as a standalone model.

2.3 Decision of the standard working model

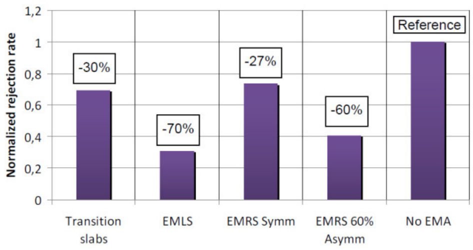
The coils of the EMA can be placed on a standard/low position or on a higher position. The positions cannot be changed automatically. In 2008 and 2009, several tests were done to determine the best position. In the standard/low position the combination EMLA + EMLS showed the best results. In the high position, the combination EMRS + EMLS showed the best results.

A comparison of the two situations showed that the highest position gave better results than the low position, which leaded to the placement of all the coils on the highest position. This resulted in the EMRS + EMLS as the first standard working model.

The combination of these 2 working modes has a negative effect: slabs can be casted with more than 1 working mode. These slabs are called transition-slabs. The quality of transition-slabs isn't always better than slabs casted without EMA. These slabs can be avoided be using a working mode for a wider range of casting speed. This can be done by using the EMRS-mode in an asymmetric way.

3 Comparison of the different modes

For all kinds of grades, the EMLS-mode showed an improvement of 70% less rejections by slivers, in which the EMLS-mode serves as best mode, following by EMRS 60% asymmetric as the second best mode.



The EMLS-mode however is only used in the highest casting speeds. This mode needs to be combined with symmetric EMRS-mode. The improvement of the symmetric EMRS is not as high as the EMLS-mode.

This combination will also generate transition slabs. This mostly happens when the casting speeds varies during casting. This speed variation occurs mostly during ladle changes. The quality improvement of these transition slabs is limited because of the unstable flow conditions.

Statistically, 50% of the slabs are casted under EMLS-mode, 10% under symmetric EMRS-mode, leaving 40% transition-slabs. This results in an overall improvement of 50% for the EMRS-EMLS model.

To avoid these transition slabs, the EMRS-mode with 60% asymmetry was chosen. This mode has the possibility to be used under a wider casting speed range.

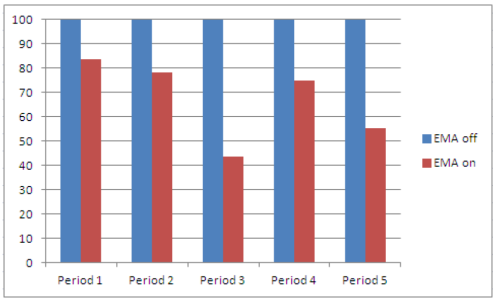
4 Quality results

4.1 Hot dip galvanised exposed ULC grades

HDG exposed ULC (ABO) grades, the EMA showed on average improvement of 32% less rejections.

The result above represents 5 different periods.

For these grades, transition slabs showed practically no quality improvement. In some

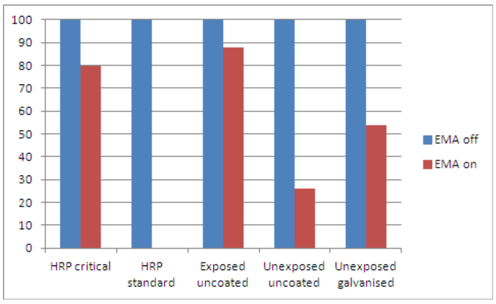


periods, the quality of these slabs got even worse.

This is why for these grades, the 60% asymmetric EMRS-mode was chosen as new EMA model.

4.2 Other steel families

The quality results for the other steel families vary from 12% improvement to 100% improvement, meaning that the quality improvement is strongly depended on the type of grade. To improve the quality, the EMA model has to be adapted for each grade type individually.



5 Conclusions

An ElectroMagnetic Actuator offers a way the reduce the amount of slivers. The amount of reduction is however strongly influenced by the working mode and the grade type.

To improve the quality, the EMA-mode has to be carefully determined and evaluated regularly.

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