NEW MEASUREMENT SYSTEM ON CONTINUOUS CASTING TUNDISHES AT STEEL OF WEST VIRGINIA PROVIDES TRUE STEEL RUNNING LEVEL AND INCREASES YIELD BY ACCURATE DRAIN CONTROL*

Mark Gilliam[1]
Phillip Wolfe[1]
Jason Rulen[1]
Jeff Smith[1]
Robert McGuire[2]
Anthony Lyons[3]

Abstract

Control of true steel level in the tundish during casting is desired in order to maintain the correct pressure head and thus provide a stable flow to the mold. Also the control of tundish draining prevents slag carryover and can increase yield at each end of cast sequence. At Steel of West Virginia (part of the SDI Group), it was understood that to be able to measure the true steel running level and control the drain level at the end of casting would be a great benefit during production at their three strand billet caster. This paper sets out to show how an evaluation process was started to find the best method to determine steel level in the tundish and to prevent the steel level dropping low enough to allow slag to enter the mold. Also how the decision was taken and a real time molten steel measurement system was installed and by utilizing the resulting data in the process, how slag in the mold was removed as an issue, how lost production was reduced and how consistent steel level has provided constant casting speeds and improved stream integrity, all leading to realized quality improvements. Other areas discussed within the paper will be the training of operational staff, the difficulties to be overcome when first installing new equipment and how these teething problems were cured by close co-operation between the steel plant and the equipment suppliers. In conclusion the paper will discuss the production improvements achieved, production cost savings at the plant and how the generated data was integrated into the plants process control system.

Keywords: Continuous casting; Steel level in tundishes; Sensors; Real-time measurement; Running and drain level.

[1] *Steel of West Virginia, Huntington, WV, USA.*
[2] *Metal Products and Engineering US LLC, USA.*
[3] *Agellis Group AB, Sweden.*

ISSN 1982-9345

1 INTRODUCTION

Steel of West Virginia (SWVA) is a mini-mill located in the city Huntington, West Virginia, USA. The plant started in 1907 as a rail re-rolling mill and has operated almost continuously since that time. The plant is a wholly owned subsidiary of one of the leading North American steel producers, Steel Dynamics, headquartered in Fort Wayne, Indiana. The Melt Shop at this plant consists of two electric arc furnaces and a three strand continuous billet caster with an annual capacity of 285,000 tons which supports two special section rolling mills. The plant runs at near 100% capacity.

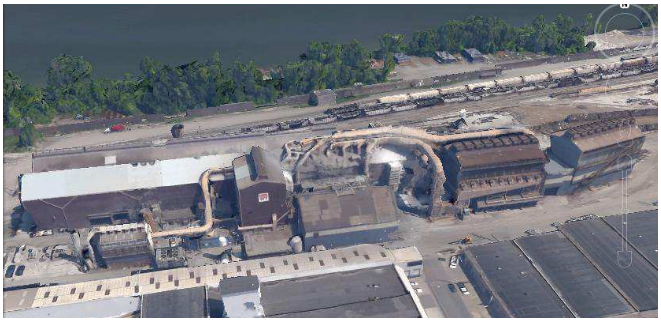

Fig. 1 Steel of West Virginia SWVA Melt shop.

In 2011 SWVA started the process of evaluating the best method to determine steel level in the tundish. The tundish at SWVA is small and contains only 6800 pounds (3084kg) of liquid and has a steel residence time of only 4-5 minutes. SWVA did not have tundish weighing or any other method of measuring the level of steel other than using a rod dipped into the tundish to determine the slag/steel level. This created quality issues when the level in the tundish dropped low enough to allow slag to enter the mold. At least twice per month the steel dropped to this low level which allowed enough slag to enter the mold to cause a break-out in the caster. This resulted in 2 hours of delay per event to clean up the mess and restart the caster.
The two methods considered as a solution to this problem were to install load cells on the tundish transfer car or to go with the Agellis EMLI-T system. The reason for choosing the EMLI-T system was the ability to know the actual level of steel in the tundish as opposed to simply having a weight and making assumptions about steel level.

2 MATERIAL AND METHODS

2.1 Principles of Electromagnetic Measurement

The Agellis EMLI-T Tundish Measurement System utilizes electromagnetic techniques.
In Figure 2 the principle of measurement is depicted. A sensor supplied with a selected current and frequency induces a current of the same frequency in the corresponding opposed sensor by electromagnetic coupling. As the metal level in the tundish varies, the electromagnetic coupling changes the amplitude of the induced receiver current. The calibrated signal output is linearized to denote the actual metal level in the tundish.

ISSN 1982-9345

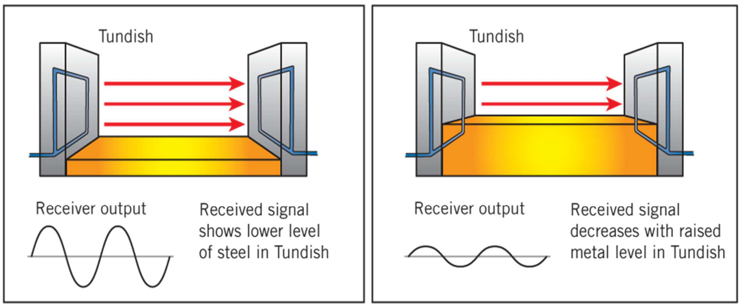

Fig. 2 Principles of measurement.

The advantages of utilizing such a measurement system is the possibility to measure the real steel level over the whole depth of the tundish including the level when draining at the end of casting. The real steel measurements are not affected by the presence of slag.

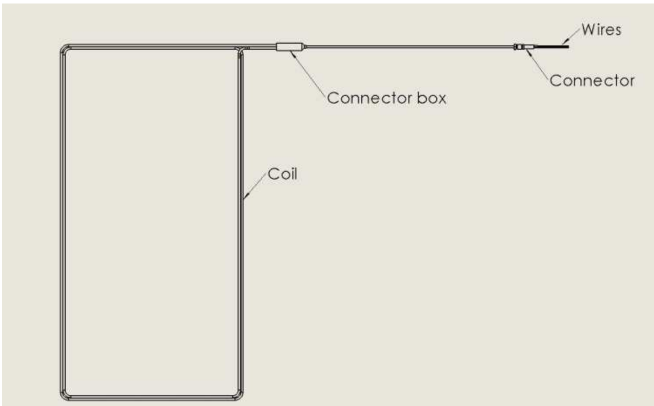

Fig. 3 Sensor Loop Design

The sensors, shown in Figure 3 are specifically engineered for each tundish type in order to fit the required measurement range. The material used for the sensors has such qualities that it does not require any cooling to operate well within the conditions experienced in the tundish, withstanding 900 degrees Celsius continuous operation and chemical corrosion.

2.2 System Installation

The EMLI Tundish System is designed to have its sensors installed against the inside steel shell of the tundish behind the refractory. See Figure 4 below. The sensor installation is simple and undertaken during tundish reline. The required tundish equipment, once installed, is well protected and survives for many years without requiring change. The position and protection of the sensors assures their longevity and a sensor exchange is normally undertaken during a total refractory relining.

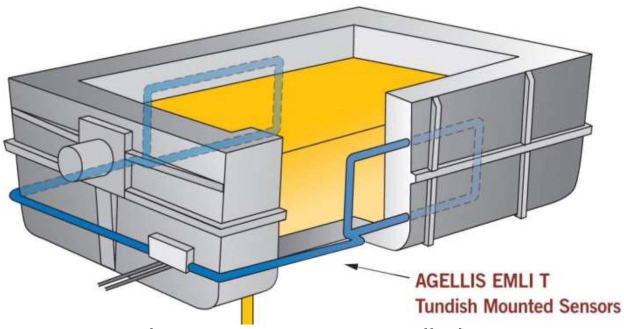

Fig. 4 Sensor Loop Installation

ISSN 1982-9345

To avoid disturbing production the installation of the sensors on each tundish was performed as the tundishes came out of service for re-line. The framework protecting the sensors was welded in place and the sensors installed with non-magnetic stainless steel placed over them, as shown in Figure 5 and 6. The non-magnetic stainless steel covering the sensors allows the electromagnetic field to pass straight through.

Fig. 5 Tundish Preparation

Fig. 6 Sensor Loop Installation

To prepare and equip a tundish takes about half a day due to the welding of the frames.
However, once completed, the sensors remain in place for a long time and any sensor replacement after a couple of years operation can be performed in much less time, as the framework will already be in place. Figure 6 shows a new installation and also the sensor framework after some months of use.
The tails of each of the Sensor Loops were fed through the tundish wall via holes sealed with cement material so as to prevent any gas escape and connected to the connector on the outside of the tundish. Each tundish was then re-lined as normal ready for use as it can be seen in Figure 7.

Fig. 7 Relined Tundish

Connectors were installed on the outside of the tundishes ready for quick connection to the systems flexible cable. A quick release mechanism was also installed to enable the flexible cable to be pulled free without damage when there is an emergency tundish removal. See Figure 8. The EMLI electronics is connected to the sensors via the flexible cable when the tundish arrives into the casting position, prior to the opening of the ladle slide gate.

Fig. 8 Tundish connector

2.3 System Layout, Connection and Configuration

Positions for the EMLI-T units were chosen for operational convenience and easy access. See Figure 9 below.

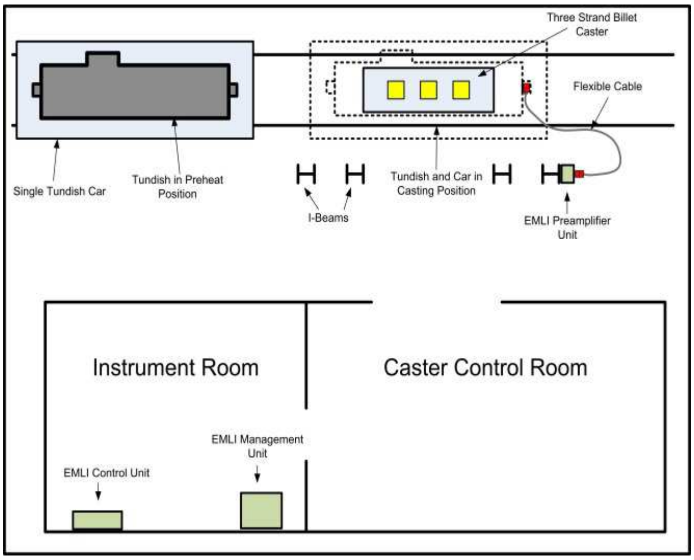

Fig. 9 Caster Shop System Location

Protection and survival of the flexible cable was also important, so the cable is specifically engineered for operating on the casting floor in steel plant conditions.
The EMLI-T connection configuration consists of the tundish equipment, a flexible cable, a wall connector, a pre-amplifier unit, a control unit and a management unit. The pre-amplifier unit is placed within 20 meters from the tundish car casting position. The unit is engineered to be directly installed on the casting floor area and is contained in an IP66 rated industrial box measuring only 200x300x155mm. See Figure 10 below.

ISSN 1982-9345

Fig. 10 Pre-amplifier unit on the casting floor

The control unit can be placed within 200 meters from the pre-amplifier unit anywhere on the casting floor area or in an electrical room. The control unit itself measures only 700x500x255 mm and is also contained in an IP66 rated industrial box prepared for wall installation. See Figure 11 below.

Fig. 11 Control unit on the casting floor

The management unit is typically installed in an electrical room or in the casting floor control room. The management unit is composed of an industrial PC and other related electronics and can be contained in a specific cabinet or even configured in a virtual PC environment. The management unit is used to set-up parameters, access historical logs, log system parameters in real-time, monitoring the status of the control units, fault finding and allows on demand remote support.

ISSN 1982-9345

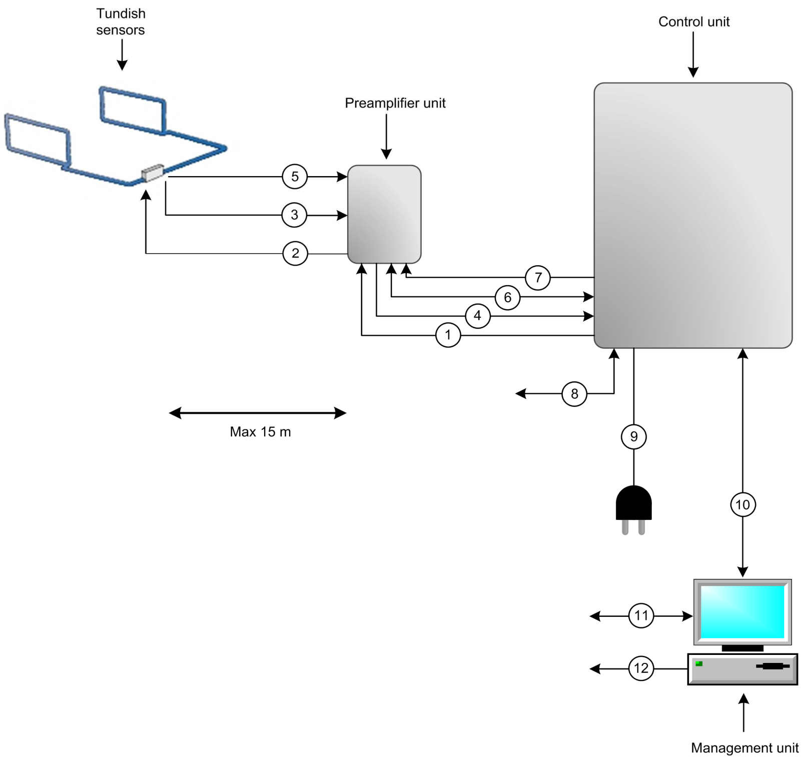

Fig. 12 System connection diagram

The Agellis EMLI-T system can be integrated with a plant level 2 system directly from the control unit via ordinary 4-20mA lines or via a Modbus/Profibus interface. As can be seen in Figure 12 the Control Unit acts as a central hub for all the main signals. At SWVA the Control Unit is currently configured to deliver the processed electromagnetic sensor signal directly to the plant PLC. When fully automated, the 4-20mA signals are supplied to the ladle slide gate control system and also provide steel level information to the plant PLC.

2.4 Operation of the EMLI-T system

The operation of the EMLI-T system is simple as all that is required is for an operator to connect the flexible cable to the tundish when it comes into casting position. The system calibrates automatically to the signals being received from an empty tundish. When the ladle slide gate is opened and steel is poured, the system tracks the steel to the pre-selected operating level in the tundish and then provides continuous signals to the slide gate control system so as to maintain the required operating level. The EMLI-T system was connected to the plant PLC system to allow control and easy access to historical trending information. During the installation of the EMLI-T system an LED display was added on the wall of the casting bay so that operators could monitor and adjust the steel level from the ladle platform area. See Figure 13 below.

ISSN 1982-9345

Fig. 13 LED Display Casting Bay

Once the level measurement was proven to give accurate information, Vesuvius, the ladle slide gate supplier, was contracted to automate the control of the slide gate based on feedback from the EMLI system. The tundish is 17 inches (43.18cm) deep and the desirable operating level is 16 inches (40.64cm) with a minimum acceptable level of 10 inches (25.40cm).
Now once the ladle is open and stable, the system is put into automatic mode and the steel level is maintained throughout the heat to the SWVA specification of plus or minus one inch (25.4mm). Information on tundish level is available throughout the caster and provides real-time and historical trending.

3 RESULTS AND DISCUSSION

3.1 Measurement Data

The measurement data provided by the EMLI T system was cross checked by comparing it at first with dip-pin measurements.
When the tundish is running at the required steel level, there is a pressure head associated with the metal exiting the tundish nozzle and entering the mold. A stable pressure head based on true steel level greatly assists control of the level in the mold.
If the steel in the tundish drops below a certain level during a ladle change, the pressure head naturally drops.
However, as the system tracks the true steel level, the process can be controlled correctly and ladle changes should go smoothly. Due to the nature of the small size of our tundishes and the narrow level window available, a very precise steel level measurement is required to maintain the SWVA process specifications. In Figure 14 below, a screen shot taken during the commissioning of the system shows the measured metal level (red line) during a ladle change sequence. At this stage of the project the regulation of the steel flow to the tundish was not yet automated but controlled manually.

ISSN 1982-9345

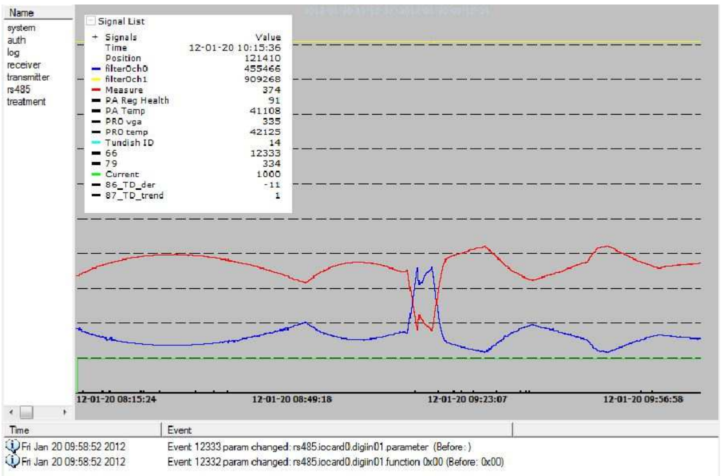

Fig. 14 Level measurement during a ladle change

The measurements generated by the EMLI-T system are both accurate and precise since the system is monitoring the actual steel level at all times. This gives better repeatability and reliability than traditional load cell systems that use a weight figure to estimate a corresponding level. Since the tundish volume is not constant the estimation of a level based on a weight figure is inaccurate.

Figure 15 below is an example of a comparison between measuring the actual steel level and tundish weight. The steel level measurement reacts instantly to ladle gate movement (increasing/decreasing the flow of steel to the tundish), whereas the weight measurement provides a more erratic reaction not representative of actual steel level.

It shows a clear and almost immediate relation between the steel level (blue line) and the gate position (red line). The weight measurement (green line) does not correspond to a correct steel level feedback. A correct ladle slide gate regulation must be based on the true steel levels and not on the tundish weight to ensure correct performance and as a result, product quality.

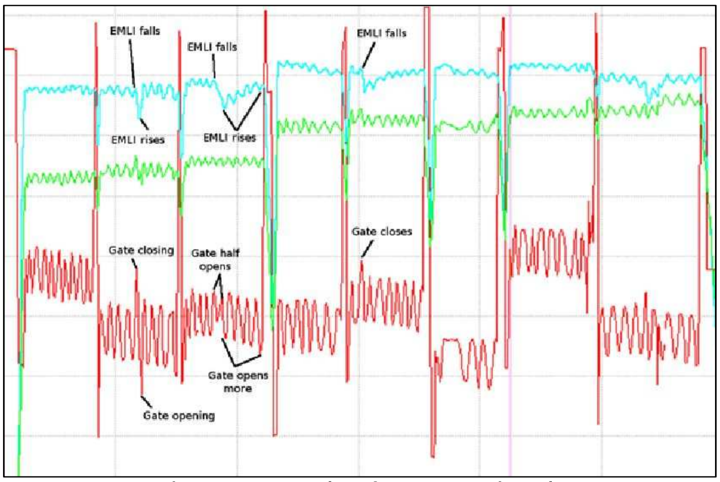

Fig. 15 Example of EMLI-T Signals

3.2 Operating Problems Experienced

Training on the system was straightforward with all SWVA caster and technical personnel being quickly familiar with the required operating procedures. Any problems can be rapidly assessed via the fault finding software on the Management Unit and it is also possible to connect the system remotely to a service center if required, to further assist in correcting any issues we may have.

* *Technical contribution to the 46º Seminário de Aciaria – Internacional, part of the ABM Week, August 17th-21st, 2015, Rio de Janeiro, RJ, Brazil.*

Benefits that SWVA have experienced

1. Since the implementation of the EMLI system we have never run slag into the caster molds. This was the initial reason for buying the EMLI system. Prior to the EMLI installed slag was introduced into the molds 1-2 times per month resulting in up to a total of 4 hours lost production per month.
2. Steel level is maintained at a determined set point. Casting on this machine is done through metered nozzles and the consistent steel level provides increased constant casting speed and improved stream integrity. Minor adjustments in speed can be made by adjusting the steel level.
3. Realized quality improvements which are based on maintaining a full tundish to SWVA standards and accurate display of steel levels during a ladle exchange.

4 CONCLUSION

As can be seen in the previous sections, the measurement results attained with the system are consistent, reliable and accurate to within expected limits.
By installing the Agellis EMLI-T system SWVA have received many practical benefits, so the decision to try to improve tundish steel level control and reduce waste at the end of casting now has the chance to be a very successful plant project.

Acknowledgments

This paper is published by permission of Steel of West Virginia, Metal Products & Engineering-US LLC and the Agellis Group AB. The contributions of our colleagues are gratefully acknowledged.

REFERENCES

1 McGuire B.: EMLI Tundish Level Measurement System Pre-engineering Report – Steel of West Virginia, MPE-US LLC.
2 P. Bloemer, A. Lyons: Case Study – EMLT Höganäs Halmstadverken, Sweden AGELLIS Group AB MAR/REP/001277/AG Rev A.
3 AGELLIS Marketing Dept.: EMLI Tundish Real Metal Level Measurement System Overview, AGELLIS Group AB COM/DES/002253/AG REV B.