Metal Tapping Flow Regulation System – A Large Scale Industrial Experience

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Abstract

One of the objectives through the whole process of primary aluminium production is to deliver a metal free from impurities. During the pot metal tapping, bath can be sucked together with the metal. Unwanted bath tapping has negative effects through equipment soiling, pot disturbance and above all on metal casting, inducing extra costs, delays on metal delivery and metal production losses. Fives ECL developed and adapted a retrofitable patented system based on off-the-shelf components. The system is based on the automatic control of the tapping flow rate, which allows tapping the targeted metal quantity without bath. The Tapping Regulation System was integrated in all aluminium Pot Tending Machines and tapping ladle lifting beams at Sohar Aluminium in Oman where all metal tapping operations have been converted to this system.

Keywords: Metal tapping operation, automatic control of tapping flow, tapping regulation system, quality of metal, casting

1. Introduction

Fives ECL has developed a metal tapping flow regulation system based on the control of the compressed air flow feeding the ejector of the ladle, as explained by Bouchard et al. [1].

As depicted in Figure 1, the system basically 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.

The system has been first developed in Rio Tinto Alma in Quebec facilities where it has been tested and qualified.

Sohar Aluminium Plant in Oman expressed its view to get solutions from suppliers that save operational expenses and improve quality and productivity in the smelter, specifically with the metal tapping process. Particularly Sohar Aluminium, focused on the tapping operations, addressing metal purity, tapping tubes and crucibles clogging, and bath level stability in the pot. That situation generated cleaning operations of tapping tubes and crucibles and sometimes ladle capacity restriction.

The aim of Tapping Regulation system is to provide the smelters with a solution allowing them to save money. In particular by producing a better quality of aluminium, by saving energy needed to produce compressed air, and by reducing ladle cleaning costs.

Fives ECL and Sohar Aluminium agreed to cooperate in order to implement a tapping flow regulation system on all tapping equipment. This paper presents the main steps of this project and the findings.

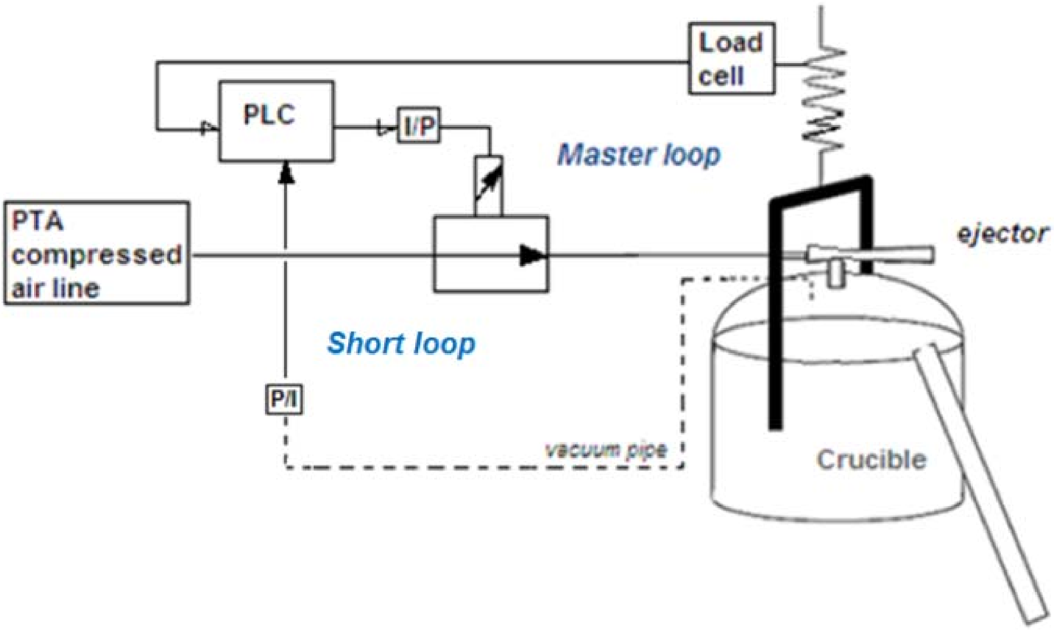

Figure 1. Regulation principle.

2. Project Description

2.1 Context

Sohar Aluminium plant produces 390 kt of primary aluminium, per year with 360 pots. The tapping operation is organized with 11 Pot Tending Machines (PTM), and 5 ladle lifting beams and a set of ladles and covers equipped with ejectors and tubes. The work is organised on a tapping cycle where 3 pots are tapped consecutively in the same ladle.

One of the objectives through the whole process of primary aluminium production is to deliver a metal free from impurities. During the pot metal tapping, bath is sucked in conjunction with the metal. Bath adjunctions have negative effects both on electrolytic cell operation and equipment soiling but above all on metal casting, inducing extra costs, delays on metal delivery and metal production losses. Moreover as many smelters Sohar Aluminium could increase current, in order to increase the smelter capacity. This requesting more accuracy on the process, increasing the risk of pot disturbance when siphoning more bath during metal tapping operation.

2.2 System integration

Each ladle beam was equipped with a pneumatic regulating valve, and a pressure current transducer. In addition to the existing air hose coupling, a quick connection has been added for measuring vacuum line. This additional line is very light and is attached to the main compressed air feeding line. The load signal which allows the estimation of the metal flow rate, is generated by the existing hook load cell fitted in the lifting hook. A small electrical plug has been added to the tapping hook for transmitting both the set point signal to the regulating valve and the vacuum feed-back signal. The regulating algorithm is implemented in the existing Programmable Logic Controller (PLC) program as an add-on, with parameters limited to the relevant ones only. That is possible thanks to the previous prototype development carried-out in Alma.

The standard operating procedure remains the same; the flow regulation system does not change the operator tasks, excepted for the connection of the electrical and vacuum plugs at the beginning of the tapping shift when the lifting beam is hooked to the PTM.

2.3. Project phases

The project is split in five main steps:

1. First step: Definition of a measuring protocol in order to estimate the quantity of the bath sucked with the metal.
2. Second step: Measurement of the initial situation without flow regulation.
3. Third step: Installation, set-up and follow-up of the system on the first crane and ladle couple unit during 3 to 4 weeks. After 200 tapping operation performed, 80 batches of data were collected.
4. Fourth step: Deployment of the system on all the fleet and training for maintenance on new instruments.
5. Fifth step: Follow-up of results and data collecting.

3. Findings

3.1. Results

A reduction of about 50 % of the quantity of bath sucked with the metal has been observed during a six month period of follow-up. Form a practical point of view, vortices in the metal pad were reduced thanks to the limitation of the very high flowrates, in time and in frequency.

The regulation system is a self-adaptive system. It requires no action and or adjustment from the operator, for example this system automatically compensates the differences induced by the effective section of the tube which can vary a lot between a brand new one and a tube with soiling.

As an illustration of a typical behaviour of the regulated tapping sequence, Figure 2, shows the evolution of the main regulation parameters during the tapping of three consecutive pots into the same crucible.

For each tapping sequence, the first step is to generate the vacuum in the crucible; as commonly known, comparison between the figures shows that the corresponding period is each time shorter, the volume occupied by the air in the ladle being smaller. Once a minimum vacuum level is reached, the metal starts to flow in the crucible (continuous lines - mass flows), then the vacuum set point (broken lines) is generally reduced to limit the flow. That particular phase demonstrates clearly that without the regulation system the flowrate would be considerably higher during all the siphoning period.

Differences between the three pots, for example the second pot compared to the first and the third, shows that the behaviour of the whole system can vary and so the regulation system should be able to cope with that variation. Similarly, it is observed in Figure2 for the 1st and the 2nd pot that the same vacuum evolution in the first one minute phase leads to two different flowrates. The regulation corrects the flow regime within approximately 20 s. A fixed vacuum set point would not be sufficient to stabilize the flow.

Another finding is that the flowrate is very sensitive to the vacuum level:

- A small variation of the vacuum generates a significant variation of the flowrate, typically 10 % of vacuum variation generates a variation of up to 35 % of the flowrate.

- The mean vacuum set point during the metal transfer period is very similar to the vacuum level necessary to lift the aluminium column in the tapping tube and then initiate and maintain the siphoning regime.

Consequently the measuring and adaptation of the vacuum must be quite precise; something which seems difficult to get with mechanical pressure relief valves for example.

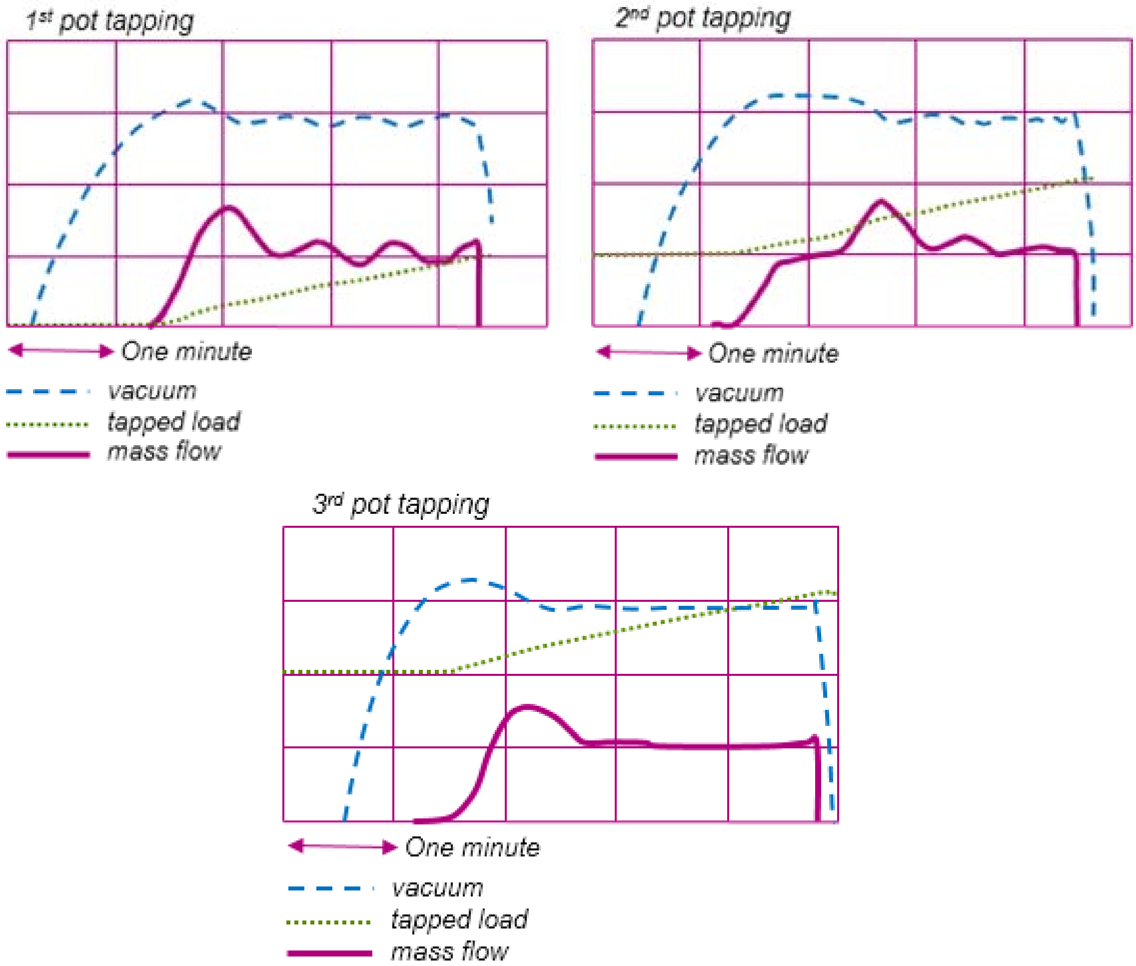

Figure 2. The evolution of the main regulation parameters during tapping three pots in the same crucible. Top left: 1st pot, top right: 2nd pot, bottom: 3rd pot.

Other consolidated data show that the mean value of the vacuum set point can vary with various crucible – cover – tube sets; this is probably due to different tube clogging stages. Once again, the regulation system is able to adapt the parameters to each of such situations; a system which would set a fixed vacuum level should not be able to do it.

3.2 Customer benefits

Sohar Aluminium appreciated the well-presented survey and test plan, local experience with the customer's people and processes, as well as supply knowledge and support provided by Fives' experts in Oman. The frequency of ladle cleaning was reduced. Delays on tapping operation were generally reduced and therefore operators felt that performance was improved, while there was no change in the operating procedure. Process management underlined that the bath level in the pots is more stable, which allows less bath transfer activities and a more steady process.

Other expected improvements could not be measured yet, such as: cast-house furnace condition, skimming and dross removal operations, finished products quality.

3.3. Key success factors

Tapping flow regulation benefits are effective if fundamental good practices are applied:

- Preheating of the tapping tube before starting the first pot tapping, for example by placing the tube just above the bath level in the tapping hole and starting the ejector air feeding during few minutes. If it is not applied then the tube will be clogged with bath during the very first tapping operation.
- A correct location of the tapping tube end in the metal pad, typically 5 centimetres above the cathode level in order to maximize the distance with the metal bath interface.
- No excessive movement of the ladle during the tapping, in particular concerning the lifting.

As the regulation reduces the mean value of the flowrate, the tapping cycle time is slightly longer; this is mechanically due to the avoidance of very excessive flowrate which should never occur during a process under control. It must be noted that the flow rate impacts only a portion of the total tapping cycle time, for instance it does not impact the time to transfer the ladle between two pots neither the time to generate the vacuum in the ladle. During the last phase the regulation valve is fully opened and then the regulating system actuates as for the non-regulated mode. This little additional time is compensated by less tapping tube exchanges. Furthermore the ladle contains more metal and less bath.

It is also important to explain to the operators the effects of the regulating system, for instance that the initial vacuum phase is not modified by the system; if not wrong diagnostics can be made. In order to improve the system follow-up some indicators have been developed in the PLC program to provide alarms to the operating team. For example these alarms can highlight warning signs such as: tube or ejector clogging, crucible air leaks.

4. Conclusion

Thanks to the prototype tested and industrialized successfully in Rio Tinto Alma smelter under very low pot metal pad, implementation at industrial scale in Sohar Aluminium was conducted quickly. We could confirm the expected benefits namely: substantial reduction of bath sucked during tapping operation, positive impact on the stability of the electrolytic process. We also implemented indicators to better monitor efficiency of the equipment.

5. Acknowledgements

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6. Reference

1. Steve Bouchard et al, et al., Regulation system to improve quality of the metal sucked during tapping operation, *Light Metals* 2014, 467-470.