Light Metals 2015
Edited by: Margaret Hyland
TMS (The Minerals, Metals & Materials Society), 2015

NEW ECL EMBEDDED SERVICE ROBOT: TOWARDS AN AUTOMATED, EFFICIENT AND GREEN SMELTER

ECL™, Jérôme Guérin, Anne-Gaëlle Hequet
ECL, 100 rue Chalant 59790 Ronchin, FRANCE

Keywords: robotics, pot tending machine, PTM, single-man PTM, hood handling, Embedded Service Robot, ESR

Abstract

The automation of modern aluminum plants together with the introduction of robotics is not a current trend but potentially a future factor able to reduce OPEX, boost productivity growth and improve HSE performance.
If increased productivity is one of the biggest reasons in justifying the use of automation, then improving operator safety is undoubtedly the number one priority driving the automation of arduous industrial operations. Many physical and rather dangerous tasks in pot-lines are still required to be carried out by a floor operator. The manual manipulation of pot hoods required for anode changing is a good example. The Embedded Service Robot (ESR) is an additional tool of the Pot Tending Machine (PTM) designed and developed to assist the pot-room operators during this operation and further safeguard them against the hazards of the smelter environment. The ESR is based on industrial robotics and driven in automatic, semi-automatic or manual mode. It is able to perform many different duties with limited impact on PTM cycle time.

Introduction

The aims of primary aluminum producers are no different from those of any other industry facing the constant challenge of cost reduction whilst meeting all Health, Safety, Environment and Quality (HSEQ) requirements. The challenges are far above average industrial standards for three main reasons:

- The selling price of the product (primary aluminum) is mainly driven by the Market Exchange (LME or SME) on which producers have limited leverage,
- The Hall-Heroult electrolysis process is, by its nature, a complex process not without risk, generating noxious emissions, high temperatures and using high amperage electrical currents
- The process cannot be interrupted, except in extreme circumstances; thus it requires equipment which can operate with high levels of reliability and availability.

In light of the above, process support equipment designers have to market solutions offering a short return on investment, guaranteed availability and a wide range of HSE features. Over the last two to three decades, developments in automation have contributed significantly to these design requirements. Devices such as Programmable Logic Controllers ("PLCs") installed on overhead cranes have opened new possibilities which are only limited by employed hardware performance, and… imagination. We have at our disposal products able and capable of driving new levels of performance, who could have conceived in the 60's that a simple query on Google search engine would be equivalent to the computation power used throughout the entire Apollo space program which lasted for 11 years and 17 missions?

The Automatic PTM

ECL first introduced programmable logic control (PLC) to the PTM 20 years ago as part of its innovation program, from this point it has never ceased in its endeavors to harness and maximize the use of the technology to combine movements, increase speeds, assist operator control, give precise indications for troubleshooting, and ultimately perform tasks automatically.
Along with the introduction to the market of the "New Generation" PTM (NG PTM) in 2005, an ambitious program was launched with two targeted steps for automating completely its pot-room operations:

1. The "single-man PTM" enabling the removal of the floor operator required to assist during anode change.
2. The "automatic PTM" enabling the removal of both the floor operator and the PTM driver, with remote monitoring tools located typically in the pot-line control room.

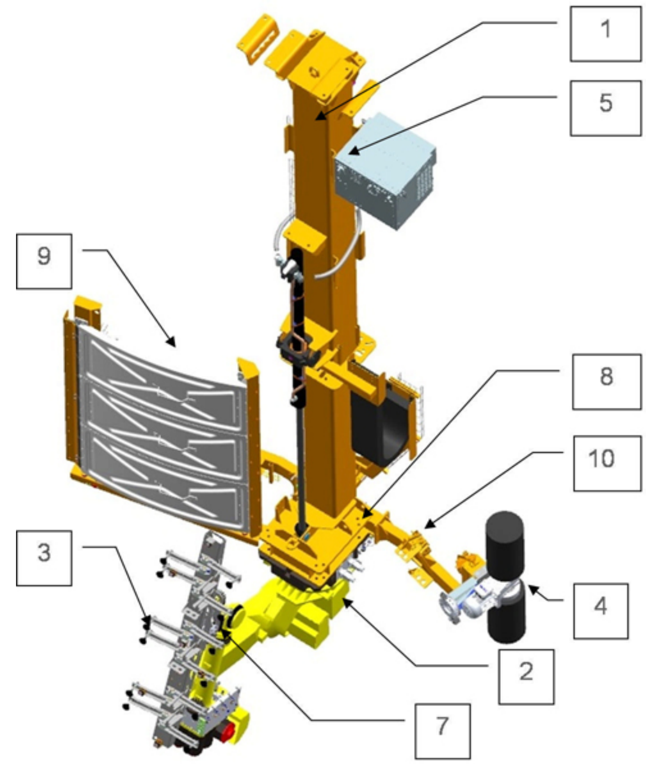
Many technological building blocks were needed to realize this automation project and they have been progressively developed, largely by in-house engineers. Efforts have particularly focused on the anode changing operation, which is both the main and highest risk task performed by the human-assisted PTM due to the proximity of hot metal, live bus bars and fluoride emissions from the spent removed anode. An on-the-fly gauging system was designed to supersede the manual chalk line principle and the semi-automatic anode leveling system (DIANA™) both previously requiring a physical reference to set the new anode level correctly in the pot. The second main system developed a pot hood handling device to remove and reinstall automatically the hoods on the pots without any human intervention. Both systems were presented during the TMS conference of 2009.

The Embedded Service Robot

Although two generations of pot hood handling devices were successfully tested in a real smelter environment, it became apparent quickly that some technical limitations would jeopardize the implementation of such a solution on a large scale. More particularly, the total time needed for the removal and replacement of the pot hood was considered excessive with an increase in total anode change cycle time, hence the workload, of the PTM. Additionally, the pot hood handling device was driven by numerical control technology which was both complex and unknown to smelters maintenance teams. A new philosophy and a fundamentally different approach were needed.
Whereas mechanical tasks had been replaced by automated systems, human tasks were to be replaced by robotics. Robotics presented new possibilities, which could drive us beyond the original idea of just carrying the pot hoods. The Embedded Service Robot (ESR) was born.

General Description of the ESR

The ESR is a modular system based on a 6-axis industrial robot (see Figure 1) adapted to the harsh environment of a modern aluminum smelter production line: intense magnetic fields, dust, corrosive environment, high temperatures, etc. Its speed and load capacity have been carefully dimensioned to maximize its versatility. The robot is attached to a telescopic mast which is itself installed onto the PTM structure. The robotic arm can be fitted with various specialized tools that are stored on-board the system.



#	Description
1	Telescopic mast
2	6-axis Robot
3	Hoods gripping tool
4	Floor brush
5	Robot controller
6	Pneumatic box
7	Tool quick-change system
8	Robot baseplate
9	Hood store
10	Tool store

Figure 1

As the NG PTM was originally designed to enable ease of technical upgrades, the addition of the ESR to the crane requires only minor mechanical modifications and PLC software updates to accommodate the new functionality. Hence, all NG PTM delivered since 2004 can easily host the ESR whereas other previous architectures may require additional mechanical modifications.

The Cycle Time – Key Acceptance Factor

As mentioned earlier, one of the main drawbacks of the pot hood handling device was its negative impact on cycle times: it was difficult to accept extending the working time of the PTM operator, although it was saving the presence of the floor operator. It was becoming evident that success would only be reached through process optimization for the PTM operator also. The speed of pot hood handling has been one of the top objectives of the development, which has led to innovative features: the 6-axis industrial robot is much faster than the previous concept. It is both physical (operations are achieved quickly) and psychological (the PTM operator actually sees fast motions). Overall, the additional time needed for opening, brushing the small slabs, and closing the pot is no more than 1 minute and 40 seconds!

The Multiple Challenges of Pot Hood Handling

The primary aluminum smelter is a real-life environment, far from laboratory conditions. Not only must pot hood be removed and replaced promptly but there is no room for a wrong operation: the pot hood must be found by the ESR even if it is not precisely positioned and / or it is slightly damaged; conversely, the pot hood must be replaced precisely in the free space of the pot. Robust algorithms were developed in order to reach high levels of accuracy and repeatability. With such performance we are able to avoid virtually all manual operations, either directly on the pot-room floor or from the PTA operator cabin as the sequences are fully automatic.

Figure 2

The potential for floor operator injury (Repetitive Strain Injuries - RSI) generated by handling up to 3 tons of pot hoods per working shift are consigned to history.

Moreover, the automatic handling will provide for care of pot hoods in a manner far superior to that of human handling. This equates to extended lifetime for pot hoods and further savings for the smelter.

In terms of environment, the ESR has a great impact on reducing gas emission through reduced and consistent pot opening time – one pot opened at a time - and optimal hood positioning. Less opening time than with manual operations and minimized air gap between hoods lead to less gas leakages escaping from the Gas Treatment Center.

Versatility through Storage

One breakthrough innovation of the ESR is its capacity to store hoods in a dedicated embarked hood store (See item 9 of Figure 1). It might sound like a costly idea to design an automatic storage requiring more parts, sensors, locks, safety devices, etc. On the contrary, it is a wise investment in terms of design and it opens an infinite range of new possibilities. By storing hoods on-board, we release the robotic arm from the hoods removed from the pot. The arm becomes then free to perform other tasks, provided that specialized tools attached to the arm can be changed quickly.

When the ESR becomes the Housemaid

Thanks to its 150 kg load capacity, operations which are beyond the physical capacity of one or even several operators can be envisaged.
One of the first natural additional tools that have been developed for the ESR is a large rotating brush, able to remove the bath spillage before closing the pot. Once the hoods are safely stored in the locking rack, the arm automatically swaps the hoods gripping tool with the rotating brush (see Figure 3) through a quick and safety coupling system. The brush then performs a complete sequence to clean the bath stays from the small slabs and working floor. Approximately 3 square meters become free of dust in less than 10 seconds! Once the cleaning is achieved, the rotating brush is automatically disconnected, stored and the hoods gripping tool used again for finalizing the anode change.

Figure 3

There are numerous other tasks which can be performed by the ESR during the anode change: the pot is open and gives access to all the repetitive or random operations that are usually undertaken manually in the process. Even better, the speed and working load capacity of its arm introduces potential for additional tasks which have never been implemented due to technical restrictions. As an example, modern electrolysis technologies chase energy loss and the ESR offers smart ways of saving the last millivolts before the connection of the new anode to the pot.
Last but not least, since the NG PTM can now interact in real time with the micropot for exchanging operational data, the ESR can be used to make the required physical adjustment of the pot to improve its productivity.

ESR Implementation – The Power of Robotics

All smelters have a different layout and own operational particularities. Where are the positive risers? What is the shape of the hoods? How many hoods and anodes to remove at a time? What are the operations we want to perform automatically on the pot? The ESR can be customized in a cost effective and timely manner: the programming language is very user-friendly, especially when it comes to describing complex trajectories around the pot. The 6-axis arm will master its environment much faster than you can imagine and will determine the optimum way of moving from point A to point B. The combined computing capacities of the on-board PLC and the robot creates a powerful PTM where faster and more accurate operations than the ones performed by floor operators can be made automatically and in hidden time when needed.

Figure 4

In terms of maintenance, the ESR is only constituted of mature technologies which have proven to be very reliable in industrial environments, with low maintenance and high Mean Time Between Failures (MTBF). Components of world-class suppliers are adapted to the very stringent design requirements to create an affordable tool. Smelters maintenance teams need only a limited training session on basic robotics for becoming autonomous in troubleshooting and in repairing the ESR.

Innovation Policy

The ESR is patent pending under no. IR7961. It is part of a constant effort to innovate and bring value to the primary aluminum industry. More than 30,000 hours of R&D are devoted every year which result in an important portfolio of patents.

Conclusion

The ESR is the ultimate tool to be engaged on to the PTM: automatic, versatile, fast and reliable. After decades of hydraulically, pneumatically and electrically driven movements, time has come to make a significant advance in the performance offered by a robotic solution. Pot hood handling and pot cleaning today have reached the required industrial maturity, many other applications will come true tomorrow. Aluminum smelting technologies are evolving, so as the equipment designed to serve them. The ESR is what you want it to be.

Acknowledgements

The authors would like to thank Etienne Tezenas and Serge Despinasse for their undying support in developing the ESR and in writing this article.