Aluminium Electrolysis Cells: Anode Changing Automation Challenges

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Abstract

Anode changing in an aluminium smelter is a complex and recurring task that directly impacts the process efficiency and operating cost. In each smelter, several hundred anodes are changed every day; this process is done with a pot tending overhead crane, which is manually operated. These operations occur in extreme environments inside a smelter, including wild swings in temperature gradients, magnetic fields, process off gasses, and dust. All these elements play havoc with advanced instrumentation, sensors and machine vision equipment. Rio Tinto has experimented and trialed to automate this task over a period of four years; whilst some aspects of the task could successfully be automated, others including the most value-added tasks could not be demonstrated with adequate success rates. This work highlighted the high degree of variability of the task, the decision process made by the operator and the influence of the environment on the ability to see and sense the work to be done. This paper will present the applications, introduce the results, present the challenges and discuss potential pathways, scalability and cost challenges.

Keywords: Anode Change automation, Machine vision, Decision aids.

1. Introduction

Aluminium smelting using AP3X technology entails the operation of typically 300 electrolysis cells in series per pot line in a smelter, each of these cells having 20 carbon anode assembly's, shown in Figure 1, which consume themselves over a 27 days period. The reduction of aluminium oxide by means of the traditional Hall-Héroult process requires a carbon reducing agent to liberate the oxygen atoms thus producing pure aluminium metal.

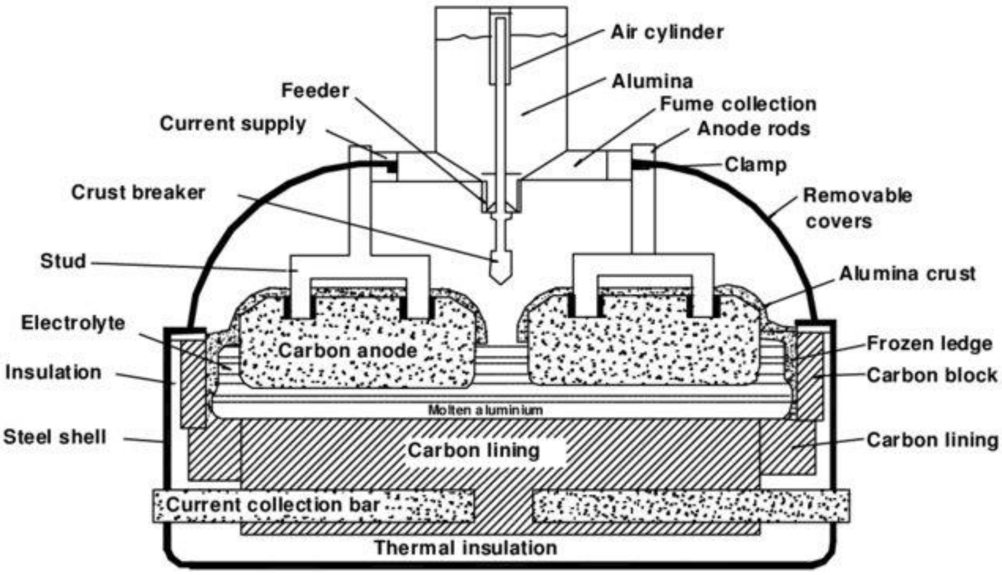

Figure 1. Typical prebake electrolysis cell cross-section [1].

In a typical aluminium smelter operation, the logistics of anode replacement occurs on an around-the-clock basis with typically one anode assembly being changed in each electrolysis cell every day. These anode assemblies are changed using a pot tending machine (PTM), shown in Figure 2, which is a highly specialized, manually operated overhead crane with its own tool suite. An anode change requires more than ten distinct activities performed by the operator with the support of a helper on the ground. Note that these activities vary from pot to pot due to specific cell conditions.

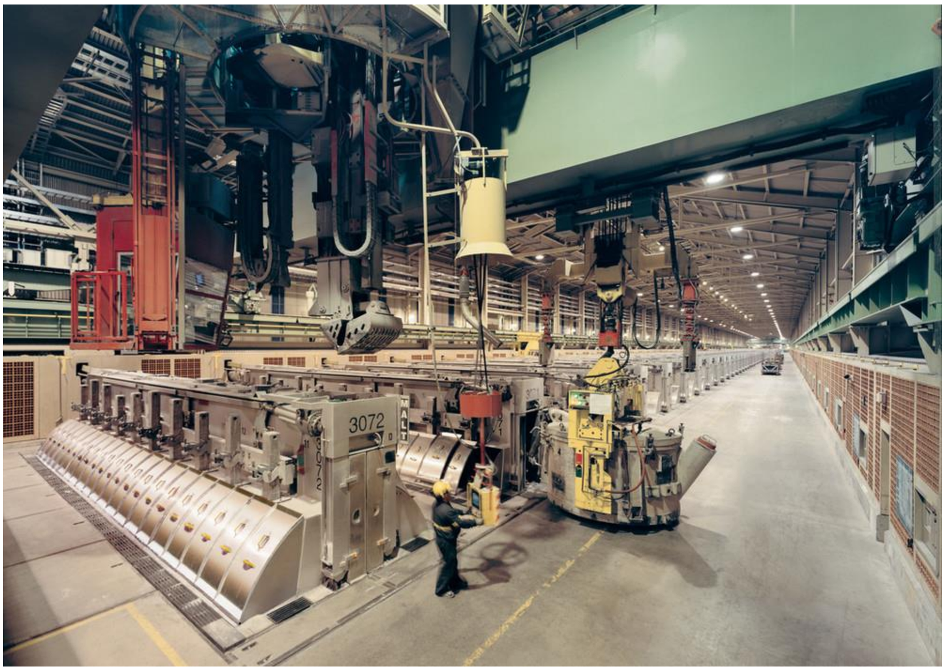

Figure 2. Typical side-by-side potroom arrangement and PTM tool tower (Rio Tinto Alma smelter).

In 2015, we have conducted a pilot program to demonstrate the possibility to automate the anode change process with advanced machine vision systems and positioning technology installed onto existing pot tending machines. The demonstration was carried out at Rio Tinto Aluminium AP-60 demonstration smelter in Saguenay, Québec, Canada. The reason behind such a choice was the possibility to have access to many enablers, which included:

- Latest-in-class WI-FI technology available;
- New equipment with minimal wear and tear;
- State-of-the-art control system with data acquisition and analysis capabilities;
- New building with minimal aging deformations and drift;
- An environment which was favorable to testing;
- An operating schedule which had the latitude to carry out industrial trials as only 19 electrolysis pots are assigned to a single crane, whereas 28 to 40 cells are typically tended by an individual PTM in full-scale smelters.

2. Purpose of Anode Change Automation

2.1 Health, Safety and Environment (HSE) Aspects

The anode change task exposes both the crane operator and operating floor handler to multiple HSE risks, currently controlled through a mix of administrative and exposure management procedures as well as personal protective equipment. These risks include:

f) Take a time-proven approach, as shown on Figure 8 below, to design future projects in the automation field.

This experience has also outlined the need to look beyond conventional automation and automation technologies and to integrate the more novel approaches that include artificial intelligence (AI) to model and control the process. Such decision-based autonomous platform would be able to react to the electrolysis process variability and aim to maintain the process efficiency, which is key to the economic viability of such a technology roll-out.

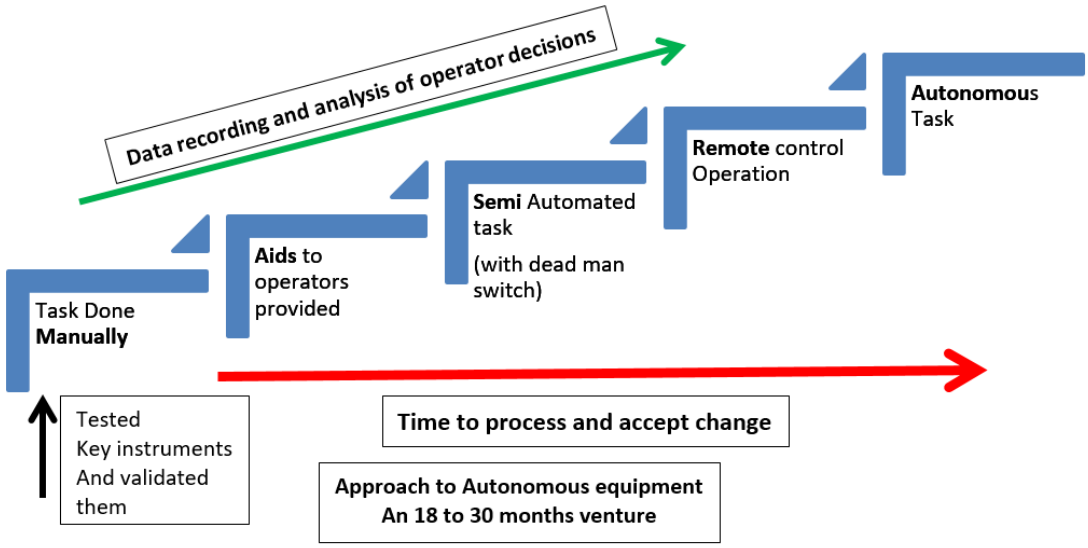

Figure 8. Proposed methodology towards autonomous operation.

6. Conclusions

This technological development trial on an aluminium smelting-related task (which was assumed to be fully understood and under control) has highlighted the limits of relying solely on standard working procedures. It also confirmed to us the hard way:

a) That we grossly underestimated the contribution of the operator to the success of the task;

b) The need to forget how we perform a given task manually and redesign it for an autonomous execution, as other industries before us (*e.g.*, automotive).

We also have to emphasize that, once Rio Tinto took over the management of the trial, the amount of effort and resources dedicated to the project increased substantially, as well as the number of external experts that were involved to help us find solutions.

Moving forward with such a technology will require open collaboration of many aluminium producers, solution providers and suppliers as the cost of building a proprietary solution will be prohibitive to any single company.

7. References

1. A.R. Burkin, *Production of Aluminium and Alumina*, Great Britain, John Wiley & Sons, 1987.