

Embedded service robot: towards an automated, efficient and green smelter

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Abstract

The automation and robotics of modern aluminum plants are no trend but a key success factor to reduce OPEX, to boost productivity growth and to improve health, safety, environment and quality (HSEQ) performances. If increased productivity is one of the biggest reasons in justifying the use of automation, the operator safety is undoubtedly the number one priority for automating an industrial operation. Many physical and rather dangerous tasks in pot-lines are still to be carried out by floor operator. The manual manipulation of hood for anode changing operations 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 operator in this operation and safeguard him against the hazards of the smelter environment. The ESR is based on industrial robotics and driven in automatic, semiautomatic or manual mode. It would be able to perform many different duties with limited impact on PTM cycle time.

Keywords: Robotics, pot tending machine, single-man PTM, Embedded Service Robot, ESR.

1. Introduction

The aims of primary aluminum producers are no different from the ones of any other industry facing constant challenge of cost reduction while 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 highly risky operation generating noxious emissions, high amperages and hot temperatures,

The process cannot be interrupted, except in catastrophic circumstances; it requires equipment which can operate with a high and maximum availability level.

In light of the above, 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 a lot on these aspects. Devices such as Programmable Logic Controllers (“PLCs”) embarked on overhead cranes have opened new possibilities which were only limited by sensors performances, microprocessors capacity and... imagination. 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 special program which has lasted for 11 years and 17 missions?

2. The automatic PTM

Fives ECL has introduced more than 20 years ago PLCs on its Pot Tending Machines (PTM) as part of the innovation program. It has never ceased since then to maximize the use of its power to combine movements, increase speeds, help operator’s decision, give precise indications for troubleshooting, and ultimately perform tasks automatically.

Along with the introduction on the market of the so-called “New Generation” PTM (NG PTM) in 2005, an ambitious program for automatizing completely the pot operations was launched with two targeted steps:

1. The “single-man PTM” enabling the removal of the floor operator who is especially assisting for anode change,

2. The “automatic PTM” enabling the removal of both the floor operator and the PTM driver, with monitoring tools located in the potline control room.

Many technological bricks were needed to achieve this automation project and have been progressively developed, mostly by Fives ECL in-house engineers. Efforts have particularly focused on the anode changing operation, which is both, the main and the riskiest task achieved by the human-assisted PTM due to the proximity of hot metal, live busbars and fluoride emissions from the spent anode removed from the pot. An on-the-fly gauging system was designed to supersede the manual chalk line principle and the semi-automatic anode levelling system (DIANA™) requiring a physical reference to set the new anode level correctly in the pot. The second main system conceived was a hood handling device in order to remove and reinstall automatically the hoods on the pots without any human intervention. Both systems were presented during the TMS conference of 2009 [1].

3. The Embedded Service Robot

Although two generations of hood handling devices were successfully tested in a real smelter environment, it appeared quickly that some technical limitations would jeopardize the generalization of such solution on the long term. More particularly, the total time needed for the removal and replacement of the hood was excessively increasing the cycle time, hence the workload, of the PTM. Moreover, the hood handling device was driven by numerical control technology which was both complex and unknown to smelters maintenance teams. A new philosophy and a different approach were needed. Whereas mechanical tasks had been replaced by automated systems, human tasks were to be replaced by robotics. Robotics was then opening new possibilities which could drive us beyond the original idea of carrying the hoods. The Embedded Service Robot (ESR) was born.

4. 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 embarked onto the PTM. The robotic arm can be fitted with various specialized tools that are stored on-board the system.

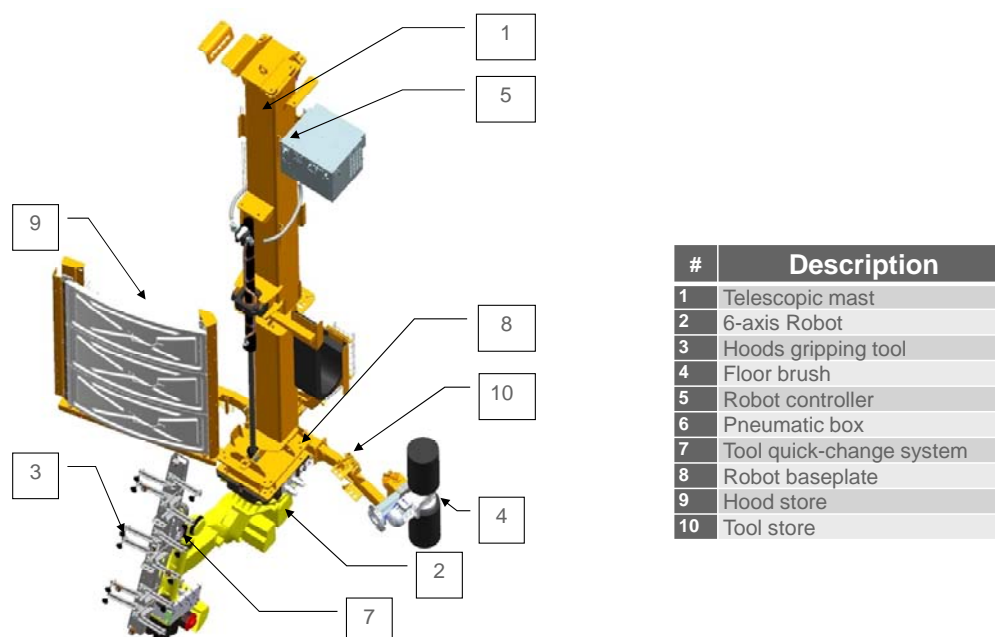


Figure 1. Embedded Service Robot.

Since the Fives ECL NG PTM was originally designed to enable technical upgrades, the addition of the ESR to the crane requires only minor modifications and PLC software update to accommodate the new functions. Hence, all NG PTM delivered by Fives ECL since 2004 can easily host the ESR whereas other architectures may require additional mechanical modifications.

5. The cycle time – key acceptance factor

As mentioned earlier, one of the main drawbacks of the hood handling device was the cycle time: it was difficult to accept as it was extending the working time of the PTM driver, although it was saving the presence of the floor operator. It was becoming evident that success would only be reached through acceptance by the PTM operators. The speed of 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 factual (operations are achieved quickly) and psychological (the PTM driver 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!

6. The multiple challenges of handling hoods

The primary aluminum smelter is a real-life environment, far from laboratory conditions. Not only must the hoods be removed and replaced promptly but there is no room for wrong operation: the hood must be found by the ESR even if it is not precisely positioned and / or it is slightly damaged; on the other hand, the hood must be replaced precisely in the free space of the pot. Fives ECL has developed robust algorithms in order to reach a hit rate beyond 99.9%. Such performance enables to virtually avoid all manual operations, either on the floor or even from the cabin since the sequence is fully automatic (Figure 2).



Figure 2. Automatic handling of hoods.

Repetitive Strain Injuries (RSI) generated by handling up to 3 tons of hoods per working shift belongs to history. Moreover, the automatic handling will care for hoods far better than any human handling. This is extended lifetime for hoods and further savings for the smelter. In terms of environment, the ESR has a great impact on reducing gas emission through restrained 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.

7. Versatile 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.

8. Versatile through storage

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 three 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. Rotating brush.

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 Fives ECL 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.

9. ESR implementation – the power of robotics

All smelters have a different layout and own operational particularities. Where are the positive (anode) 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. 6_axis robot.

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 requirements of Fives ECL to create an affordable tool. Smelters maintenance teams needs only a limited training session on robotics basics for becoming autonomous in troubleshooting and in repairing the ESR.

10. Fives ECL Innovation Policy

The ESR is patent pending under No. IR7961. It is part of Fives ECL constant effort to innovate and bring value to the primary aluminum industry. Fives ECL devotes more than 30 000 hours of R&D every year and entertains an important portfolio of patents.

11. Conclusions

The ESR is the ultimate tool embarked on to the Fives ECL PTM: automatic, versatile, fast and reliable. After decades of hydraulically, pneumatically and electrically driven movements, time has come to make a quantum leap in performance by robotics solutions. Hood handling and pot cleaning today have reached the industrial maturity, many other applications will come true tomorrow. Aluminum smelting technologies are evolving, so as the equipment designed by Fives ECL to serve them. The ESR is what you want it to be.

12. Reference

1. Nicolas Dupas, Electrolysis pots anode changing automation: Impact on process and safety performances, Light Metals 2009, pp 515-518.