Anode Setting Pattern Changes in Sohar Potline Operation

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Abstract

In modern aluminium reduction prebaked cell technology, anode changing is the highest disturbance to cell performance in many aspects, including thermal balance, anode current distribution, and the electric current flow. In the extreme, pot instability can occur and energy consumption may increase. Selecting the optimum anode changing sequence or pattern is essential to optimize the thermal balance, anode covering practices, and energy consumption for the individual cells. This results in optimized operational practices such as the optimized covering material, minimum anode incidents and metal purity. In this paper we present the Sohar Aluminium smelter experience and transition strategy in converting the operating anode change sequence from the butterfly pattern to the typewriter pattern. Also, the potential gains of pot and potline performance are shown.

Keywords: Aluminium reduction cells, Anode changing patterns, Butterfly anode changing pattern, Typewriter anode changing pattern, Cell performance.

1. Introduction

The Sohar Aluminium (SA) plant is operating a single 360 pots AP40 design, with a potential total metal production of 395 000 tons per year, a carbon plant producing baked anodes and a casthouse to cast the molten aluminium into final P1020 products of ingots and sow's format. In addition, the plant has its own 1 000 MW power plant, a substation with 5 rectifiers, each rated at 103 kA and a port terminal.

Aluminium smelters using prebaked anodes technology are the most common nowadays. As a continuous process environment, main operations are on repetitive cycle mode, for 32 hours cycle operation for Sohar Aluminium case. Each operation is a disturbance to the pot operation, but they are essential to the smelting operation as a continuous production process.

Different technologies are competing on how to reduce the impact of the essential operations disturbances such as: optimization work on the magnetic field and busbar design, simplified operations and cell design. Meanwhile the operating smelters management are focusing on optimizing those operation to obtain better current efficiency and reducing the energy and other specific consumption with respect to the technical basic data list (BDL) provided by the technology supplier. Any smelter has the continuous improvement challenge and the drive to optimize how to operate to obtain the optimum results to meet the BDL itself or better than the BDL expectations.

Sohar Aluminium smelter initiated a review of the anode change cycle or pattern targeting to achieve benchmark results, promoting continuous improvement through lean six sigma approach and statistical analysis.

The anode change operation is the most disturbing operation to the aluminum cell and any change in the standard procedure will have a direct impact on cell performance itself, positively or negatively. Thus, any change to this operation will have to be established or performed after a robust validation process.

The anode change operation has a direct impact on pot's thermal balance, electric current flow, heat dissipation and overall current efficiency performance. In continuous smelter operation, the challenge remains in all technologies at every new anode change by considering the neighbouring and the oldest anodes behaviour, the anode position to the metal velocity pattern, cold anode offset and resistance compensation, anode energization power and the magnetic field impact at individual anode location [1].

In this paper we will cover the Sohar Aluminium experience in the migration to the typewriter pattern and how the new sequence improved the quality in the operation and the pot performance.

2. Anode Sequence Optimization Elements

Triggering the need to optimize the anode cycle at any plant is often dependent on how passionate the organization is to further improve how they operate, moving away from their comfort zone. In addition, the pot might have a performance limitation to accept a further lower ACD operating zone, as required during planned amperage increase. Efforts need to be consistently made to optimize key parameters such as bath power, internal heat, instability level. superheat, etc., in order to facilitate the amperage ramping up progress.

To improve pot performance, it is required to have robust and consistent operation standards, along with discipline in the execution, so the human factor will not distract our analysis and conclusions.

Figure 1 chart illustrate the different stages to be covered during the process. It is very important to model and simulate the alternatives before piloting, avoiding multiple tests as these are difficult to manage and to coordinate/integrate with normal operation. Also, it takes longer time with less efficient comparison. Optimization opportunities are reduced, considering the normal potline life with a dynamic event and variability sources including material, pot life, amperage setpoint, ambient and climate changes and other external factors.

A short list of only 2 options for the pilot test were selected, for better optimization opportunities, hence better visibility to reach the optimum solution. It is essential to have a statistically representative sample for each pilot model.

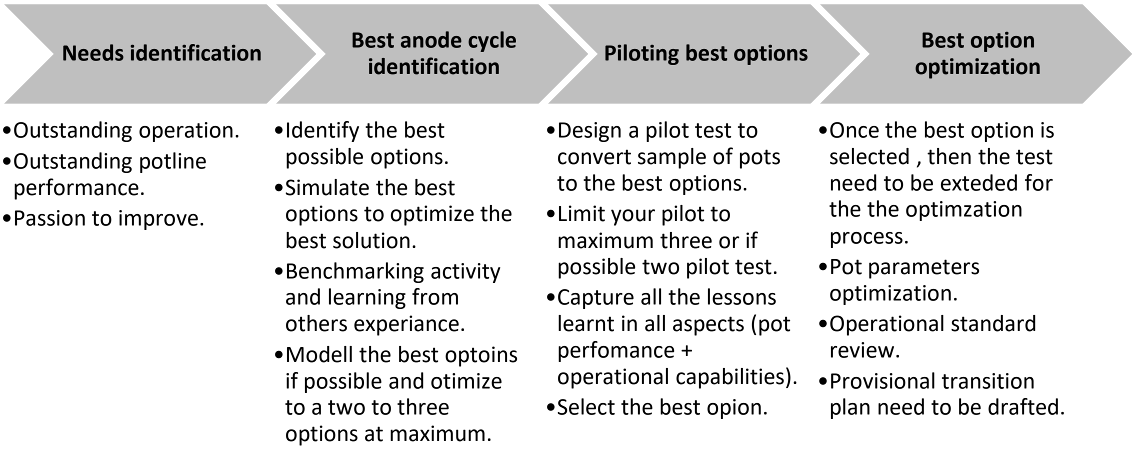

Figure 1. Summary of main stages for decision making and planning of anode cycle conversion.

3. Main Stages to Convert a Running Potline to a New Anode Cycle

After confirming the optimum anode cycle for the targeted potline, the next challenge is the transformation stage or the transition period, which is a key measure for the success of the project, starting from the preparation of the plan itself and ending with the parameter’s optimization and the continuous fine-tuning stage. It is very important to have a robust plan for such project, as it requires the attention and cooperation of all teams, including operation, technical, services and maintenance. Hence, the communication and training departments play a key role in people’s motivation and acceptance of the new change.

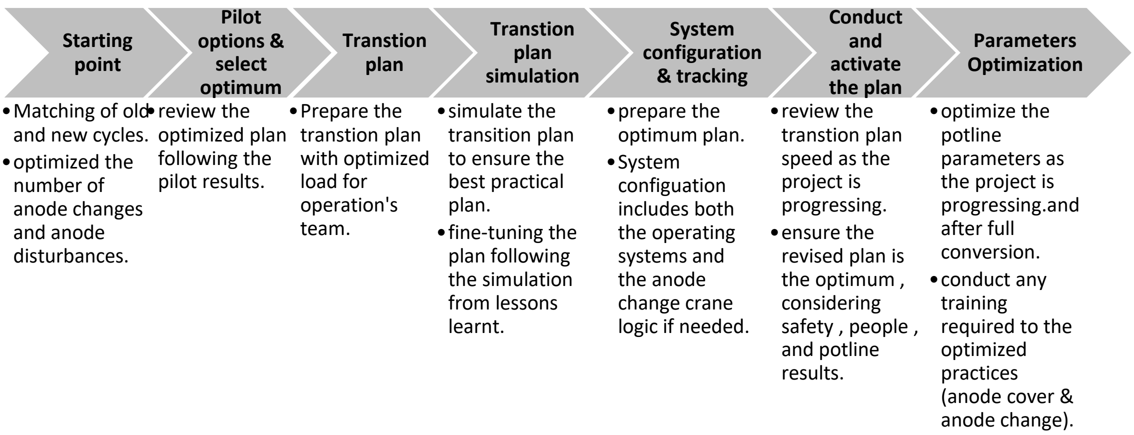

Figure 2. Key steps in planning a full anode change pattern conversion to a running potline.

4. Insight in SA Anode Cycle Transformation

Following the above systematic approach, Sohar Aluminium team selected the typewriter or the sequential patterns after a list of potential options and modeling of the best two optimum options. Also, at the implementation stage the team worked out a robust plan concerning a list of agreed criteria and project scope boundaries, leading the team to the optimum conversion starting point. The following options were considered: minimizing the number of anodes disturbances such as minimizing the number of new anode changes and minimizing the number of anode consumed, anodes rotation or movements, avoiding or minimizing the double consecutive anode changes, reducing or eliminating number of the PTA rotations (i.e. working in one side of the pots at each time), anode rotations or movements at the same pot and no anode movements crossing the pots for thermal control purpose, standardizing one conversion sequence for all pots for robust operational execution and follow-up, avoiding generation of big unconsumed anode left with greater than 14 days or residual life optimizing the anode gross consumption, and finally to implement the conversion on a group of three pots at minimum for better operating system configuration (ALPSYS system).

Following the SA experimental and testing protocol, it was essential to have a statistically representative sample of the whole potline population, considering both the test and the reference group. On the other hand, as another dimension on sample size selection, is the magnitude of effort required by the team and the duration of the testing itself, therefore the team selected six pots sets of two groups for both test and reference groups, moreover initial testing period was identified to be two anode change cycles and above (i.e., 26.7 x 2). The first cycle is the transition or the transformation cycle, and afterwards it is the performance monitoring stage. Figure 3 illustrate the difference in anode change sequence between the new and the old change pattern.

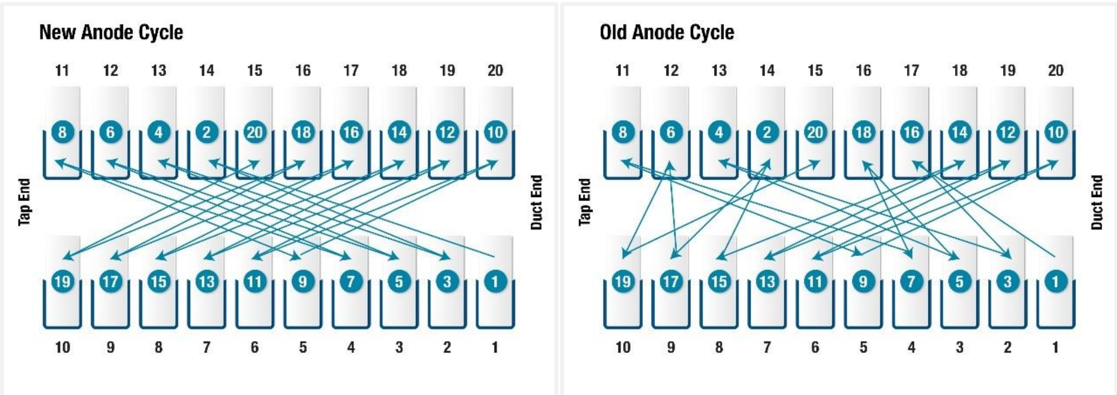

Figure 3. Difference between the anode change sequence. Left: old pattern. Right: new pattern.

On the following sections, we will cover the pilot results, which was the base behind the management team in confidence with the new pattern roll out decision. In addition to this, we will also cover the potline main gains from the typewriter cycle transformation through focusing on projected impact on the overall pot thermal balance, pot life, cover mix circuit, mass balance and overall potline performance.

5. Thermal Impact of the New Cycle

The results presented in the coming sections are covered with the comparison between the reference group, which were representing the old anode change pattern and the test group of pots (pilot group) which were representing the new anode change pattern (sequential/typewriter). The main drive behind the team passion to change the cycle was the challenges faced with the old cycle on the effort spent to maintain an outstanding covering standard, which were occasionally leading the teams to increase on anode covering or and very exceptionally on the air burn incidents. And because of the repetitive over-covering incidents, the effect on the side wall protection, clad failures, stem damages, thermal balance, parasitic feeding increases, etc., could be significant. Thus, this project considers treating the thermal balance, heat dissipation improvement being the target gain after the cover standard improvement and its consequences on reducing the stem damages.

The results below show the comparison of the pilot pot group with respect to the reference pots. Overall, clearly the test was showing how the covering standard has improved and how the variation on the anode cover height was significantly reduced as well (considering both anode to anode variation and variation due to anode age). Moreover, the impact on the heat dissipation and heat transfer were also studied in different aspects to validate the selected anode sequence effectiveness towards having a solid conclusion on the pattern performance before the roll out and implementation activities takes place.

5.1 Impact on the Anode Covering Standard.

One of the main drives to change to the new cycle, is to improve the covering quality standard; clearly the sequential anode change sequence reduces the variability on the adjacent anode's age differences, to 64 hours age fixed, which allow to maintain a very good covering standard and ensuring better pot dressing to the anode with reduced effort. The old anode change cycle has a very high variability on the anode age, which in turn makes it very difficult to control the cover height on the adjacent anodes to the new one in multiple positions.

Figure 4 illustrates the difference between the old and the new anode cycle on the cover height. It's clearly indicating the reduced number of high covers and reduced variability on overall pot cover height. Then, the only challenge with the new sequence is how to avoid the over cover on the adjacent anodes to the new anode which could last for 64 hours or less and to ensure optimum new anode cover at every new anode's change.

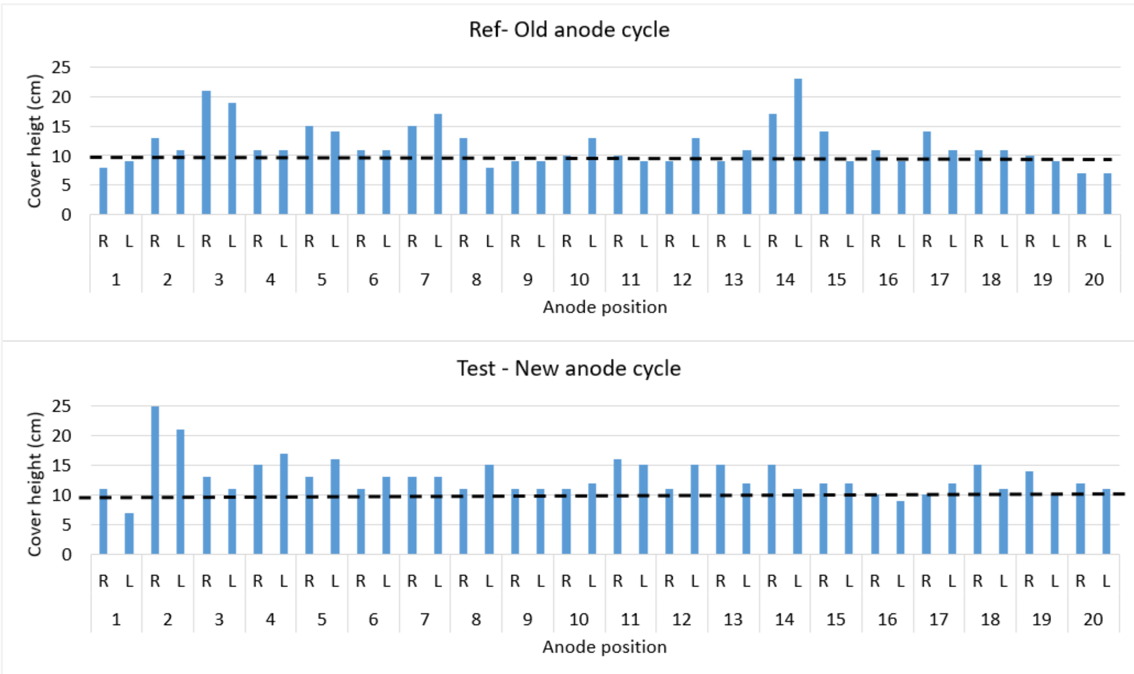

Figure 4. Snapshot of cover height measurement illustrating the difference between both anode cycles.

It is a challenge to control the cover level between the new anode and the adjacent old anode due to the risk of partially exposing the new anode for up to 64 hours. One solution is to "overcover" this portion of the anode - until the next anode change 64 hours later. Overall, this has less impact on heat dissipation when comparing to the old cycle, where high cover incidents last for more than 10 days.

5.2 Impact on Heat Transfer Area

The heat dissipation area is reduced by almost 10 % comparing to the old cycle by reducing the fins effect factor (i.e., reducing heat transfer surface area by reducing the anode exposed to radiation side area. In Figure 5, it is possible to visualize the difference between the two cycles in terms of anode side surface and fins phenomena factor.

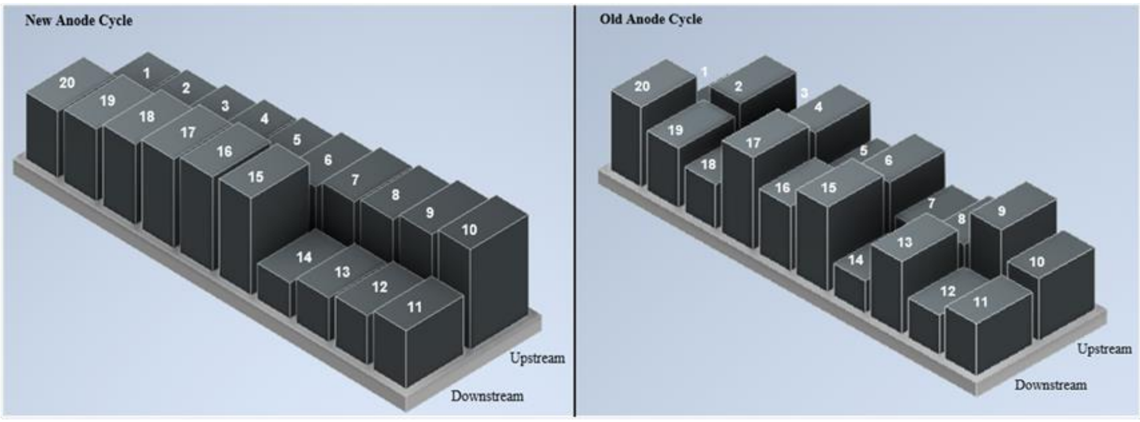

Figure 5. Snapshot illustrating the difference on anode heights between the two patterns. Left: new, right: old.

By reducing the fins phenomena throughout the anode age and replacing it by consistent heat dissipation area, will have a positive impact on reducing the variability on heat dissipation. Also, will prove a more homogeneous side heat radiation and top heat losses at the running cells, which will be discussed and explained next.

5.3 Impact on Heat Dissipation

In overall, there is a reduction of the top heat dissipation resulting from the impact of the new cycle on the cover height and the heat dissipation area. It can be confirmed by measuring the pot gas temperature. The charts below illustrate the reduction on the heat losses from the top of the cell with a potential drop of 3 % to 5 % comparing to the old cycle, with a reduced pot to pot variability.

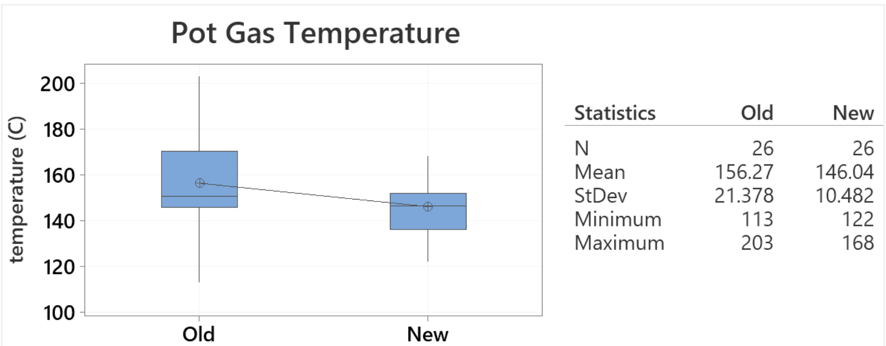

Figure 6. Box plot analysis illustrating the reduction on the top pots heat losses.

5.4 Impact on Side Shell Heat Dissipation

The sidewall heat dissipation is also impacted which was confirmed by measuring the pot side shell temperature. The Figure 7 charts illustrate the difference between two cycles on sidewall temperature, where it is clearly confirming the reduction side shell variation and eliminating hot spots generation.

The Figure 7 charts are confirming the positive impact of the homogeneous anode cover on the side heat dissipation consistency with respect to both anode age and position.

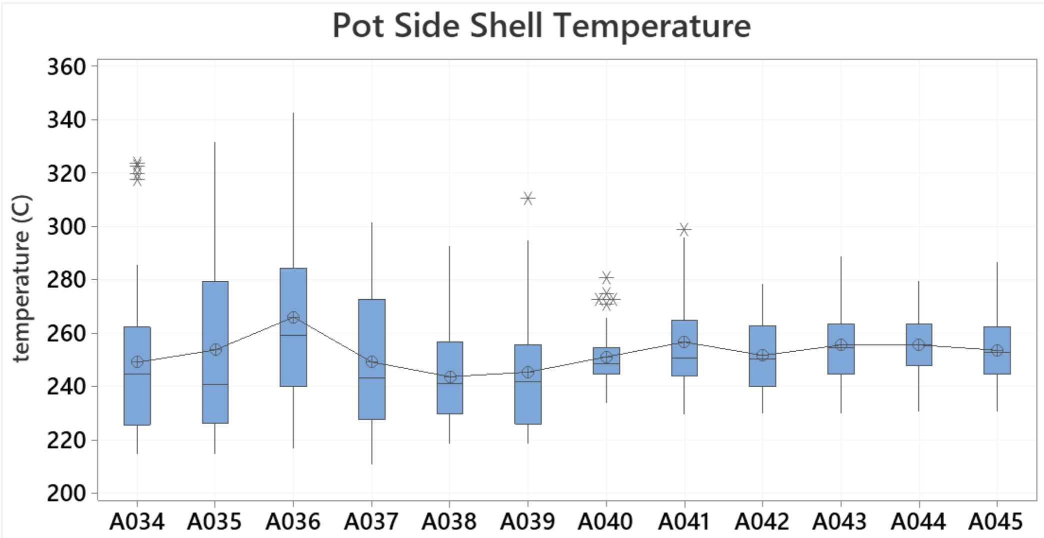

Figure 7. Improvement on side shell heat dissipation between the reference pots (old: A034 to A038, New: A040 to A045).

6. Performance Impact on the Pot Life

The improvement on heat dissipation and homogeneous heat losses, as illustrated above, had a direct impact on the side wall protection thus reducing the probability of side wall damage events, hence should lead to the extension on the pot life in the long term.

Pot line performance evaluation after the cycle conversion confirmed the positive impact on the side wall protection by having zero reported incidents related to red shells.

The pot autopsy conducted also confirmed the improved side wall protection showing a good overall side shell condition in general, especially on previous observed localized side erosion position.

7. Main Potline Gains After the New Cycle Conversion

Besides the illustrated gains on the homogeneous heat losses and side wall protection, further gains where projected before the implementation and confirmed throughout the pilot tests. The gains were related to pot performance, cover mix consumption and quality, as well as reducing people and equipment exposure.

7.1 Pot Performance

Improvement on pots instability, which allows to optimize pot voltage because reduces additional power to thermal balance and instability treatments, has been verified. The total gain in instability level was projected to be between 5 to 8 nΩ in pot noise and almost 0.03 to 0.05 µΩ in overall pot operating resistance. Figure 8 shows the instability improvement after the potline transformed fully to the new pattern by mid-August 2021. In addition to that it illustrates how well was the transition period operated since the start in March 2020.

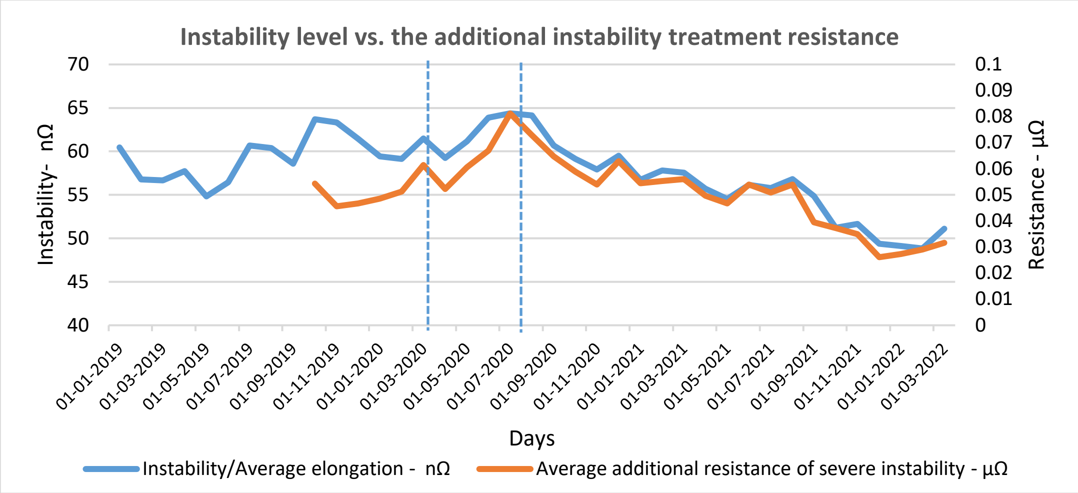

Figure 8. Instability level vs. the additional instability treatment resistance.

This instability improvement can be explained by two main contributors which are: the improvements on the side wall and the reduction of the parasitic feeding. The side walls present a better homogeneity which led to have a consistence side wall thickness throughout the anode life. Almost all the numerical modeling studies of the cell had confirmed the effect of the side wall thickness reducing the horizontal current leading to less horizontal current reducing magnetic forces, hence reduced metal bath interface disturbances. This all reflected in the instability measures gains mentioned above, and consequently less additional power consumed for the instability treatments. Also, less disturbances in thermal control were observed. Combining all the above gains makes a very good recipe for current efficiency improvement and at the same time better pot life projections [2].

7.2 Cover-Mix Consumption and Improving Cover Quality

The new pattern results in a reduction of cover mix consumption. This is because the improved control on the covering operational practice leads to less disturbances in the material quality by having a better closed system with less fine material generation. Also, results in a better solid crust formation which is consequence of the reduction of basement spillages and improvement in the thermal balance of the pot.

However, we noticed on this new cycle that the finer cover mix is more challenging to control the flow of the material on the top of the anodes, thus it is very important to ensure the optimum pots parameters and cover bath circuit robustness to gain and maintain the full potential benefit from the cycle transformation [3, 4].

7.3 Reducing People and Equipment Exposure

This new anode cycle was projecting a consistence cover bath reduction of a 30–40 % with respect to the previous anode cycle, which was a result from the improved control on the covering practices. The new cycle allows better utilization on the covering material and optimizing the excess of the covering material on the top of the anodes reducing the deadstock level, enabling the shopfloor to obtain a 90–95 % covering quality from the first cover of the newly changed anodes. Similarly, this optimization was extended to the pot tending activities and reflecting the same optimized quality control and reduced effort.

Moreover, the optimized covering practice and quality enables the team to have a better control on the material and reduces the basement spillages. So, this optimization was projecting a potential 30–40 % reduction of people effort and overall equipment exposure, including the whole bath circuit equipment and conveying system, pot tending assembly cranes (PTAs), cover mix filling station and basement cleaning machines.

8. Main Challenges Faced and Lesson Learnt

An anode change cycle conversion project is one of most challenging projects as it has direct impact in one of the main potline operations and the highest disturbance in the cell performance. Thus, it requires a strong and brave leadership decision to go with the change. This type of project requires a massive team effort. Also, it requires a proper piloting technique to support the team to optimize the effort needed throughout the transition journey. Therefore, empowering and pushing the team spirit and motivation is an essential measure to the project success. Another big challenge is the implementation and quick adaptation of the new/revised operational practices.

9. Conclusions

The anode change pattern project was a successful story at Sohar Aluminium Smelter towards a technical and better productivity performance, which was considered as one of the enablers to the current benchmark and outstanding performance among other projects conducted over the last three years.

Changing the anode pattern in a running potline is not an easy decision, as it requires a strong confidence base in all levels of the organization, in which Sohar Aluminium management team worked strongly to establish throughout the past years. In addition, handling such project in a modern young smelter without the need to an external consultant or even external resources in implementing the change confirms the maturity of the organization in all different levels.

10. References

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