

25 years of continuous improvements in TALUM smelter

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Abstract

TALUM is the only primary aluminium producer in Slovenia since 1954, when production in Soderberg Potline A with a capacity of 20 000 tonnes/per year was started. With the erection of the Soderberg Potline B in 1963, the total capacity was increased to 55 000 tonnes per year. The modernization program of primary aluminium production started in 1985 with the introduction of Carbon Plant in 1987 and the Pechiney AP18 technology in Potline C1 in 1988. In the same period, the Soderberg Potline B was re-constructed to pre-baked technology. During the last 25 years, with the implementation of many innovations from TALUM's Continuous Improvement Program (CIP), Talum established one of the most efficient productions of primary aluminium worldwide in energy consumption, carbon consumption and pot life. The CE of 96.30 %, a DC energy consumption of 13 000 kWh/t Al, a net carbon consumption of 392 kg C/t Al and an average pot life of more than 3 500 days are the results of technical improvements in smelter processes such as development and implementation of best practice, optimization of process control and operational parameters, improvement of cathode design, application of innovative design of anode, etc. Talum's Technology Roadmap for the next decade until 2025 is already defined.

Keywords: Technical improvements; slotted anodes; energy consumption; cathode optimization.

1. Introduction

After 125 years of operation, Hall-Heroult process cell productivity has improved dramatically through the development of high amperage cells. However, energy efficiency improvement levelled off after the seventies [1]. The long-term demand outlook for aluminium has been strong and is likely to remain so. Significant growth in demand will be driven primarily by the continued urbanisation and industrialisation of emerging economies, particularly those of China and India. Aluminium demand is expected to grow by four to five per cent a year over the next two decades [2].

Reducing the production cost is an ongoing process in every smelter. To remain competitive continual improvement in efficiency, cost and productivity is necessary. Prebaked anodes contribute as the biggest variable impact to the aluminium production cost [3]. Optimization goals may focus on the anode plant to produce cheaper anodes with the same performance in the pots or on the potrooms to use anodes of superior quality to produce metal at reduced cost [4].

The technologies of aluminum electrolysis include cell design technology, potline building technology, operation technology and cell preheating and start-up technology. These technologies play important roles as they influence cell life, energy consumption, potline current and current efficiency [5].

Since the beginning of the aluminium industry great efforts have been made to improve energy consumption. In the first half of the 20th century, energy consumption was halved. This effort was particularly important in Europe where energy was already more expensive and less available than in North America at that time. At the beginning of the nineteen seventies the most energy efficient smelters were able to operate below 13 DC kWh/kg Al [1]. It is widely accepted that the service life of an aluminium electrolysis cell is mostly limited by the performance of the pot sideling [6,7].

In this paper some technical improvements in the TALUM AP 18 potline processes, which have influenced energy consumption, net carbon consumption, average pot life, current efficiency and also metal quality are presented.

2. Technical improvements of potline processes

Main goals of technical improvements have been:

- ◆ Increase of productivity,
- ◆ Decrease in the level of impurities in primary metal,
- ◆ Decrease of the specific consumption of sources (energy, raw materials, manpower hours),
- ◆ Decrease of the negative impact on working conditions and local environment.

The factors that influence pot productivity are potline current and current efficiency. The potline current is limited by thermal stability. To increase the potline current some modifications are needed (cathode design, anode dimensions, pot operation parameters). Low levels of impurities in primary aluminium are very important for companies such as Talum, which are trying to improve their market competitiveness with managing the optimal amount of secondary aluminium in their products. Higher productivity and low level of impurities are very much preferable, but specific consumption of sources needs to be considered, too. As part of the sustainable development of the production process and Talum's social responsibility we also include the continuous improvement of working conditions and our impact on the local environment.

2.1. Anode quality and geometry optimization

High anode quality by Talum definition meets the following criteria:

- ◆ Chemical purity and homogeneity,
- ◆ Thermal shock resistance,
- ◆ Resistance against air and CO₂ oxidation,

on assumption that the production costs per unit (raw material, energy, maintenance, etc) are low.

High quality anodes are not a guarantee for good results of the potline operation. On the other hand, with poor anode quality, good results are not achievable. In Talum, conversion from Soderberg paste plant to prebaked anode plant was realized in 1987 (reconstruction of green anodes production tower, new closed type baking furnace, new rodding shop). The production of Soderberg paste was terminated in 1991 when an old Soderberg potline (53 kA) was stopped. Since then, Talum produces two types of prebaked anodes only (for 180 kA and 75 kA pots). At the early stage of prebaked anode production, activities were focused more on availability and stability of the process (doing by learning) but since the last ten years the quality issue has been the highest priority. Based on its own experience and available knowledge, several improvements of existing concepts and applied practice of the prebaked anode production process were realized:

Quality issues:

- ◆ Decrease of level of impurities (catalytic elements) in anodes recycled material,
- ◆ Fines homogenization,
- ◆ Conversion from solid to liquid pitch,
- ◆ Introduction of intensive mixer/cooler,
- ◆ Erection of slots at vibro compactor,
- ◆ Automatic control system in green anode production,
- ◆ Laboratory analysis portfolio,
- ◆ Informatization.

Working and environment conditions were also Improved with:

- ◆ Defluorization of Baking Furnace exhaust gases,
- ◆ Pitch Fumes Treatment Centre in green anode production.

In anode butt recycling, the decrease of sodium and iron content was substantial (Na < 250 ppm, Fe < 350 ppm). The anode butts cleaning system (shot blasting) was improved and the elimination of iron particles (magnetic elimination) after grinding as well. The improvement was based on a better control by operators, too. Fine fraction (0 - 1 mm) and filter dust from anode butts management are excluded from recycled material and sold to the steel industry as slag foamer. On the other hand, this granulation contains more than 30 % of catalytic elements.

The variation of fines directly influences anode paste characteristics. With adjustments of the material on input in the ball-mill and with better control (Δp regulation) of closed circuit even with a non-dynamic classifier our Blain variation is ± 300 Blaines.

With the conversion from solid to liquid pitch our purchasing position was improved, and ecological problems during transport, unloading and implementation of tar pitch in production process were avoided. The quality of the anode paste was improved and productivity was increased, too. At a second stage of paste mixing, co-kneader was replaced with intensive mixer/cooler to improve homogeneity and anode paste temperature stability. Maintenance costs were decreased, too.

Technology (modifications of model, new slot cleaning device) for production of slots during vibro compacting operation without any negative influence on green or baked anodes reject ratio was developed. The positive influence of slots on pot stability and CE is significant.

With the described improvements the net carbon consumption was decreased to 392 kg C/t Al in the last year (Figure 1).

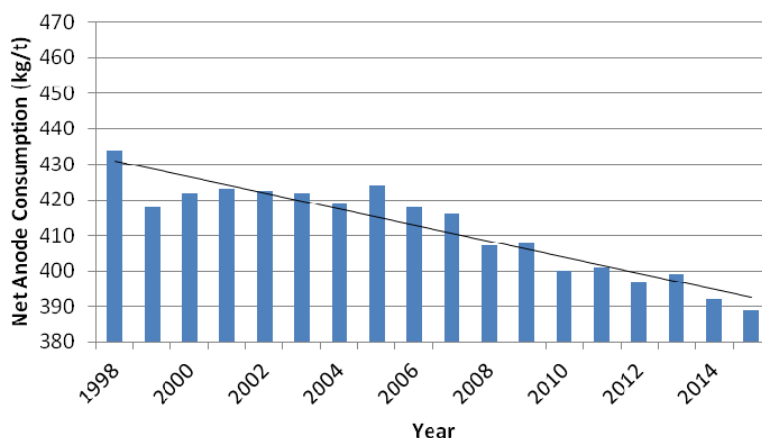


Figure 1. Net carbon consumption.

In 2003, the project for automatization of all production lines was started. Manual control of the process was replaced by PLC control. The production processes are remotely controlled from one location only. The stability of the processes was increased and level of objectivity during decision making (based on data not subjective estimation) was improved. The number of operators was also decreased. To increase objectiveness of validation of our progress, a product quality laboratory tests portfolio was completed with the analysis of air and CO₂ reactivity, air permeability, Blaine number of fines and anode butt hardness. Our own Information System named ANODIS was built to simplify collecting and processing available data for further technological analyses and reports.

Successful execution of described activities in combination with continuous development of knowledge and understanding of the process has a very positive impact on the majority of anode quality parameters. Figure 2 presents the most important baked anodes quality parameters.

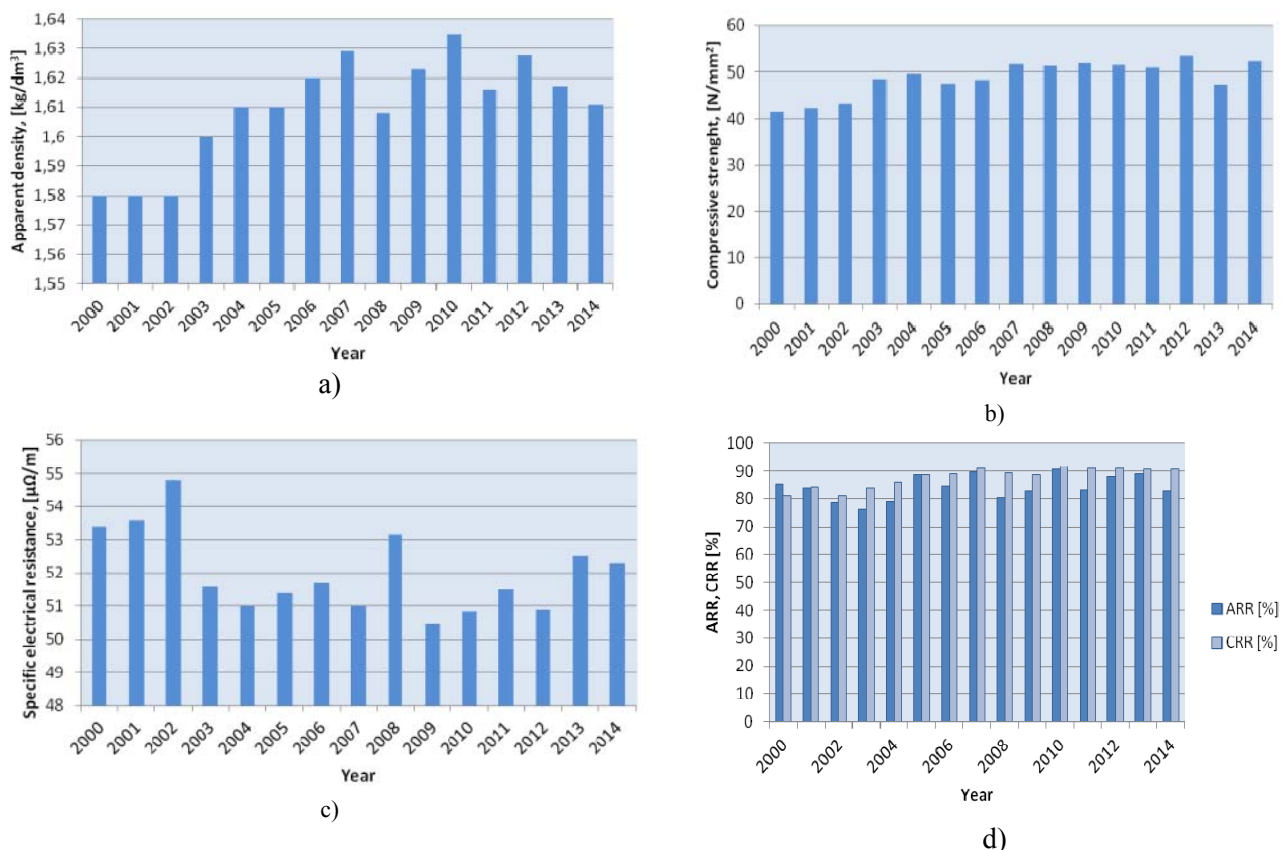


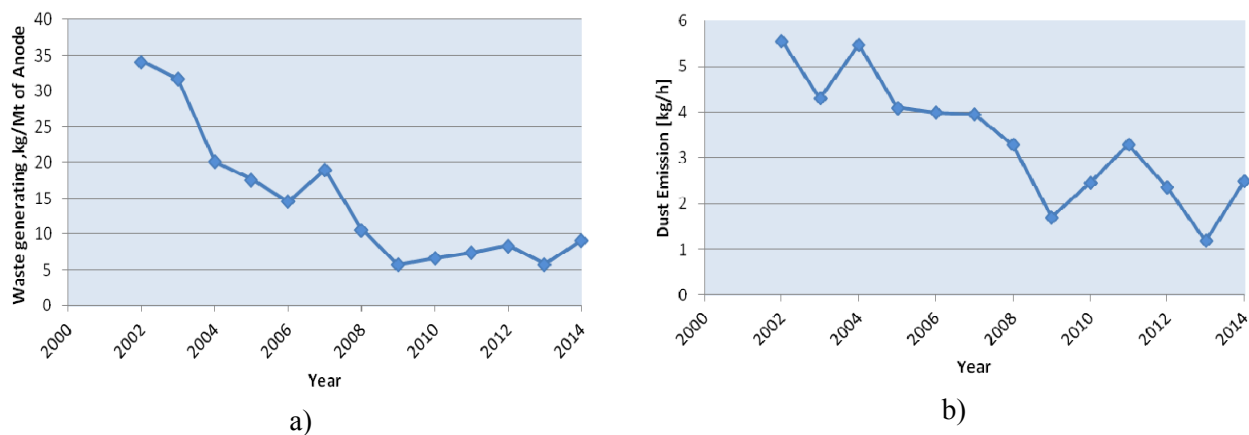
Figure 2. Baked Anodes Quality Parameters: Apparent density (a), Compressive strength (b), Specific electrical resistance (c) and ARR, CRR (d).

To support efforts for higher intensity of production in the potline, the cross-section of the anode was increased by 5.3 % (length from 1 450 mm to 1 530 mm) and the depth of holes was changed from 130 mm to 140 mm. For current above 200 kA the length of anode was increased to 1 600 mm. Also, shape modifications on the anodes were done (Figure 3).



Figure 3. Slotted (a) and shape modified anode (b).

With several activities in material flow management (recycling, separating, collecting, etc.) the amount of waste and particularly hazardous waste was decreased. Overall, the dust emission from outlets of filters has been below 5 kg/h on the average in the last few years (Figure 4).



a) **Figure 4. Waste Generating (a) and Dust Emission (b).**

2.2. Cathode material

The aluminium industry is an energy intensive technology. This is forcing us to further examine the reduction of specific energy consumption. The energy efficiencies depend mainly on the technology and materials. To reduce total voltage drop in pot, it is necessary to use better materials with lower resistivity. To achieve this, more and more graphite-based cathode blocks are used in operation. TALUM took a different step by introducing new cathode materials:

- ◆ Anthracitic,
- ◆ Anthracitic with 30 % graphite,
- ◆ Graphitized.

When we step to 30 % graphite material only small adjustments were necessary. When using the graphitized cathode blocks, the new technological parameters for a stable process running according to new conditions had to be defined [DR].

Electrical resistivity is decreased by a factor of 2 to 3 according to standard material. Once graphitized, the resistivity is almost identical between 20 °C and 1000 °C.

Thermal conductivity varies with the temperature. The thermal conductivity increases by a factor of about 2, when the cathode is heated from 20 °C to 1000 °C.

Talum has used potlines graphitized cathode blocks since 2003. The advantages of using graphitized cathode blocks are:

- ◆ Lower cathode voltage drop (CVD),
- ◆ Greater electrical stability of the operating pots,
- ◆ Lower specific energy consumption due to lower CVD,
- ◆ Current increase potential due to new thermal balance.

2.3. Start up optimization

To secure optimal pot life, proper preheating and start-up procedure should be used. The temperature in the central channel should be approximately 900 °C when the bath is poured. On other hand, the gradient temperature during preheating should not exceed 20 °C/h.

Thermocouples were installed on the cathode as shown in Figure 5 to optimize the preheating procedure. In Figure 6 the temperature evolution and number and timing for shunts applied is presented and Figure 7 shows the installed thermocouples in the pot

With number of shunts and timing, the optimal temperature set point and gradient has been defined. Talum uses the electrical preheating. All together, 10 shunts are used at the start of preheating. Two shunts every 5 hours according to schedule shown on figure are removed.

In order to benefit of some swelling effect of the cathode blocks, the basic bath during first days of start-up and especially before metal addition is used.

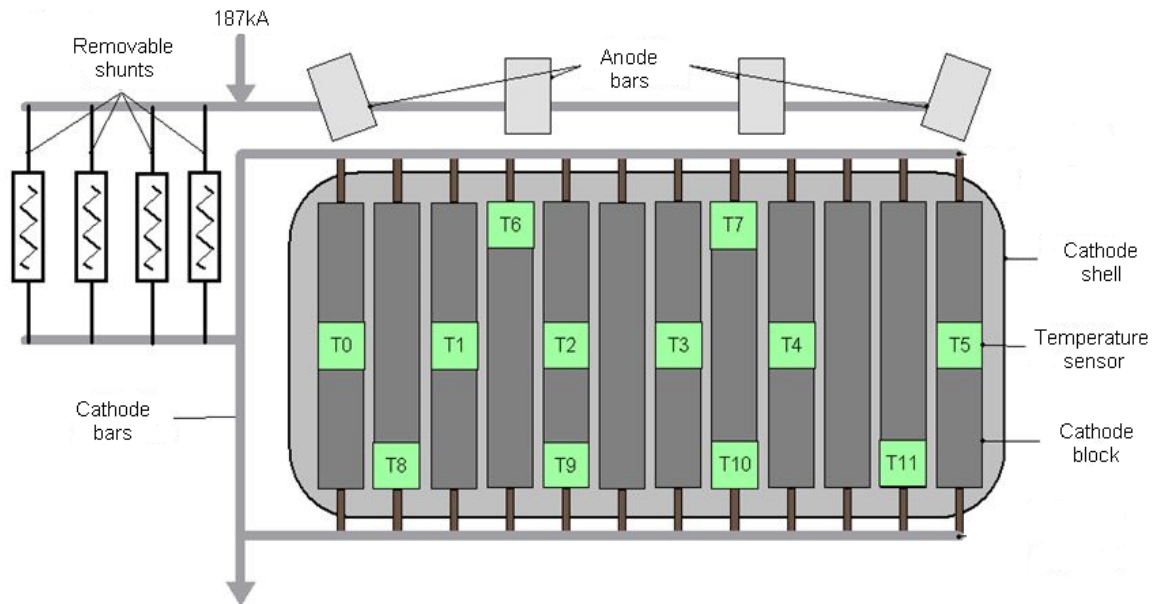


Figure 5. Installation of thermocouples for T measurement.

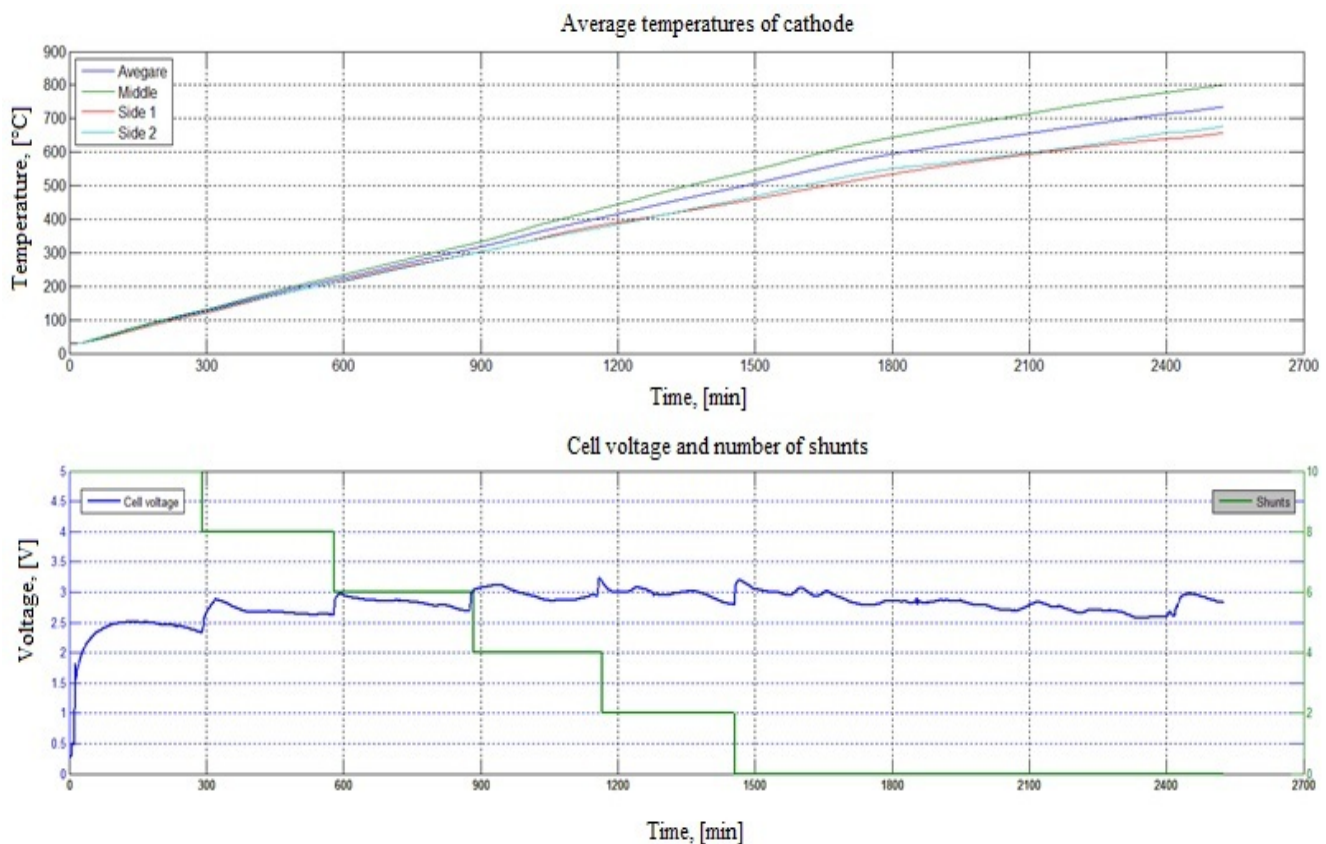


Figure 6. Temperature evolution and number of shunts.

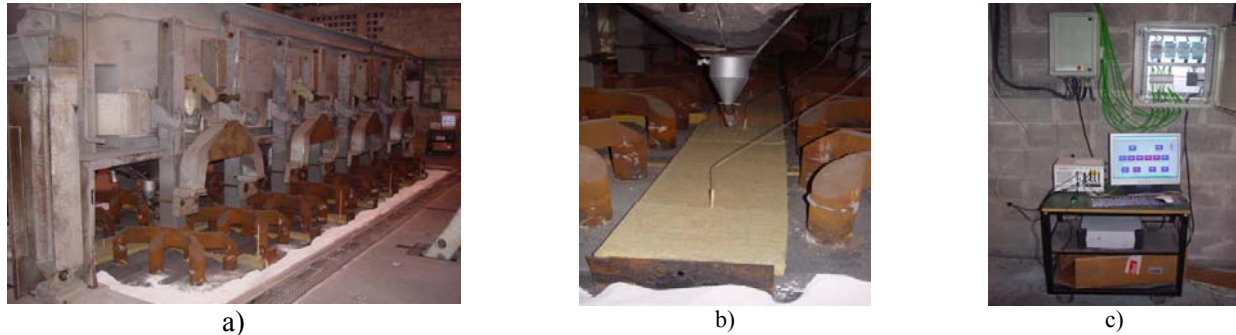


Figure 7. Thermocouples on side (a), on central channel (b) of pot and measuring system and data processing (c).

2.4. Restart of partially relined pot

The restart of a partially relined pot must be carried out controlled and with the prescribed protocol. First, the shut down of the pot with the next sequences must be done:

- ◆ At the shut down all aluminum in the pot must be tapped,
- ◆ In the pot approximately 3 cm electrolyte should remain to protect cathode against humidity,
- ◆ Anode bus bars after shut down are raised, but 24 hours after shut down, they must be lowered to the lowest point (healing),
- ◆ All cracks in central channel should be covered with crushed bath to protect cathode against humidity
- ◆ Until complete cooling of the pot, the anode cover must be checked.

Before restart of partially relined pot, anode and anode superstructure should be removed. In the next phase the cleaning of the cathode follows. If the anode bus bars are too damaged, it is necessary to repair them; if not, the grinding of contact surface is sufficient. Then cryolite and eventually the aluminum plate must be removed. This must be done very carefully, to prevent damage on cathode, frozen ledge and on ramming ledge. For better electrical contact between the cathode and the coke bed, it is necessary to remove oxide from the cathode surface (Figure 8.a).

Before placing anodes on the cathode, under each anode a coke bed must be installed (Figure 8.b). Also verticality of anode bars must be checked. Anodes are covered with cryolite, similar as at the general relined pot. Preheating of the pots is carried out similarly as at the general relined pots (described in 2.3). Preheating time is usual shorter because of higher cathode resistivity and thicker coke bed and depends of cathode age at shut down. Preheating time amounts between 36 to 45 hours. Procedure of start up is similar to the procedure for general relined pots (Figure 8.c).

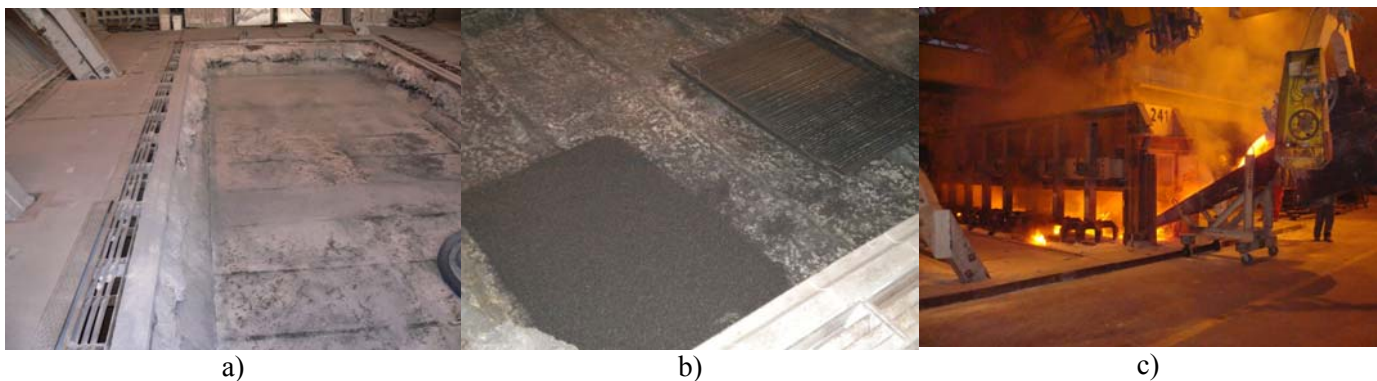


Figure 8. Cleaning of cathode (a), coke bed (b) and start up (c) of the partially relined pot.

2.5. Metal treatment with TAC and ACS

To remove impurities from the aluminium and to ensure high quality of the end products, metal treatment station with the TAC (Treatment of Aluminium in Crucible) and ACS (Aluminium Crucible Skimmer) system was installed during the last year (Figure 9). The TAC is used for sodium, calcium and lithium removal in the crucible. Figure 10, shows that the Na content in the metal decreases during the TAC operation. To remove the bath material and the dross from aluminium an automatic skimmer (ACS) is used.



Figure 9. Metal treatment station.

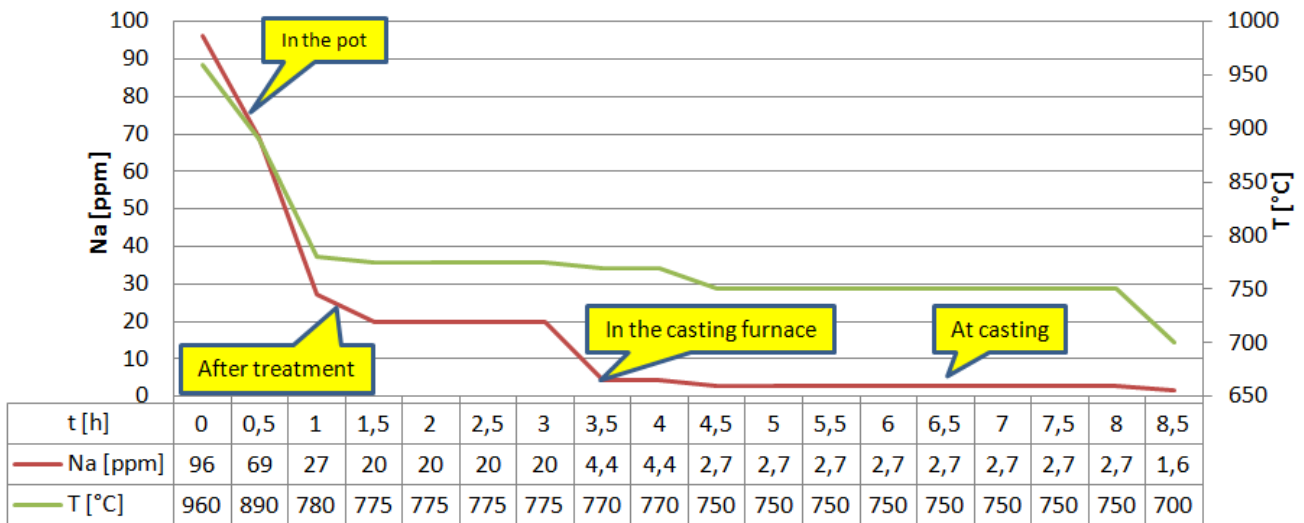


Figure 10. Na content during preparing of the metal.

3. Technical results and discussion

3.1. Total production

Figure 11 presents the yearly production of TALUM AP18 potline. Production was increased during the observed period by a current increase. In the year 2002, the production doubled due to start up of additional 80 cells. The only period with production output decreasing was in 1996 due to energy crisis in Slovenia and in 2009 because of the world economic crisis, when half of the potline was stopped.

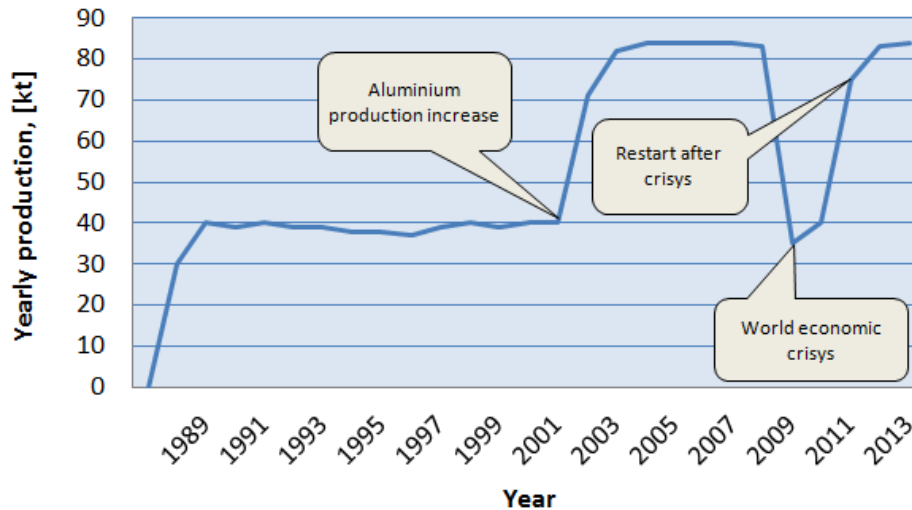


Figure 11. Annual production of AP18 potline in TALUM.

3.2. Potline current

The historical events in our new country influenced potline current. In 1991, the former Yugoslav electrical grid was reduced due to civil war and therefore TALUM optimized potline operation to minimum energy consumption by lowering potline current. Continuous increasing of the potline current was taking place during the last decade. An important increase of current from 177.1 kA in 1992 to 189.1 kA in 2006 resulted from the continuous improvement program. Current increase from 1988 until today is shown in Figure 12.



Figure 12. Potline current increase.

3.3. Current efficiency

Increasing the current efficiency to maximum makes requires to drive the process continuously to the limit. Optimization of operational parameters, improvement of cathode design, optimization of process control system and application of slotted anodes as well as the improvement of anode quality resulted in average current efficiency of 96.3 % during the last five years. Figure 12 shows the factors that influenced the current efficiency.

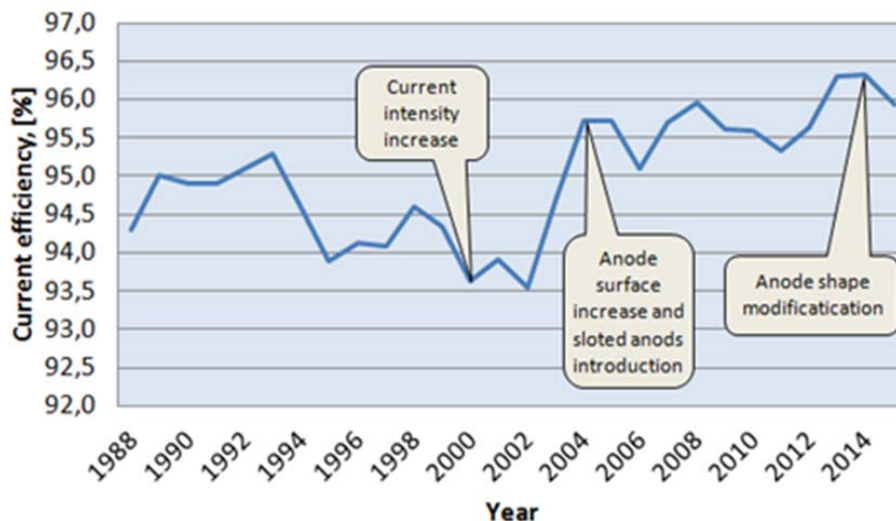


Figure 13: Current efficiency with important factors for the increase.

3.4. Pot stability

Pot stability improved with the anode shape modification. The instability of the pot decreased from 0.115 $\mu\Omega$ to 0.085 $\mu\Omega$ (Figure 14). Also energy consumption savings are significant.

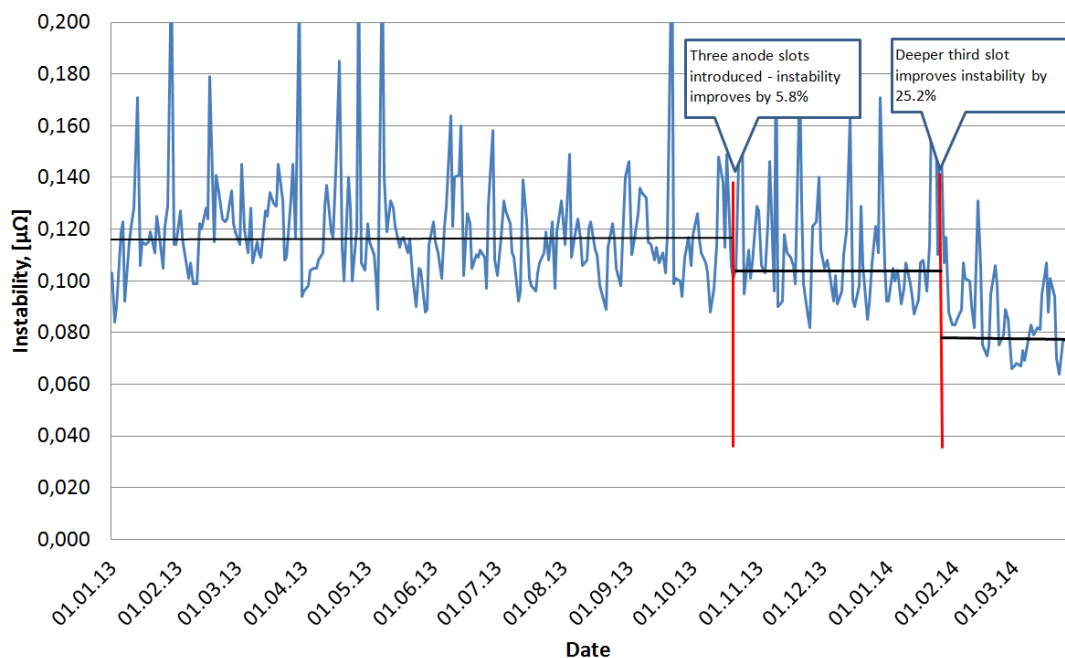


Figure 14. Pot instability improvements due to anode slots.

3.5. Pot life

With all technical improvements, the average pot life was increased to more than 3 500 days (Figure 15) in spite of the introduction of graphitized cathodes in the year 2003. The most significant factors that have influenced the pot life increase are:

- ◆ Application of validated cathode materials,
- ◆ Consistent implementation and supervision of all phases of cathode relining,
- ◆ Stable pot operation.

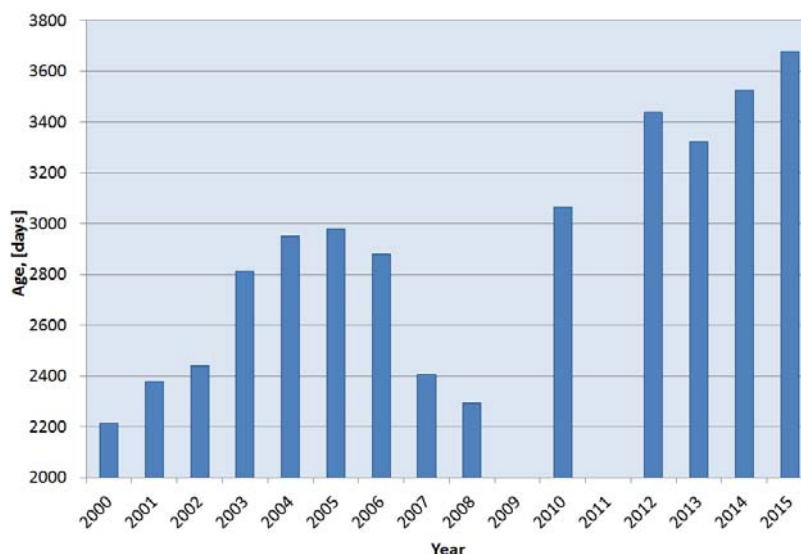


Figure 15. Age of TALUM AP18 pots at cut-out.

3.6. Metal purity

With the installation of the metal treatment station for primary aluminium the big step toward for high quality aluminium product was achieved. Significant decrease of Na, Li and Ca content in primary aluminium were achieved. Figure 16 shows Na content results of primary aluminium before and after the treatment. The content of Na in aluminium was decreased from 90 - 100 ppm to 3 - 13 ppm on the average.

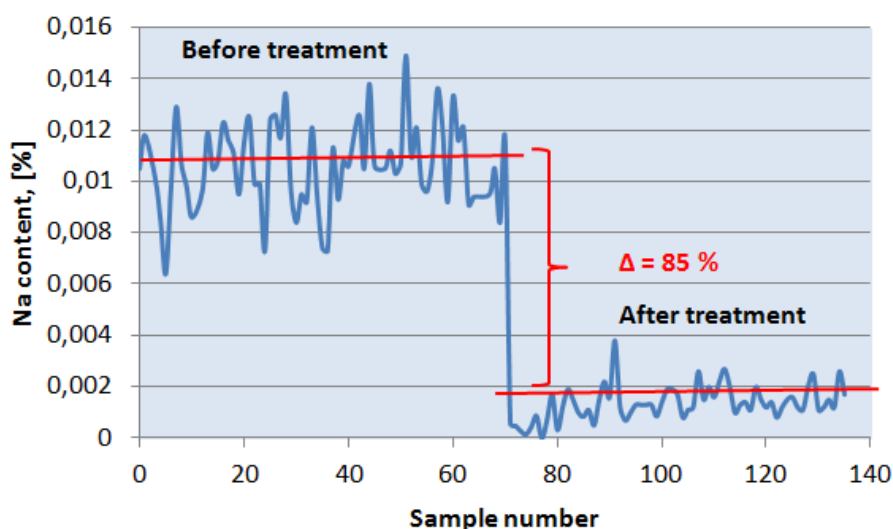


Figure 16. Na content before and after treatment.

4. Summary

During the last 25 years, with the implementation of many innovations and continuous improvement, TALUM established one of the most efficient productions of primary aluminium worldwide in energy consumption, carbon consumption and pot life. Most important improvements in recent years are the prolonging of pot life to more than 3 500 days and the carbon net consumption of 392 kg C/t Al. With the innovative shape modification of the anode a decrease of pot instability of more than 20 % was achieved. The new innovative anode shape also decreases energy consumption by 50 - 100 kWh/t Al. With the metal treatment station for primary aluminium, we ensure high aluminium purity for production of high quality aluminium products. Content of Na, Ca and Li in aluminium is decreased to a minimum.

Our efforts in the future will be focused on higher levels of automatization and will include controls with expert knowledge. Further improvements of particular production lines are possible, especially transport of anode paste from mixer to vibro-compactor. Also optimization of anode shaping processes is possible.

A lot of effort is made to improve the heat distribution inside the baking furnace. Over-bending of anode baking furnace heating walls with negative impact on baking quality and costs, is still an unsolved problem.

The highest quality is not our highest priority. Our goal is an optimal balanced combination between technical, quality and economical parameters. Our challenges in the future are the increase of potline current for increased productivity (while keeping the same technical parameters) and improved supervision of all processes in the potline.

5. References

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