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Automatic Control of Molten Metal Flow for Improving Casting Performance

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The ways to gain better quality and higher casting performance is an urgent topic among aluminium producers today. This issue is also often on the agenda at conferences like this and the subjects and technologies to achieve this varies. Controlling the molten metal flow by maintaining predefined levels or level patterns is one powerful tool on the way to attain this. Precimeter is specialized in applications for non-ferrous molten metal level measurement and molten metal flow control. By integration of Precimeter products, any casting machine or process can have automatic level and flow control. By retrofitting, any existing casting line with traditional technology can easily be upgraded with Precimeter technology and improve casting performance in a cost efficient way. This paper will focus on the main benefits from automatic level control and how some plants have achieved improvements in their casting process of DC (Direct Chill) slab (or rolling ingot) casting after implementing Precimeter technology.

Keywords: *DC casting automation, Level, flow, control.*

1. Introduction

When casting slabs there are a lot of different factors and parameters that affect the quality of the product. The cooling system, water flow and temperature, degassing, filtering, melting temperatures, grain refining, casting speeds etc. are all important factors and without any direct relation to metal level control.

However, when we look at, metal distribution, metal transfer, fill rates, cooling optimization and metal solidification, metal level control is a powerful tool that is needed to reduce the shell zone, prevent butt curls and cracks and to improve the surface structure.

Metal level and flow control will also enable repetitiveness and traceability through recipes. By accurately controlling the metal level the plant will gain productivity through higher recovery, shorter cycles and less down time. On top of this, maybe the most important thing of all, operator safety will be highly increased due to atomized start and shutdown operations.

2. Metal Level and Flow control equipment for DC slab casting

A typical fully automatic casting system can consist of ProH metal level sensors, starter dams, pin positioners and a furnace control system (such as a tap out actuator or a tilting furnace control system). This equipment is easily installed on the existing launder system by local resources or using the flexible Precimeter mounting rig suitable for any launder type and size.

2.1 Sensors

The Precimeter digital camera laser sensor has been developed exclusively to measure on molten metal surfaces. The Precimeter ProH series is specifically designed for high performance in different aluminium (and other non ferrous metals) applications. Measuring stability and accuracy (typically 0.1mm) with any alloy makes it one of the best performing sensors for mould level control available on the market today. The Precimeter ProH sensors are being used world wide by most major aluminium producers and are also integrated by many casting equipment manufacturers in their casting lines and machines.

2.2 Actuators

To control the metal flow in a DC slab casting machine a pin position actuator is used to adjust the metal flow through the pin/nozzle setup. Adjustment is very precise using stepper motors to control the pin movement in steps as small as 0.01mm. Failsafe design of the actuators by an emergency close function that stops (or opens if desired) the metal flow in any case of power loss or other emergency condition is another important feature in DC slab casting machines.

Other types of actuators, such as adjustable dams and tap out actuators are also available to provide complete metal transfer and flow control.

2.3 Metal Level Control systems (MLC)

A Precimeter MLC-system is a control system using high performing PLC-systems, HMI-interfaces and computers to control, record and analyzes the casting process and metal flow control. The MLC-system is easily integrated and combined with existing control systems for casting machines and various pit utility systems.

2.4 Cast house implementation

Automatic mould level control is available from most suppliers today when purchasing a new casting line or casting machine. For a lot of companies, especially smaller producers, this may lead to heavy investments in replacing all (or parts) of their equipment in their casting line. What everyone might not be aware of, is that some of the benefits from new casting machines can be achieved with less investment and without replacing any of the existing equipment. By *retrofitting* your casting machine with Precimeter products for molten metal level control some of the benefits from new equipment are achieved with increased casting quality as a result.

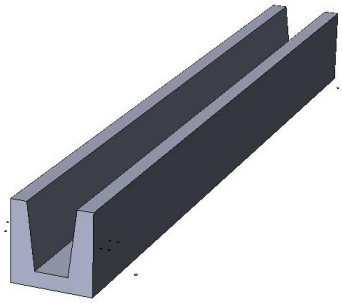

Fig. 1 - Empty casting launder for metal distribution to casting moulds.

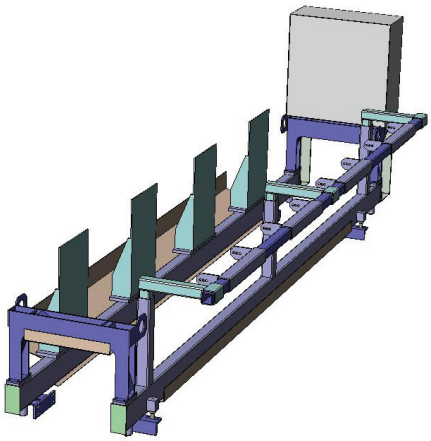

Fig. 2 – The Precimeter flexible mounting rig is adaptable for all launder dimensions and suitable for easy retrofitting.

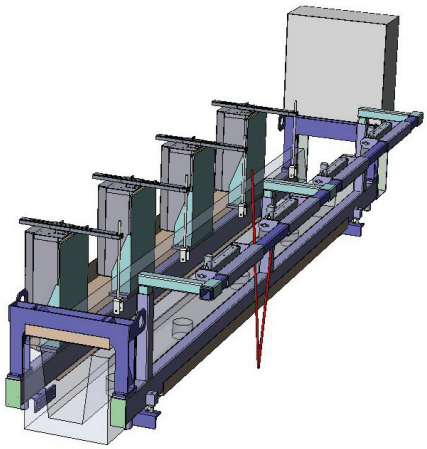

Fig. 3 – Precimeter flexible mounting rig with casting equipment docked on top of casting launder (transparent).

3. Quality factors

3.1 Low metal head

It is well known that casting with low metal head minimizes butt curl and reduces shell zones, resulting in superior surfaces and high recovery rates. This results in significant savings in downstream scalping and edge trimming operations.

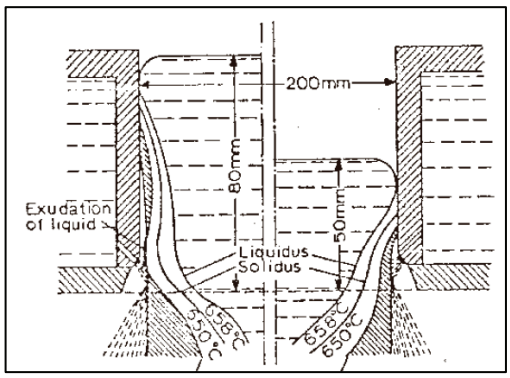

Fig. 4 – Low metal head (right side) avoids the reheating effect caused by the air gap between mould and ingot side (high metal head on left side).

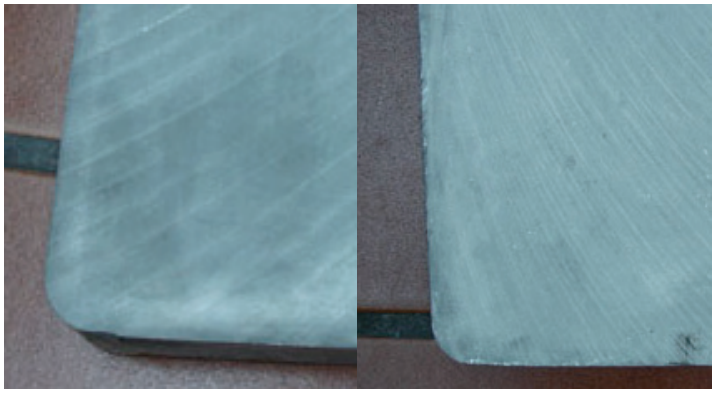

Fig. 5 – Photos from plant example below (Table 1). Left cut from slab cast with high metal head (75 mm) shows visible shell zone structure (aprox. 15mm). Right cut shows cut from the same mould cast with low metal head (55 mm). No visible shell zone (aprox 2 mm).

Plant example:

One example of reducing the shell zone is a slab casting plant in Mexico. After upgrading from Spouts and floats to an MLC-system from Precimeter, they reduced the shell zone from roughly 12-15 mm down to 2-5 mm.

Table 1 – Comparison of scalping reduction from casting with low metal head.

Original setup before upgrading:	*New setup after MLC-control:*
Spout and Float (manual).	Spout and pin (automatic level control).
Metal head: 70-75 mm (+-2.5 mm)	Metal head: 55 mm (+-0.3 mm)
Scalping needed: 15 mm	Scalping needed: 5 mm

Except for the use of a new pin and spout the casting machine remained the same. The improved casting quality was achieved using the same launder system and the same moulds etc. The Precimeter equipment (sensors and actuators) was retrofitted on the existing casting machine keeping the investment to a minimum.

3.2 Fill rate control

By controlling the actual fill rate of the mould, the initial filling of the moulds can be optimized to suite the alloy behavior and the cooling efficiency of the moulds. This will help to reduce material tensions and stress that causes cracks and butt curls. When the perfect fill rate for that specific casting condition is found, the MLC-system casting recipe will store and repeat this through every cast.

Plant example:

One example of reducing cracks by fill rate control is a slab casting plant in the UK. After upgrading from level control by steady eddy to automatic level control with Precimeter products, the amounts of cracking slabs was reduced from 10% to 5% (casting their most difficult Alloy).

By elaborating and adjusting the mould fill rates differently depending on mould sizes (and types) and alloys, the plant managed to reduce the material tensions and stress created at the start of cast. Once you find the optimal settings, different recipes for different products enables repetition from cast to cast.

3.3 Metal level casting curve

With Precimeter MLC-systems and automatic level control the metal head can be adjusted during the time of casting. The metal level in the mould can be controlled by following a predefined level curve. This level curve is scheduled by time or cast length. By doing this the metal head level can be optimized and changed automatically for different casting speeds and cooling characteristics. Once again, this will reduce shell zones and metal tensions. It will also enable casting at higher speeds.

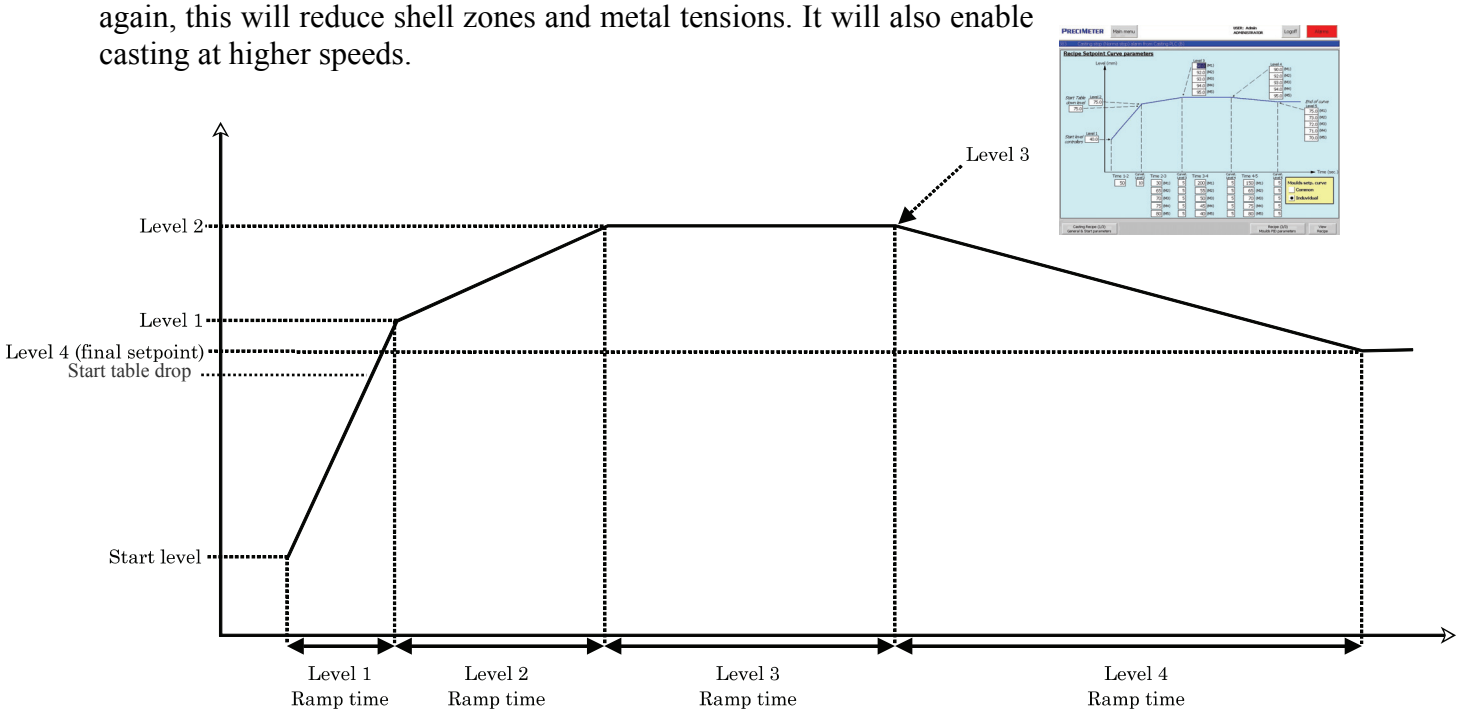

Fig. 6 – Metal level casting curve that adjusts (from recipe) mould fill rate, casting table drop, and metal levels through out the entire cast.

3.4 Mould Metal distribution

Getting rid of floaters and/or mechanical devices (like steady eddies) inside the melt will reduce turbulence and distribution disturbance. A typical pin and spout setup with combo bags will improve the metal distribution in the moulds. They are best combined with digital camera laser sensors and pin position actuators to control the level without any turbulence or fluctuation. With the measuring accuracy of the Precimeter ProH sensors of 0.1 mm the level can be controlled inside 1 mm (+- 0.5 mm or better) without any contact with the molten metal.

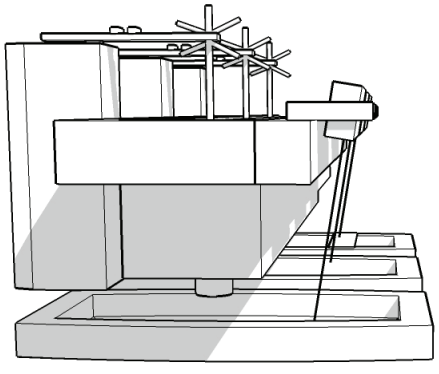

Fig. 7 – No floaters needed in the molten metal. Level measuring by non contact camera laser sensor

3.5 Metal transfer and flow control

Metal transfer to the casting line is one further area where metal quality and conformity can be affected. Any cascading or turbulence of metal will create a rupture in the protective aluminium oxide surface layer. With automatic level control the metal flow can be controlled all the way from the furnace to the mould to ensure a laminar, non turbulent flow.

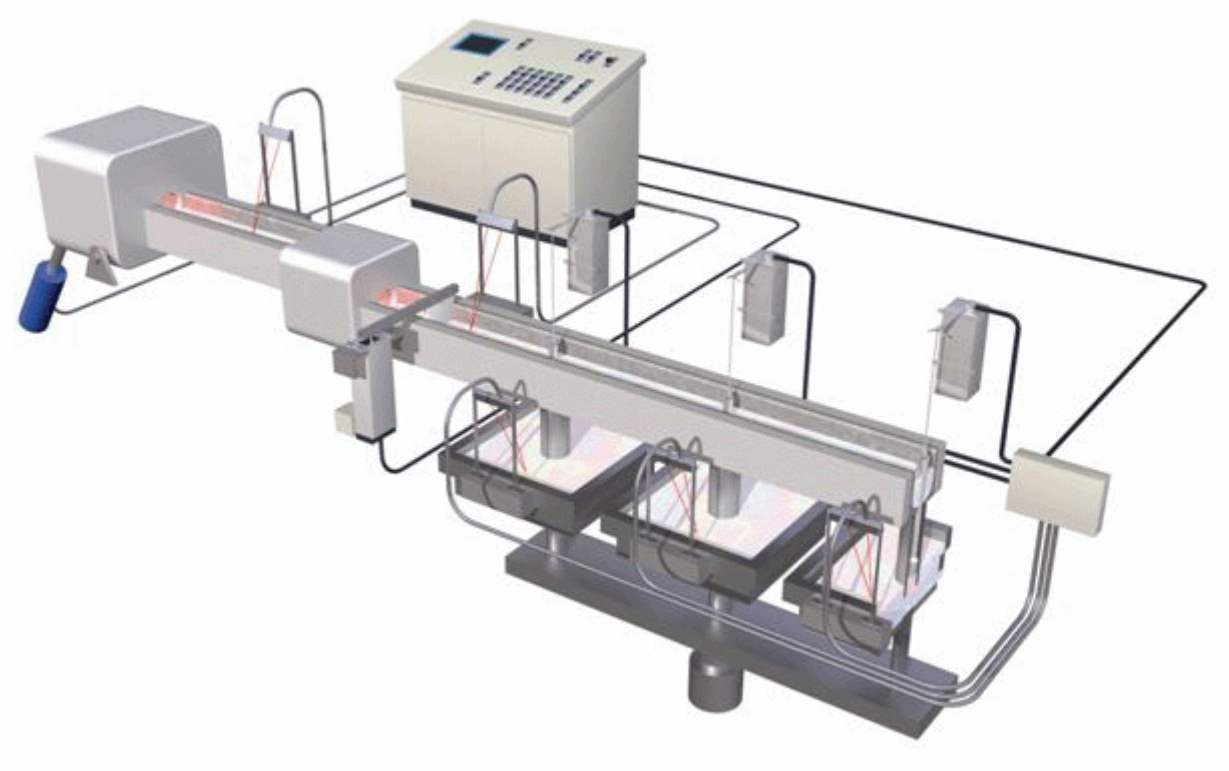

Fig. 8 – Slab casting process with metal level and flow control all the way from the furnace to the moulds.

3.6 Traceability

Automatic level control enables the recording of the information regarding metal levels and metal flow for analysis and improvements. This will help to identify the optimal control settings that suit the specific casting process the best.

4. Safety

Safety has been an important issue in the metal industry for a long time. By making the casting process fully automatic, the operators do not have to be in the machine area during casting. By monitoring the process from a designated and safe area, operator injuries can be avoided. Failsafe design and automatic shutdown in event of any abnormal situation also minimizes the risk of injuries as well as equipment damage.

Plant example:

A slab casting plant in Sweden has reduced the risk of operator injures during casting to close to zero. The operator(s) are monitoring and operating the complete casting process from inside an operator room. All tasks involving close contact to the molten metal during casting have been automated. After installation and commissioning they have had no reports of casting related accidents or injuries.

Brief casting sequence:

* Operator selects casting recipe
* Operator completes all “before cast preparations”
* Operator starts the cast by pressing the start button from inside operator room
* Metal flow from furnace starts automatically
* All Moulds are filling up identically using fill rate control
* Drop of the casting table is done automatically according to recipe
* Mould level is controlled according to specified level curve during the complete cast
* Metal flow is stopped automatically in order to reach the given ingot length
* Casting table is stopped and the remaining metal is automatically drained to designated location
* The casting system is “dry” from molten metal and operators can enter the casting area for “after casting procedures”

In any abnormal situation or loss of electricity, the system will immediately stop the metal flow into the moulds, stop the feeding of metal into the launders and automatically drain the remaining metal to a designated location. The operators do not in any case physically interact to stop or start the metal flow.

5. Conclusion

The process of DC slab casting is an application that will gain a lot from automatic metal level control. If the casting line is old or new doesn’t matter. Upgrading a plant by retrofitting, or by replacing existing equipment, with products for automatic level control will for sure improve productivity by the factors described in the quality and safety chapters. Automatic level control on a DC slab casting machine gives higher recovery through reduced butt curls, reduced cracks, less scalping, less downtime due to accidents and the repeatability of quality.