Welding Damaged Risers and Busbars without Potline Outage

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Abstract

Running potlines with a low anode-cathode distance (ACD) and higher amperage than original design, remains a challenge, and requires an excellent operation of the pots, as well as a steady pace in operations schedule. Low ACD pots need to operate within their operation band and require extremely rapid action to return to setpoint when an incident occurs. Aluminium Dunkerque, on its way to operate above 400 kA, noticed that a pot could fail in a few hours if high instability pots were not treated as soon as possible.

Damaged anode risers or bus bars can generate high instability in a pot or its adjacent one. Because of high magnetic field, it is quite difficult to make repairs as potline shutdown is usually required. Therefore, it is usual to run a few pots with damaged risers or busbar until the next programed potline shutdown or, when enough pots are to be repaired, to program an outage specifically to repair them. In the meantime, it is usual to take multiple actions to restore the structure temporarily to improve to a certain extent the current flow in the damaged busbars. Laser welding technologies exist and they can be used for laser welding in high magnetic fields. They are costly (above 500 k$ investment) and require a long time to make a weld. Aluminium Dunkerque put in place a new welding technique that allows most repairs on damaged risers and busbar without a need to stop the potline current.

Keywords: High amperage potlines, Welding in high magnetic field, Welding of damaged busbars.

1. Introduction

Aluminium Dunkerque Smelter is located in Northern France and started operations in 1991 with AP30 pots running at 290 kA. Since then, the smelter implemented multiple amperage increase projects allowing to reach 30 % higher amperage than the original one. Looking towards increasing the amperage above 400 kA, Aluminium Dunkerque is progressively reducing its anode-to-cathode distance (ACD).
During this process it was noticed that the pot robustness was impaired in their capacity to withstand high instability. Unexpectedly, Aluminium Dunkerque experienced a number of pot stoppages linked to high instability levels over a short period of time (less than 12 h). Despite actions to reduce instability on these pots, it was very difficult and sometimes nearly impossible to restore some pots to their normal operating condition. This led to multiple objectives to improve response time to defaults as well as operational stability of the pots. One of the key objectives was to reduce the impact of damaged busbars on pot instability.

During the different amperage increase projects over the last 30 years (Figure 1), the busbar system was not modified. In the meantime, the increase in magnetic fields led to difficulties in welding on the anode risers thus deteriorating the resistance and increasing the temperature of the busbar system. In recent years, Aluminium Dunkerque noticed an increase in bus bar or weld

breakages (Figure 2), deteriorating the stability of the pot itself or the neighboring pot. All repairs required a potline outage to weld on these pots; therefore, and like many smelters, Aluminium Dunkerque was usually waiting to have a minimum number of pots to repair to initiate a potline outage (duration 30 to 45 minutes). In the meantime, damaged pots were monitored closely and required multiple actions to maintain an efficient electrical contact on the damaged bus bar. Nevertheless, the pot instability would still remain higher than in a normal configuration thus leading to the loss of current efficiency.

Figure 1. Amperage increase in Aluminium Dunkerque.

Figure 2. Example of broken weld on the middle riser.

Figure 3 shows an example of pot behavior with damaged weld on an anode (positive) riser; even if the riser has been tightened to recover the best electrical contact possible; the anode beam movements during tapping generate movements on risers, ending up with a loose electrical contact. As soon as the riser is reconnected and tightened properly the pot recovers its stability.

2. Investigating Solutions

The main objective was to reduce the delay between busbar breakage and repairs, and repair the busbar without any potline outage. Aluminium Dunkerque investigated laser welding solutions. These enable welding at full amperage (tested up to 360 kA according to suppliers) and reduce voltage drop across the weld by at least 10 mV compared to regular welding. A visual comparison between these two types of welds is shown in Figure 4.

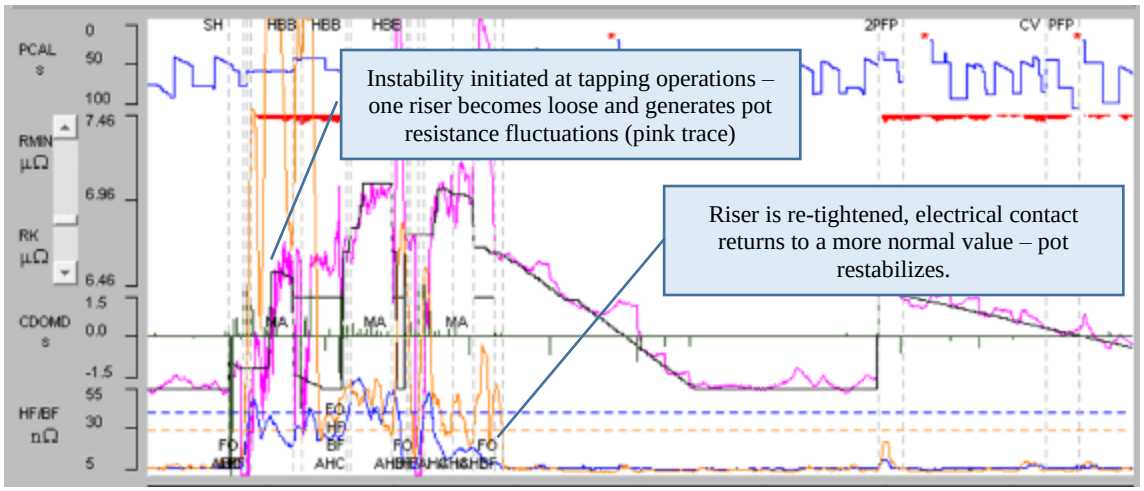

Figure 3. Example how a broken weld on an anode riser causes pot instability.

Figure 4. Usual anode riser welding (left) vs laser welding (right).

The laser welding requires longer time to weld 5 risers than the traditional welding; this extra time needs to be considered in financial evaluation. The cost of the equipment at time of the study was above 600 000 USD (transportation and training included). It was also estimated that the additional time required to weld incurred an additional cost of 2000 USD/pot. Although suppliers estimated voltage drop gains up to 16 mV, Aluminium Dunkerque retained a reasonable assumption of 10 mV. The measured voltage drop increase in electrical connections during amperage increase was 8 mV over a 10-year period due to deteriorating quality of the weld. The payback of the laser welding solution was 4 years with an internal rate of return (IRR) at 27 % with the constraint of rewelding all the pots in 8 months (33 pots per months, or 2 pots/day, 5 days a week). Depending on smelter availability of CAPEX and OPEX, the riser voltage drop and the response to constraints stated, this solution could be implemented.

On the other hand, Aluminium Dunkerque did investigate possible solutions without major investments and performed tests (with its local supplier Clauser Dunkerque) using traditional arc welding without potline outages. In the meantime, tests were also performed to reduce energy loss in the welds but these tests are not reported in this paper which is about welding.

Many trials were made for different busbar damages including melted busbar after a pot tap-out. During the trials, magnetic fields were measured to optimize the welding. A computer model was created to adapt the procedures for welding preparation according to the position of the defect found. Magnetic shields for welding developed by the contractor are also used. Aluminium Dunkerque is now able to weld conductors without potline outage in the positions described in Figure 5.

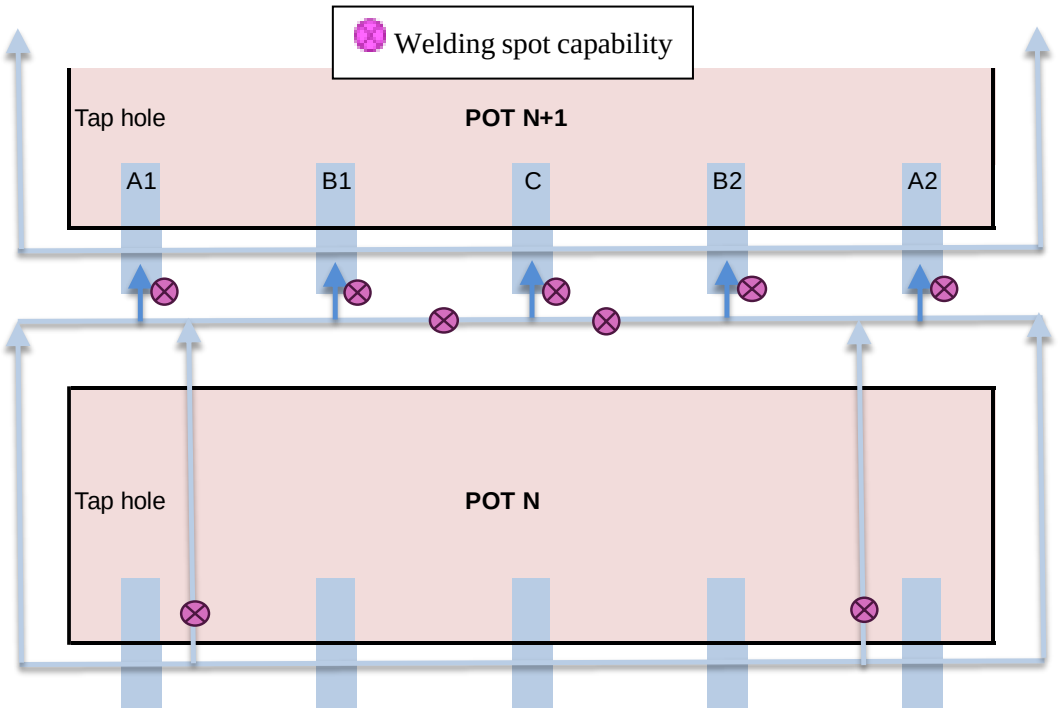

Figure 5. Welding spots capability.

3. General Description of the Process

Depending on the damaged busbar position, the process to prepare pots for repairs is different. The general intervention process may require:

- Temporary shutdown of the pot to be repaired and/or the adjacent pot
- Removal of short circuit wedges and/or equipotential wedges
- Amperage decrease to a level acceptable for the potline.

Aluminium Dunkerque has developed its own procedures for the temporary shutdown and restart of the pots to be repaired and is able to carry out intervention limiting shutdown duration to 2 hours maximum.
When a power reduction is required, a specific procedure has been put in place to limit the thermal impact, the loss of production and the generation of anode effects. The actual duration of the power cut is 45 minutes maximum.

4. Achieved Results

Aluminium Dunkerque has been able to reduce or eliminate the need for potline stoppages to carry out busbar and anode riser repairs. In 2020, no scheduled potline shutdowns were launched for repairs, compared to the usual 3 to 4 per year in previous years. The procedure developed by Aluminium Dunkerque for shutting down and restarting the pots allows for almost immediate return to normal operation (Figure 6). Aluminium Dunkerque, following its new procedures, is

able to re-weld massively damaged conductors due to pot leakage as well as anode risers. Some examples of welded busbars with the new procedure are shown in Figure 7.

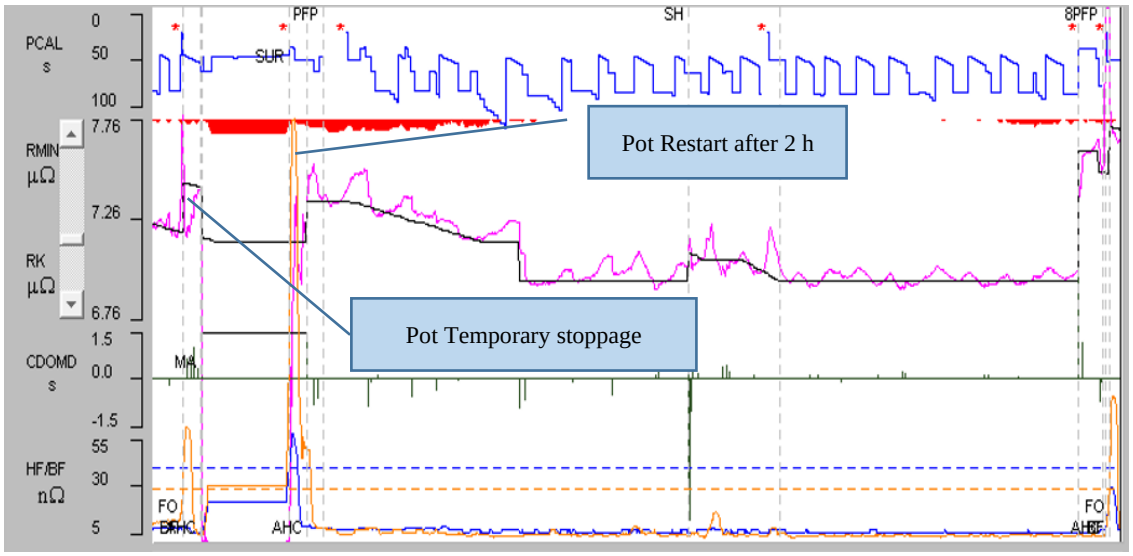

Figure 6. Impact of a 2-hour shutdown of a pot.

Figure 7. Bus bar prepared before welding (damaged part has been cut off).

Figure 8. Bus bar after its welding repair (located under the potshell).

Figure 9. Same as Figure 7 with different view.

Figure 10. Anode Riser C located in the middle of the pot.

5. Conclusions

Aluminium Dunkerque has increased amperage by more than 30 % since startup in 1991. This increased the magnetic fields, and decreased welding quality on risers. During that period, voltage drop increased by 8mV in riser welds, leading to increased temperature of the bus system and increased broken weld frequency.

Laser welding was investigated as a solution to recover proper weld quality and reduce energy consumption in the bus without having to shut down the full potline. Laser welding was not tried or used on site; nevertheless, it can remain an alternative solution depending on CAPEX and OPEX availability. Energy costs, estimated voltage drop decrease and organizational readiness to perform rapid welding on the full potline to recover weld quality were used in economical evaluation of laser welding.

Aluminium Dunkerque has developed a low-cost solution based on measurements and experience and is able to reweld damaged risers and bus bars without having to shut down the potline. Massively damaged busbars, and damaged riser welds have been repaired with these new procedures without power shut down. In 2021, more than 30 pots have been repaired without power shutdown.