USE OF FLUX DISTRIBUTION MECHANISM FOR MOLD FLUX PERFORMANCE IMPROVEMENT IN THE CONTINUOUS CASTING PROCESS*

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Abstract

Casting fluxes are one of the key factors to guarantee a good performance of the continuous casting process. Fluxes are added over the liquid steel in the mold, where carbon in the flux reacts with any air present, to form a reducing atmosphere of CO (g) to protect molten steel from oxidation. Then the oxide components form the sintered layer and they melt to form a liquid flux pool. Liquid slag from the pool infiltrates into the mold/strand channel and lubricates the newly-formed, steel shell. It was very common in the past that the addition of casting flux in the mold was made manually by the continuous casting strand operator, where the addition uniformity would mainly depend on the attention of the Operator in process and the addition standard would change from one operator to another, may causing variability on the continuous casting quality parameters. This paper presents improvement of continuous casting parameters such as, stability of flux thickness and reduction of dust in the continuous casting process, with the use of flux distribution mechanism in two continuous casting machines from two different steel plants.

Keywords: mold flux, continuous casting of steel, flux feeder.

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1 Introduction

Mold fluxes play an important role in the continuous casting of steel. As a mix of minerals and synthetic raw materials with carbon source, it has the main functions described by Mills [1] after fed on top of liquid steel in the mold.

(i) Protect the steel meniscus from oxidation
(ii) Absorbing inclusions floating up from steel
(iii) Provide thermal insulation to prevent the steel from freezing
(iv) Provide the optimum level of horizontal heat transfer between steel shell and mold
(v) Lubrication of the steel shell

Considering the temperature difference between the atmosphere (~ 35ºC) and the liquid steel (~1550ºC), the mold flux reacts with air present to form a reducing atmosphere of CO (g) to protect molten steel from oxidation. As the temperature increases from the top to the liquid steel, mold fluxes turn to a sintered layer, form a mushy slag and the oxide components form a liquid pool, named liquid slag. The liquid slag continuously infiltrates into the gap channel between the solidifying shell and the mold. Most of the first liquid entering this channel freezes against the water-cooled, copper mold and forms a glassy, solid slag film. The glassy layer may partially crystalize and contribute to the horizontal heat transfer control [2]. It is generally considered that the liquid slag film runs with the strand, and the solid slag film remains in contact with the mold, as it can be seen in the figure 1.

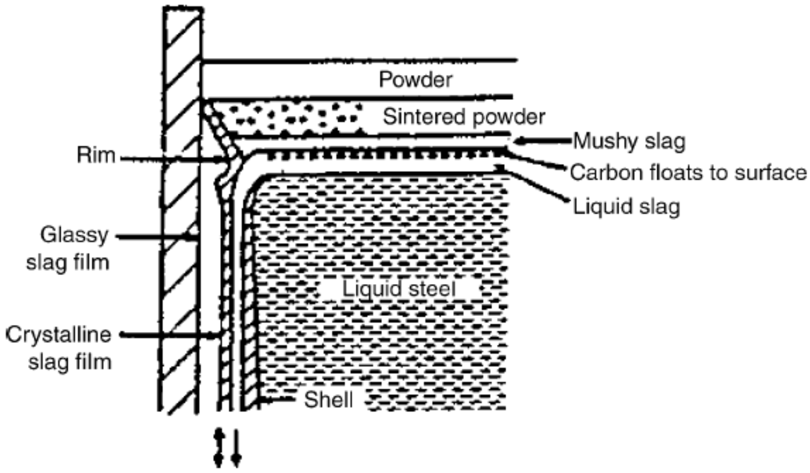

Figure 1 – Schematic drawing of the various slag layers formed in the mold [1]

With the goal to assure the good performance of casting fluxes, it is very important to maintain the continuous addition of fluxes into the mold. For many years the casting flux was manually added by the strand operators of continuous casting machine using a wood toll. Figure 02 illustrates this operation.

(a) (b)

Figure 2 – (a) Operators positioned in front of continuous casting machine following the addition of mold flux (b) detail of mold flux addition using a wood tool.

The constant and consistent addition of mold flux in the mold helps to compensate many of the variation in continuous casting condition by being flexible. Figure 3 shows the variables of continuous casting process and their effect in the continuous casting process and on process control.

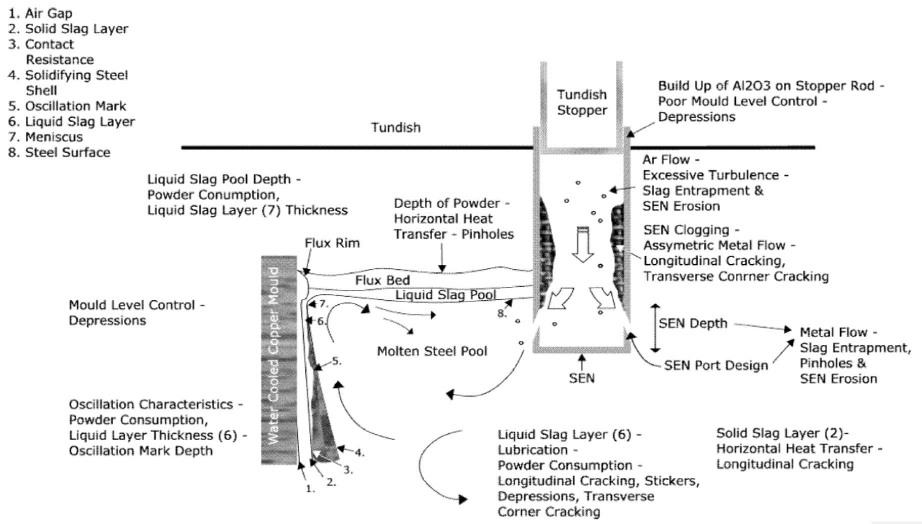

Figure 3 – Schematic Diagram showing the cause of various defects and operational problems in the continuous casting process

Manual addition does not guarantee the uniformity of casting flux in the mold as some distraction may occur by the Operator resulting in the lack of liquid slag available to properly feed the gap between the mold and solidifying steel shell. Insufficient flux application can generate mainly slab surface depressions, deep oscillation marks and stickers as per missing liquid flux lubricating the gap between the solidifying steel shell and the mold, beside other operational problems such as SEN (submerged entry nozzle) premature failure occurrence and lower stability of mold flux.

Different types of mold flux feeders were developed and Wang et al [3], demonstrate comparison made on automatic slag feeding by means of gravity, mechanism and gas-worked, and a model with a robot arm can be seen on the patent citation [4]. Many of the old-style feeders in operation still rely on the operator input to control mold flux thickness in the mold.

This article presents an automatic flux feeder designed to control consistent powder thickness and reviews case studies outlining the benefits seen in operation from this capability. Photos in figure 4 illustrate the consistency of powder thickness measurements with the new flux feeder as compared with an old-style flux feeder that does not have this feature.

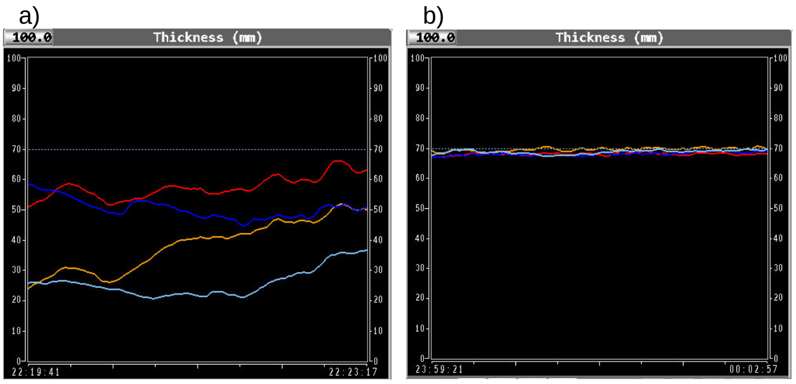

Figure 4 – Photos illustrating the thickness of mold flux in a) old style flux feeder and b) new style flux feeder described in this article

1. Materials and Methods

1.1 Equipment Description

The flux feeder presented in this article is a self-contained delivery system designed to be pushed into position on the casting-floor. The integrated dosing system delivers the mold flux at the desired flow rate through the discharge lines. With a maximum of four discharge lines, the unit can deliver the mold flux at a maximum flow rate of 7,2 kg/min (1,8 kg/min per discharge line).

The equipment uses compressed gas (air, argon or nitrogen) to convey the granulated mold flux from a remotely located bulk source into the mold through the discharge lines as shown in Figure 5. The machine controls the amount of casting flux supplied to the discharge nozzle without interference with the mold flux level sensor in the mold.

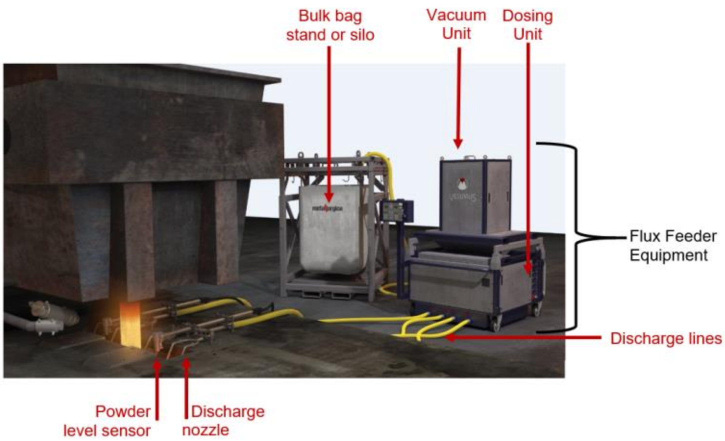

Figure 5 – Schematic diagram of flux feeder in the mold

The machine is supplied with a pick-up wand to be inserted in a bulk bag or a silo. It has been designed to have a common frame and to be configured either in the two lines version or in the four lines version to provide the mold flux into the mold. Figure 6 illustrate the equipment used in this article with four lines.

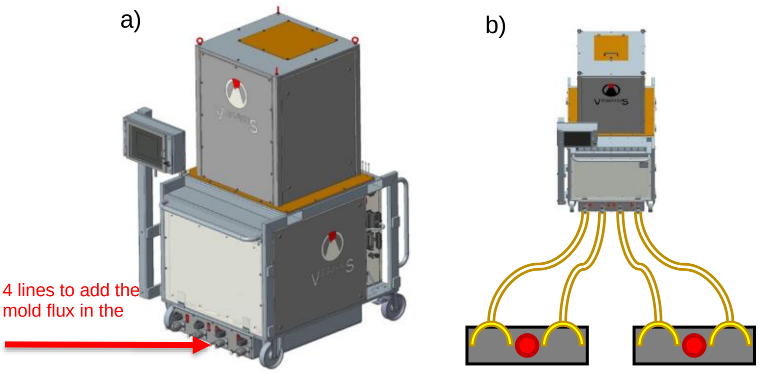

Figure 6: **a)** Equipment with 4 lines to add the mold flux into the mold. **b)** Details of the lines adding mold fluxes into two strands in the continuous casting machine

The machine is essentially composed by two parts:

- The lower part called Dosing Unit: it contains all the devices to dose and evaluate, in real time, the flux flow rate delivered to the mold through the supply lines;
- The upper part called Vacuum Unit: it uses a compressed fluid powered system to convey the flux from a remotely located bulk source into the receiving vessel to maintain an appropriate volume of flux in the machine.

A wireless hand-held operator terminal is used to manually adjust flux flow rate delivered to the supply hoses or to switch in automatic mode. In the automatic mode the system will adjust the flux flow rate to maintain the desired flux thickness in the mold. An HMI (human machine interface) fixed on the machine frame or at a remote location enables the operators to have access to the parameters of the feeder. Its touch screen shows a synoptic view to quickly have information about the state of the machine (operating values, alarms, flow rate, etc.…).

A standard nozzle has been used, which was installed at the end of the discharge lines to ensure a proper and homogeneous distribution of the mold flux inside the mold. These were made of austenitic stainless steel to limit the disturbances on the electromagnetic mold level sensor.

All data in the trials were recorded in an internal memory for post-evaluation.

1.2 Method used

Trials were done in two steel plants, named **Steel Plant A** and **Steel Plant B**.

2.2.1 – Evaluation of mold flux stability with the use of automatic system of flux feeder equipment at Steel Plant A

In one typical heat of continuous casting steel in the Steel Plant A, the mold flux thickness has been evaluated in the right and left side of the mold to assess the uniformity. Comparison was made using the period of 8000 seconds before automatic system and 6000 seconds after the automatic system.

2.2.2 – Submerged Entry Nozzle (SEN) premature failure cases at **Steel Plant A**

During the period of 5 months before the use of the flux feeder and 18 months after the use of mold flux feeder, the SEN premature failure has been compared. The following parameters were used:

- SEN premature failure happening before 16h of casting time was recorded;
- The index number of breakages per month and per caster has been presented;
- The production in the period was stable and the average of heats were 700 per month

2.2.3 – Air born particle measurement at **Steel Plant B**

For the evaluation of air born particle measurement, the performance of dust tests using the parameters described below has been compared:

- Casting Speed: 1,55 m/min
- Steel Quality: 126L

- Flux Type used: Scorialit SPH-SL 450/SD
- Mold Size: 1200 x 250 mm
- Strand 1: New flux feeder concept has been used
- Strand 2: Gravity model flux feeder has been used

For the dust test, the following procedure to measure the dust has been adopted:

- Pre-weight (mg) of the filter (P1)
- Expose the filter in a position of 30cm from the mold surface for 35 minutes;
  Weight again (mg) the filter (P2), to quantify the dust collected using the equipment from an external, professional and certified dust measurement company

Figure 7 shows the equipment used and the filter being pre-weighted.

a) b)

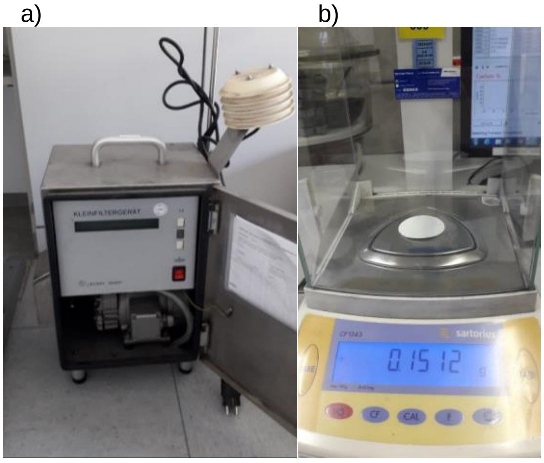

Figure 7 shows (a) the equipment used for the dust measurement of the mold flux in the mold and (b) the filter being pre-weighted.

2. Results and Discussion

3.1 Evaluation of mold flux stability before and after the use of flux feeder equipment in the automatic mode at **Steel Plant A**

Data has been collected before the automatic mode for 8000 seconds and after the automatic mode for more 6000 seconds, as demonstrated in the Figure 8.

X axis shows time in seconds, and Y axis shows the length in mm. The description of curves is described below:

- Green curve: Mold flux level thickness in the right side of the mold;
- Yellow curve: Mold flux level curve in the left side of the mold.
- Red curve: Mold flux top surface in the right side of the mold
- Purple curve: Mold flux top surface in the left side of the mold

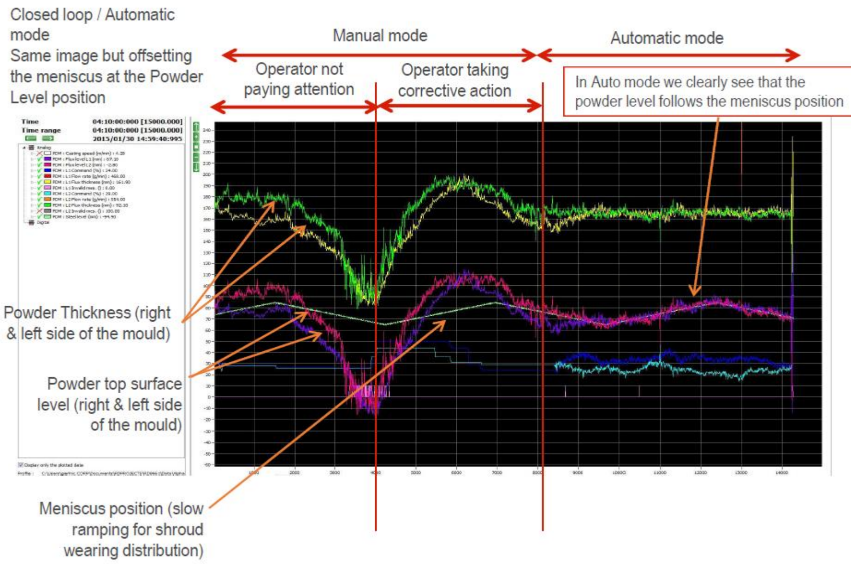

Figure 8 – Evaluation of the mold flux stability before and after the use of flux feeder in the **Steel Plant A**

It can clearly be seen ~~a~~ stability of the mold flux thickness after the automatic mode in use, ensuring the availability of mold flux in the mold, when the system is fully automatic.

3.2. Submerged Entry Nozzle (SEN) premature failures at **Steel Plant A**

Before the Flux Feeder installation, Steel Plant A was operating an open loop system with no mold flux thickness control. The mold flux level was set by the operators according to a visual mark in the mold. The mold flux level was then located around the same area of the SEN, generating excessive erosion and sometimes SEN premature failures.

With the implementation of the Flux Feeder in closed loop, the mold flux level moves with the steel level and is located at different heights of the SEN. The erosion of the SEN is thus more homogeneous, and SEN premature failure was reduced.

Figure 9 illustrates the process of open loop and close loop in the mold flux thickness

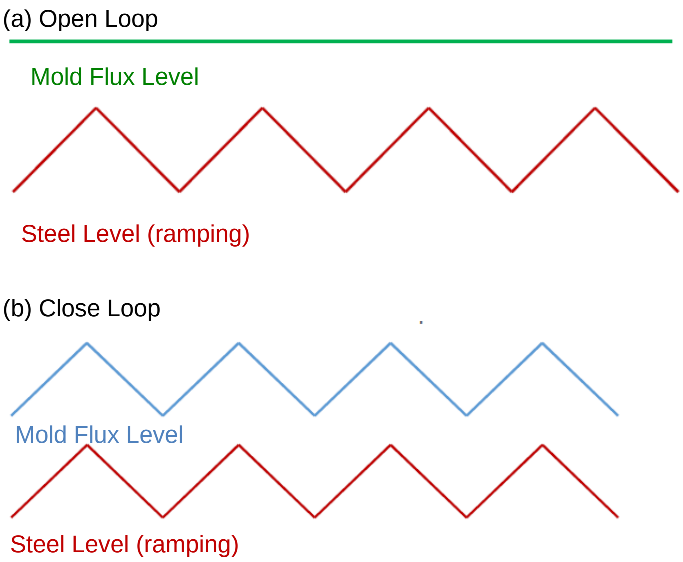

Figure 9 – Diagram showing mold flux level in the (a) open loop and (B) close loop

The premature SEN failures were eliminated (15.6 cases per year) with the use of automatic flux feeder.

3.3 Air born particle measurement data at **Steel Plant B**

Results obtained are described in Table 1.

Table 1 – Average of Air born particle measurements at Steel Plant B in mg/Bm^3

Strand 1 (New Flux Feeder Concept)	**Strand 2 Gravimetric System**
0.17 mg/Bm^3	0.13 mg/Bm^3

With the use of the flux feeder, a reduction of 23,5% of air born particle was obtained.

4 Conclusion

Results with the flux feeder usage presented in this paper, showed an improvement in the mold flux application during the continuous casing process as per the attainment of the following points:

- Achievement of more stable mold flux thickness guarantying the stable availability of mold flux in the mold, avoiding several defects such as slab surface depressions, deep oscillation marks and stickers as per missing liquid flux lubricating in the gap between the solidifying steel shell and the mold (case B),
- Reduction of SEN premature failure as per the stability of mold flux level, avoiding the concentration of SEN attack due to less excessive erosion in a concentrated SEN position (Plant A);
- Reduction of 23,5% of air born particles (Plant B).

Comentado [JRB1]: casting

Comentado [JRB2]: I suggest to use “ensuring” the correct word guaranteeing is seldom used.

5. References

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