REGULATION SYSTEM TO IMPROVE QUALITY OF THE METAL SUCKED DURING TAPPING OPERATION

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Abstract

One of the objectives you can target from the whole process of primary aluminium production is to deliver a metal free from impurities. The tapping operation consisting in sucking liquid aluminium from the pot in a crucible through a tapping tube remains an operation requiring precautionary measures. On one hand, the operator has to correctly insert the tapping tube into the electrolytic cell at the lower part of the metal pad. And on the other hand, the volumetric flow during tapping is difficult to regulate. If the flow is excessive, it can result in bath being sucked with the metal. Bath adjunctions have many negative effects both on electrolytic cell operation and equipment soiling but above all on metal casting.
To avoid such concern, ECL works in close collaboration with Rio Tinto Alcan in order to develop and adapt a system described in patent and based on components of the shelves. This system allows the control and the regulation of the flow rate of aluminium sucked from the pot by means of loops control and signal processing in PLC which controls a valve on the compressed air supply. 200 tapping operations have been performed in Alma's plant resulting in ensuring the efficiency and reliability of the solution and significant benefits such as less equipment cleaning cycle and better metal casting.

Introduction

Here is the reality whatever is the production: produce more by combining quality, rapidity, cost-savings and safety. The Engineering Department of equipment suppliers such as ECL works hard to meet these expectations. The aim is to provide the smelters with solutions allowing them to both save money, in particular by supplying energy-saving equipment or solutions reducing equipment maintenance costs; and produce high quality aluminium in a safe environment.

The solution of the regulation system presented here meets all these criteria. It took as its starting point that a significant amount of electrolytic bath (typically 15 kg of electrolytic bath per ton of molten aluminium in most cases) was sucked during tapping operation due to a lack of flow rate control. This bath has negative effects notably for metal casting and especially when it comes to produce certain aluminium alloys requiring low sodium concentration. Consequently the bath removal from the electrolytic cell impacts negatively the tapping operation. Tapping equipment are soiled faster and metal treatments before casting are more demanding with regard to efforts and costs. It should also be noted that the more the electrolytic bath is sucked with the metal, the more the tapping tube and the crucible will be soiled, eroded and even blocked. The frequency of the cleaning of the crucible is therefore pretty high.

The regulation system is also in correlation with the technical developments of the electrolytic process, particularly with the new standard of low Anode-Cathode-Distance (ACD) pots. Decreasing the ACD lowers the voltage and energy requirements of the cell (cost-savings) but weakens the stability of the process, especially during tapping operation. That's why the fact to regulate and control the metal flow rate to avoid bath fluctuations will impact positively the stability of the process as explained in the literature(1): the relative amount of residue increases linearly with the tapping mass flow rate, and then exponentially at higher mass flow rates.

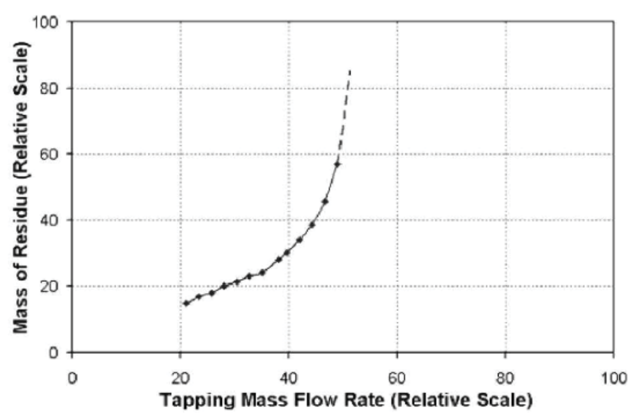

Figure 1: Impact of tapping mass flow rate on bath aspiration (1)

The objective of the regulation system is clear: limit the siphoning of electrolytic bath during the tapping operation to minimize those negative effects and help smelters in their daily efforts to produce more, cheaper and faster.

Context

As a brief reminder of the aluminium production process: many different operations on the electrolysis cells are essential to produce metal in the pots. These operations can be grouped into two categories: operations related with anode changing and operations related with tapping operation. A tapping operation consists in drawing liquid metal from an electrolytic cell and filling a crucible with a predefined mass of metal. The mass of metal to be siphoned is pre-defined in accordance with standard operating procedures and will depend on the production levels of the electrolytic cell and minimum metal levels required to maintain a cell in operation. When it comes to proceed to tapping operation, several aspects have to be taken into account in order to limit bath siphoning and reach a good quality level of molten aluminium. The tapping operation from an operating electrolytic cell is usually done with a crucible embarked on the Pot Tending Machine.

The first important step is to insert the tapping tube into the electrolytic cell at the right depth in the metal. Not too deeply and not either above the metal where the bath is. In the first case, we can observe:

- An excessive speed due to the reduced liquid flow cross section and consequently an erosion of the cathode. This excessive speed could lead also to a powerful vortex resulting in more bath entrainment.
- A risk of sludges' aspiration.

In the second case, the bath will be sucked by vortex effect.

Once well positioned, a vacuum is induced into the crucible, usually using an air injector whereby the metal is aspired through the tube. The air flow through the air ejector can be controlled manually using a valve on the compressed air supply. To resume, a good tapping operation depends on the right immersion depth of the tube (Operations conducted carefully and diligently) and the flow rate control (good and stable target flow rate).

In practice, very light touch is required so as not to overshoot the target metal flow rate. Consequently a stable metal flow is rarely, if ever, obtained and very large fluctuations can be observed during tapping of a bunch of cells. Some of the factors, which can explain some of the variations in flow rate are numerous for example: the position of the crucible relative to the metal/bath interface, any obstructions limiting free flow of metal into the tube such as surface variations on the cathode surface of the electrolytic cell or lumps of solidified bath, variations in air temperature during tapping, variations in tapping in how well the crucible is sealed, variations in air pressure supply, crusting of tube from bath entrainment, movements of the metal in the pot etc.

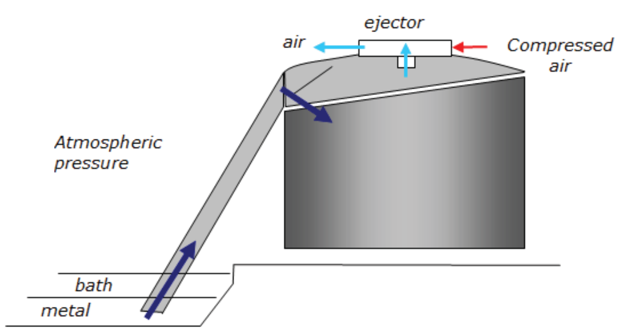

Figure 2: Schema of the principle of the aluminium tapping operation

General principle of the tapping regulation system

Given the difficulty to provide manually the fine adjustment in vacuum to maintain an ideal metal flow rate which maximizes productivity without compromising quality (bath entrainment), ECL designed, set up and tested in Alma's plant a system based on the automatic control of the flow rate to reach the target metal flow rate. Basically the system comprises among others a control unit and by means of loops control and signal processing in PLC adjusts the supply of compressed air in the air ejector through a valve and therefore the vacuum pressure depending on the headspace in the crucible and the weight of the crucible during tapping.

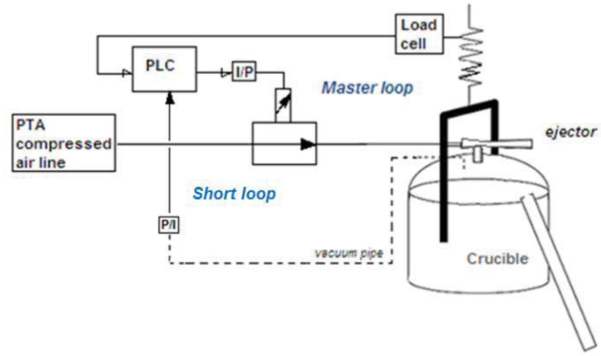

Figure 3: Regulation loops

This system allowing siphoning the metal to be transferred at a pre-determined target flow rate into the crucible consists in:

- An air ejector coupled to a source of compressed air and in close communication with the headspace in the crucible
- A vacuum transducer fitted on the cover of the crucible, in communication with the headspace, connected to the control unit delivering actual vacuum pressure changes.
- A valve assembly operated by an actuator responsive to an electric current-to-pressure converter which is coupled to the control unit. The valve actuator receives information from the control unit to determine the flow through the outlet of the valve assembly. It will open or close the compressed air supply as needed.
- A dedicated algorithm which filters the weight signal and the vacuum level to reach a stable target.
- Control units connected with weighing means in order to receive weight measurements and calculate on due time the flow rate of liquid being drawn in the crucible. The control unit adjusts then simultaneously the flow rate of the compressed air flowing through the regulating valve in order to reach the target flow rate. The control unit includes a programmable logic controller (PLC). The PLC is directly connected with main compressed air directional valve to open the valve when a tapping operation begins and to close it when the target mass of metal has been siphoned into the crucible.

Advantages of the solution

More than 200 tapping operations have been performed with the regulation system at Alma's plant. Outcomes are clear. The maintaining of an ideal metal flow rate maximizes productivity without compromising quality. The less the bath is siphoned, the less the tapping tube is soiled or blocked and requires being cleaned or changed. The less the bath is siphoned; the easier the metal is processed in the casthouse. Consequently we can expect a decreased frequency of the crucible bricklaying. All those quantifiable advantages will help smelter to save money on

maintenance costs, spare parts costs while decreasing the cost of the aluminium alloy treatment. Casting operation will be made easier and the quality of metal sucked will generate less waste.
The solution that might be called “self-adaptive” allows an adaptation to the variable parameters such as the tightness of the crucible, the soiling of the tube or the air pressure supply.

To illustrate our key findings, a comparison between a standard tapping operation and a regulated one.

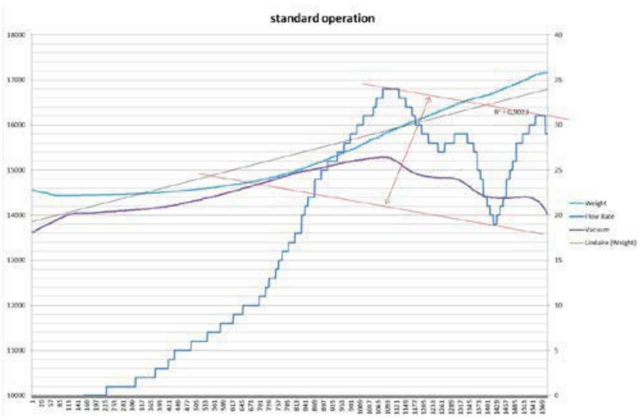

Figure 4: Standard tapping operation

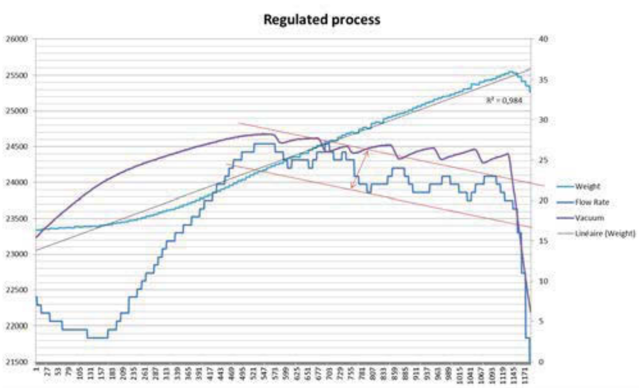

Figure 5: Regulated tapping operation

We notice here above a more frequent adaptation of the vacuum level in the crucible but more tightened. The flow is better controlled; no peak considerably exceeds the average: to about 30% without regulation against to about 10% with regulation. The evolution of the cumulative tapping weight is more linear, indicating greater regularity.

Hereunder, two different responses from the system for the same flow rate target:

Figure 6: relation between the vacuum set point and the closing of the valve

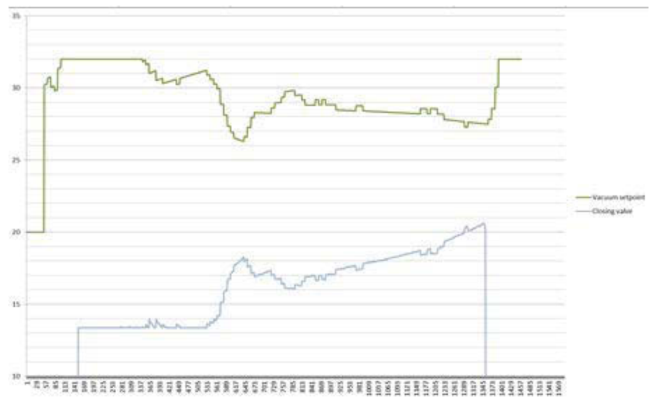

Figure 7: relation between the vacuum set point and the closing of the valve

These graphs show two things:

- The adaptation of the regulation valve in respect of the time for two different tapping operations but with the same target of metal mass flow.
- The evolution of the vacuum level in the crucible generated, among other things, by the variation of compressed air supply in the ejector resulting in the positioning of the regulation valve.

We found that the opening of the valve must not evolve in the same way between two different tapping operations. In the cases shown above the opening instruction passes progressively for the first tapping operation from a value of 32 to 20-23, between the beginning and end of the operation, while for the second one the same instruction evolves from 32 to 28, , i.e. a lower variation by a factor of 3. This shows that such a system must be adaptive and cannot be adjusted in advance on fixed vacuum target for example. The reason is the variability of factors influencing the balance of the system, for example the performance of the ejector, the soiling of the tube inserted in the pot, the sealing of the system.

Table 1: Results from the 200 tapping operations performed

	without regulation		with regulation	
min	9,6		0,0	
average	base 100		56,6	
max	490,4		548,7	
std deviation	107,3		71,8	

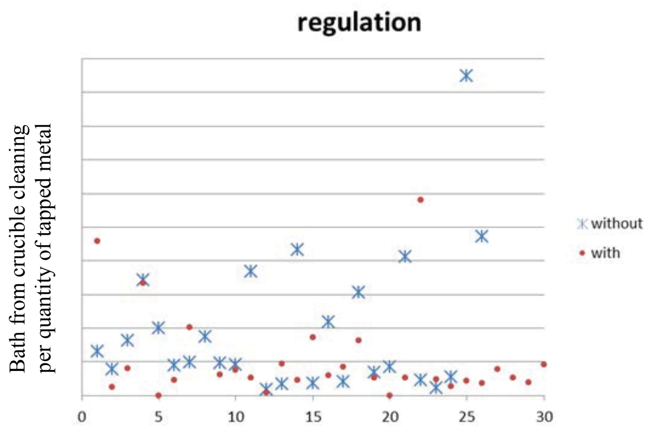

Figure 8: improvement of the tapping operation quality - less bath sucked

We measured changes in the weight of the empty crucible before and after a series of tapping operation. In doing so, we measure the rate of soiling of the crucible by the bath, expressed in kilograms per ton of metal. It can be reasonably estimated that the rate of soiling of the crucible is related to the amount of liquid bath sucked with metal. Results are summarized in table 1 and illustrated in figure 8. For a measured quantity of bath 100 for tapping operation without regulation, we obtain a quantity of bath of 57 for a tapping operation with regulation. The standard deviation is itself improved since it evolves from an equivalent at 107 without regulation to 72 with regulation. Statistical tests show that the difference is significant.

We should also mention that the fact to reduce cleaning cycle time of the crucible will have an impact on safety; operators will be less exposed to potential accident due to tube handling.

The solution, whether we are talking about a Greenfield project or a Brownfield one, is adaptable to any smelter configurations using the AP Technology™. The system can be integrated directly in the automatic system of the Pot Tending Machine or installed in the tapping beam of the crucible.

Conclusion

The regulation system is a self-adaptive system. It requires no action and/or adjustment from the operator. The system provides transparency and combines good process quality and fast potline operation.

Acknowledgements

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References

1. Vincent Goutiere and Claude Dupuis – "The mechanisms of bath carry-over with molten aluminium in smelters" - *Light Metals 2008*