Development and Introduction of Slotted Anodes Technology at Talum Smelter

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Abstract

Talum is the only primary aluminium producer in Slovenia since 1954, when production in Soderberg potline with capacity of 20 000 t/year was started. In 1987, Talum's aluminium production was modernized with reconstruction of existing Soderberg potline to prebaked technology and start-up of the new prebake AP18 potline of 80 cells. Since then, Talum has established one of the most efficient productions of primary aluminium worldwide in energy consumption, carbon consumption and pot life [1]. Anodes used in the AP18 technology are among the biggest anodes (1530 mm x 1010 mm) used for aluminium production. Since the beginning Talum was facing two phenomena in the AP18 process: Significant number of horizontal cracks caused by thermal shock and relatively high electrical resistance and instability caused by gas bubbles below the big surface of anodes. Talum's response to these specific problems was slotted anode development. Talum started with industrial trials in 2001 when the potline was extended to 160 cells. At the end of 2003, slotted anodes were integrated in the process. In 2013, Talum developed technology to erect the third top-downward slot with additional positive effects on potline performance. The paper provides Talum's slotted anodes technology development in production of green anodes, deployment of slotted anodes into the electrolytic process and overall results.

Keywords: Talum; innovation; AP 18 technology; slotted anode; top-downward anode slot.

1. Introduction

Many companies all around the world introduced slotted anodes at the end of 1990s and early 2000s [2 – 4]. Talum as well put a lot of effort to develop and optimize the technology for slotted anode production. With some industrial tests the advantages of slotted anodes to minimize anode gas bubble voltage drop was proved and reduction of energy consumption was achieved. The question was not "to do or not to do?", but "how to do?"

At that time two possible ways to prepare slotted anodes were studied: Creation of slots during vibro forming of green anodes before baking or slot cutting with special machine after baking process. Both solution have positive and negative impacts on the quality, scrap ratio and overall costs of production. Finally the decision was to adapt vibro compactor with additional plates at the bottom of model and to build special machine for cleaning the slots of coke after baking.

After ten years from industrial implementation of the bottom slots on the 160 cells AP18 potline, Talum explored and researched additional benefits from the third top-downward slot,

which allowed extending the positive effect of slotted anodes until the end of anode life time. Final design of slotted anodes is shown in Figure 1.

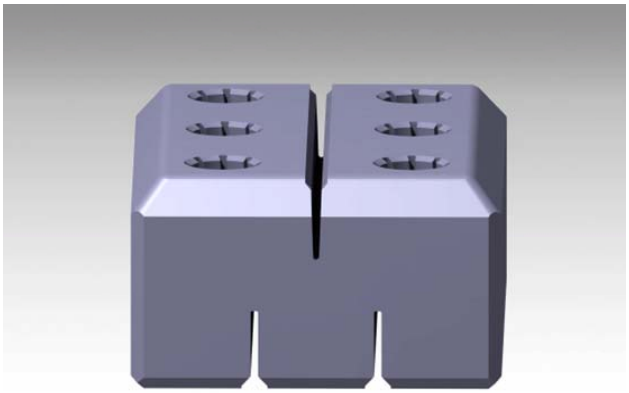
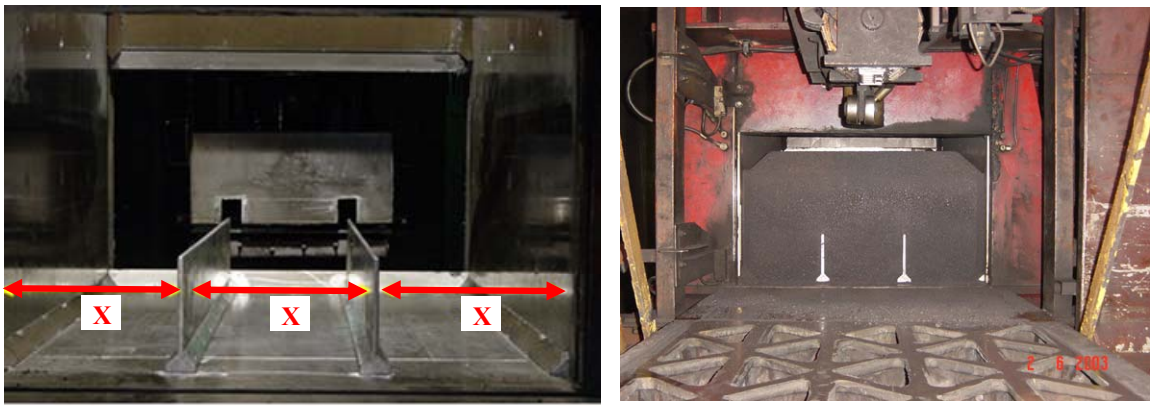


Figure 1. New Talum AP 18 anode design.

2. Introduction of Two Bottom Slots

2.1. Adaptation of vibro compacting process

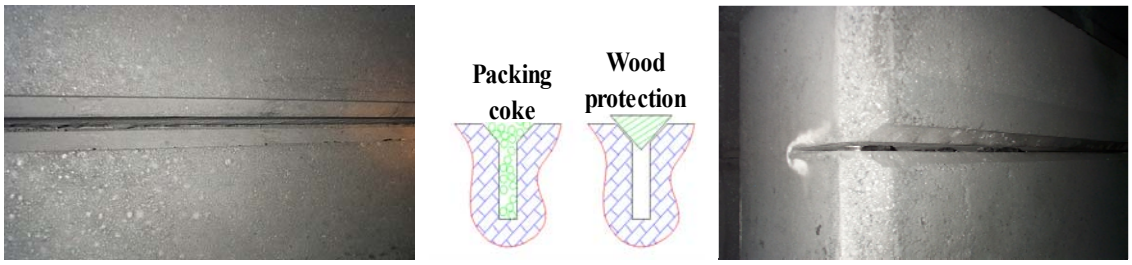
In June 2003 vibro compactor was rebuild with two conic steel plates (230/220 mm) at the bottom of model. With plates, the anode was divided into three equal surfaces. A modification of a pusher was made according to the new geometry.



a. New design of the model and pusher b. Green anode inside the model.

Figure 2. New design of the vibro compacting unit.

For anode baking tests, some anodes had the slots blocked with wood in order to prevent entering the packing coke ans some anodes were left with open slots. After anode baking, a comparison of slot deformation and sticking of packing coke on the walls between the anodes between the two groups was made. The slots filled with packing coke showed much better results (less deformations and sticking), Figure 3.



a. Slot with packing coke. b. Slot without packing coke.

Figure 3. Deformation of slots with and without packing coke.

A cleaning device for packing coke removal from the surface after baking was upgraded with rotating blades to clean the slots (Figure 4a). Green/baked storage crane was adapted according to the new geometry (assembly point) to avoid cracking of corners (Figure 4b).

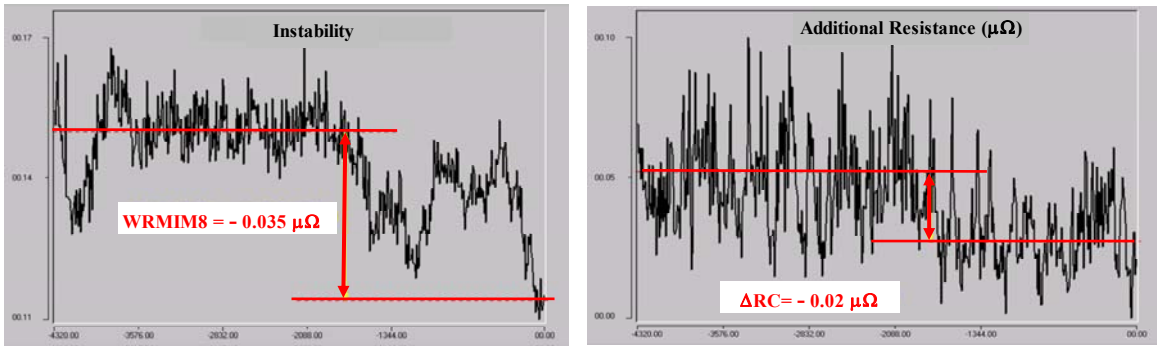
a. Slot cleaning device b. Modification of crane

Figure 4. Slot cleaning device and crane modification.

2.2. Results in the potline

With deployment of slotted anodes, results in the potline were improved substantially:

- Current efficiency increased,
- Pot instability and additional resistance decreased (Figure 5),
- Anode effect frequency and HF emissions decreased,



a. Average instability. b. Additional resistance.

Figure 5. Decrease of average instability and of additional resistance.

Due to the large contact surface when the new anode is inserted into the electrolysis cell, AP 18 anode was more exposed to thermal shock. With slots the big horizontal surface was divided into three smaller areas influenced by lower thermal stresses. Immediately after deployment of slotted anodes into potline the problem of horizontal cracks in the anodes was solved (Figure 6).

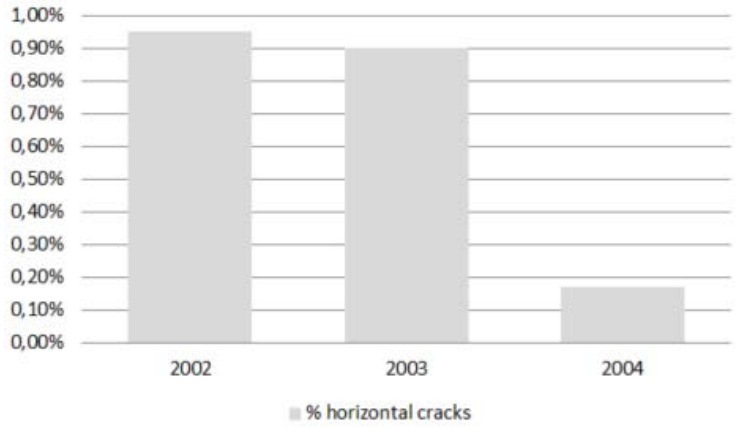


Figure 6. Horizontal cracks in the anodes after immersion into the bath.

2.2.1. Discussion

After 44 shifts in the cell, anode with 220 mm slots was consumed to the level where the positive effect of slots for additional 40 shifts in the cell was lost; out of 16 anodes in the cell only one half of them reduced the anode bubble voltage drop.

a. Anode after 33 shifts in the cell. b. Anode after 44 shifts in the cell.

Figure 7. Anode consumption as a function of time in the cell.

Increase of slot depth which is the most effective way to prolong the positive effect on voltage drop is limited with the vibro compacting and baking process. In 2013 TALUM developed technology to create the third top-downward slot with additional positive effects on potline performance.

3. Shaping of Top-downward Slots

3.1. Adaptation of vibro compacting process

Different technical solutions were tested. The best compromise between the production process and the results in the potline is a central slot from upper surface to the bottom of the anode (depth = 310 mm). In the production process a new design of mould cover with integrated conic plate was built (Figure 7).

A cleaning device was upgraded to the system of three blades from both sides of the anode.

a. New design of a mould cover. b. Adaptation of slot cleaning device.

Figure 7. New design of mould cover and slot cleaning device.

3.2. Reconstruction of anode butts cleaning system

Existing Anodes Butts Robot cleaning system was upgraded with a mechanical device to clean the butts in the central slot (Figure 8).

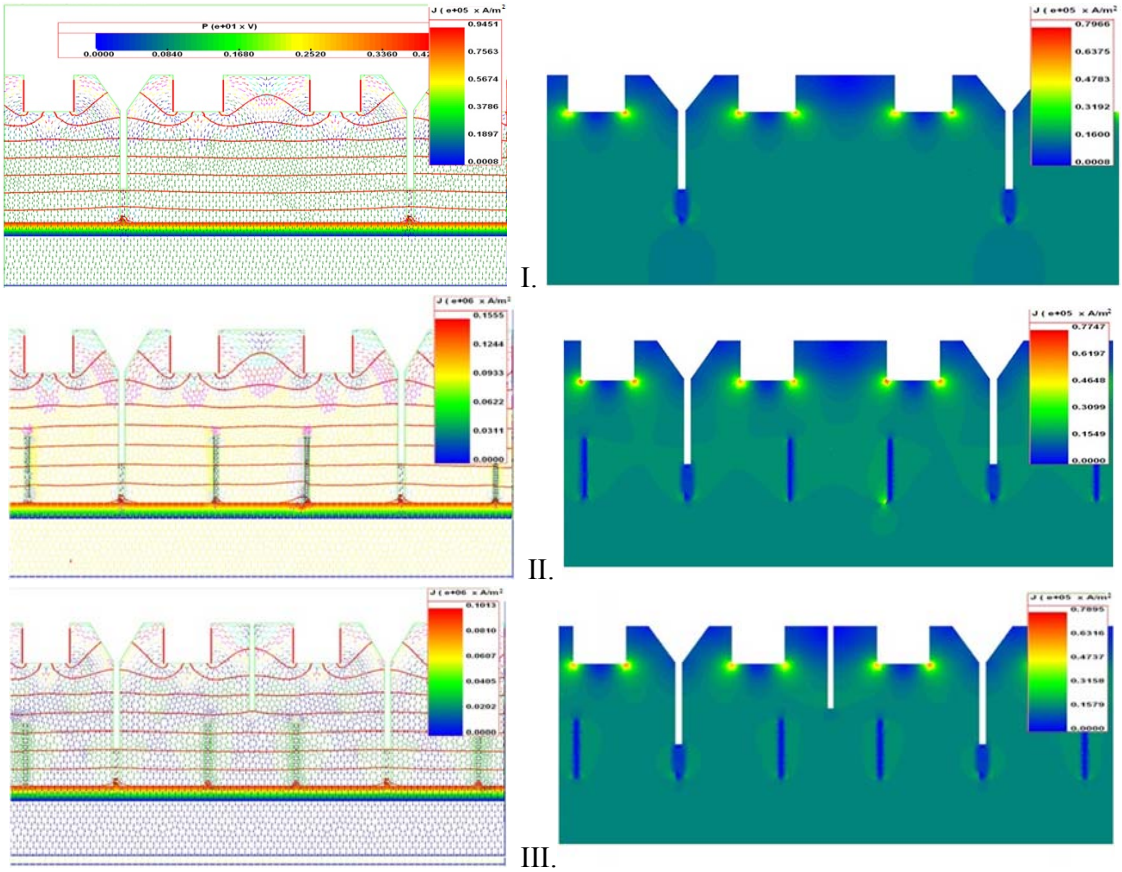
a. Central slot cleaning device. b. Anode butt after cleaning.

Figure 8. Anode butts cleaning operation.

4. Results in the Potline

Simulation of current density vectors and equipotential lines in the POLJE (FIELD) mathematical model demonstrates the effect of slots on the stability of electrolytic process. Simulation was done for anode without slots (I.), anode with two bottom slots (II.) and anode with two bottom and one top-downward slot (III.). The ideal situation will be if the current flow is oriented in vertical direction only. Because of variable geometry a horizontal component of the current flow appears. Strong Lorentz force that is generated in the interaction between the magnetic field and the current in electrolyte increases according to the proportion of the horizontal component of the current through the liquid electrolyte and metal. The Lorentz force causes turbulence in the liquid, the instability of the process and the current efficiency decrease.

With simulation it was found that horizontal component of the current was the lowest on the anode with three slots (III.) (Figure 9).



a. Current density vectors and the equipotential lines.

b. Current density.

Figure 9. Current density vectors, equipotential lines and current density (anode without slots, with 2 slots and 3 slots).

After 44 shifts in the cell, bottom slots were burned off. The top-downward slot was active from 57th until 84th shift (Figure 10).

a. Anode after 44 shifts in the cell.

b. Anode after 57 shifts in the cell.

Figure 10. Consumption of anode with three slots as a function of time in the cell.

With introduction of the third upper-down slot the average instability was reduced by 0.025 μΩ (Figure 11). The average electrical resistance was reduced by 0.032 μΩ (Figure 12).

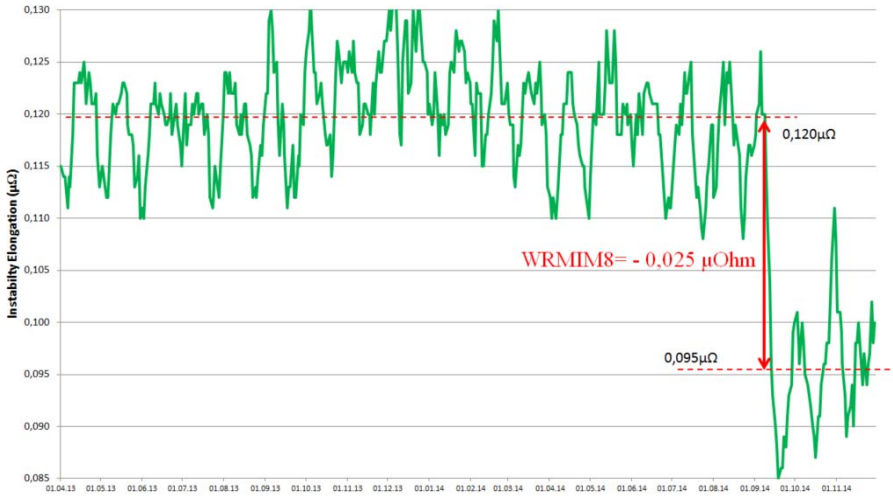


Figure 11. Average instability before and after introduction of the third top-downward slot.

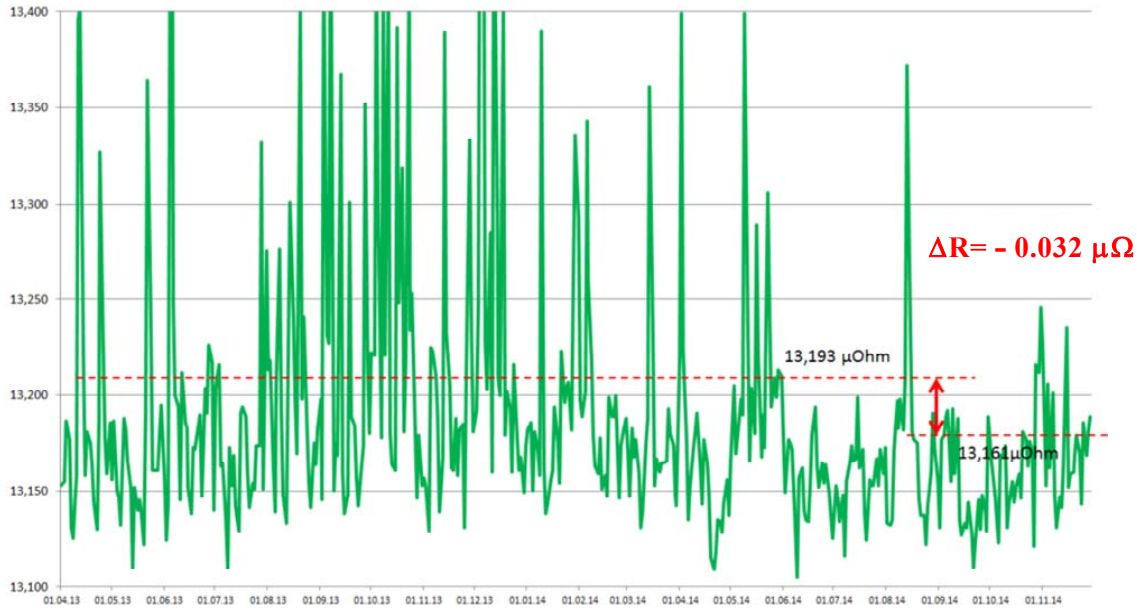


Figure 12. Cell resistance before and after introduction of the third top-downward slot.

5. Conclusions

With innovative solutions in anode design and anode production process Talum improved performances in the potline:

- The problem of horizontal cracks due to thermal shock was solved,
- Improved current efficiency and specific electrical energy consumption,
- With the third top-downward slot the positive effect of slotted anodes on the stability of process was prolonged.

The challenges for the future:

- Slots width and depth optimisation,
- Additional adjustments and R&D of slotted anodes production process and anode butts cleaning systems.

6. References

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