It was at the St. Petersburg International Economic Forum in May 2018, within the presentation of European Technology for the New Quality of Life, when the Italian company T.T. Tomorrow Technology demonstrated the anodes slotting technology as an important way to improve energy efficiency and environment safeguard in the primary aluminium production.

The aluminium industry attaches great importance not only to increase productivity and reduce costs but also to improve environmental protection and preservation. The reduction of the carbon footprint throughout the entire aluminium production chain is therefore an indispensable requirement for the metal producers.

The general economic conditions for further growth in aluminium demand and the recent rise in aluminium prices are very active drivers for increasing aluminium production. The increase in efficiency in the metal production process meets the need to reduce production costs while protecting and preserving the environment.

Recent reports show a decrease in the carbon intensity of primary aluminium production. Europe is leading the way in reducing CO₂ emissions from its primary production. A higher global average carbon intensity in primary aluminium production and peaks in local countries (such as China) underline the need to take further action to reduce the environmental impact, as all major aluminium producers appear to be committed.

**Slotted anodes technology**

Slotted anodes have been used by smelters requiring large-size anodes. Being inter-anode separations, slots can be regarded acting as expansion gaps in order to safely absorb the thermal expansions. The slots help to reduce the thermal stresses in the anodes and thus reduce the risk of cracking.

The approach to slots cut in the bottom surface of the anodes is nowadays changed and becoming extremely important, as they provide effective ways of escaping the gas formed continuously during the aluminium reduction process, thereby reducing the accumulation of gas bubbles under the anodes. As a direct result, the use of slots in the anodes allows the electrical cell resistance to be reduced and cell stability to be improved. Slots in the anodes therefore lead to reduced electrical power consumption for aluminium production.

Slots are preferably cut into baked anodes by automatic anodes slotting machines, which (due to density, quality and scrap increase issues) is more effective than forming them in the green phase of the carbon block before baking. In automatic mode, one or two slots are cut in each anode (depending on anodes dimensions) by rotating blades to a depth of up to 450 mm and a thickness of 12,10 and 8 mm respectively with variable shapes.

The carbon material removed from the anodes during the cutting of slots is completely recovered by the transport and aspiration systems after the anode slotting machines and returned to the raw material silos or the green mill.

Cutting slots with reduced width reduces the amount of carbon removed from anodes when cutting slots. Narrow slots improve the specific aluminium production per anode and extend the cycle time of the anodes.

The depth of the slots is important to ensure that the benefits will continue throughout the life of the anodes (‘full life slots’), while the slot shape, which determines the gas exit direction and related areas of influence, is also important to achieve further benefits in pot management.

**Slots cut in baked anodes**

T.T. Tomorrow Technology, a leading engineering and production company based in Italy, has acquired special expertise in anode cutting / slotting technology. The latest generation of automatic anode slotting machines confirms references and values of the main operational advantages resulting from the use of slotted anodes in the aluminium reduction process. The main advantages obtained by using slotted anodes in the electrolysis cells are:

- Reduced voltage drop (up to 80-100 mV decrease)
- Increased pot stability
- Better alumina dissolution
- Improved current efficiency.

The major advantages that are achieved by the use of slot anodes with direct effects on the economic efficiency of the aluminium smelter are:

- Energy savings
- Increased production by increasing line current, since the saved energy is used to raise the line current to produce extra aluminium
- Operation impacts
- Safety and environmental benefits.

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Anode Slots Cutting Machines

Advanced anodes slotting machines to cut deep, straight, inclined and interrupted slots.

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As mentioned above, the depth of the slot is important to ensure that the benefits can last for the entire life of the anode (full life slots). Slot shapes are important for further pot management benefits as they control the gas exit direction and associated area of influence. The latest generation of anode slotting machines can cut slots to a depth of 450 mm.

The ability to reduce the slot width also has an important impact on the economy and management of potrooms. The latest generation of anode slotting machines works to cut slots with thicknesses of 12, 10 and 8 mm. Since the weight of the carbon lost during anodes slotting depends on the blade thickness, the impact on cell performance and management is significant in favour of slots cut with thinner blades that reduce carbon loss during slotting the anodes.

Narrow slots allow a higher specific aluminium production per anode to be achieved and the cycle time of the anodes to be extended.

Fig. 2 shows the actual geometric parameters of the slots in baked anodes as achieved by the latest generation of anode slotting machines.

T.T. Tomorrow Technology’s patented Two-Axis Dynamic Groove Cutting, which is applied to the automatic slots cutting machine, allows the cutting of different slot profiles to achieve the required preferred gas exit direction and associated pot management benefits.

Special considerations apply to the conditions of interrupted slots in the pot with the gas exit direction towards the centre of the pot.

Interrupted slots are a means to facilitate gas bubbles moving rapidly to the centreline of the reduction cell to expedite the dissolution of alumina. At the same time, the slots allow to operate the pots with less pot noise and reduced pot voltage, resulting in lower power consumption and higher current efficiency.

As is well known, alumina is fed into the bath during cell operation, and it is important to have a good alumina solution. The anode gas released during electrolysis can be used to create turbulence in the alumina feed zone that supports dissolution and reduces alumina agglomeration.

For these reasons the interrupted slots are cut in the anodes in such a manner that the flow gas is directed to the centreline of the reduction cell to expedite the dissolution of alumina. Facilitating the gas flow towards the centre of the reduction cell provides operational benefits while increasing efficiencies.

In addition, conveying gas in the centre of the pots results in less erosion of the side walls of the reduction cell, which extends the life of the cell. In a pot using anodes without slots, the gas flow from the anode through the low-resistant liquid bath is almost uncontrolled. Typically this can lead to dangerous conditions on the side walls of the pot, change the thermal balance and disturbing the side ledge.

In addition to the economic benefits of an increased aluminium production – resulting directly from the reduced ACD spacing – smelters using anode slots cutting machines confirm that the slots also bring the following operational improvements:

- Increased pot stability
- Improved current efficiency
- Better alumina dissolution
- Reduced (almost eliminated) number of anode effects (thus limitation of harsh
environment and risk operations)
• reduction of greenhouses gases and CO₂ emissions.

**Future scenario in application of anodes slotting technology**

The implementation of anode slotting projects represents investments with short payback periods. Shortened delivery times from order placement to the start of production at the customer’s site speed up the start of the economic benefits. It is easy to simulate the economic results of using slot anodes. Typical amortization calculations for the implementation of a new anode slotting line in smelters with an aluminium production capacity in the range of 250,000 to 300,000 tonnes per year show a payback between 7 and 12 months.

With the latest generation of anode slotting machines, it is now possible to cut slots in baked anodes up to 450 mm deep and only 8 mm wide.

Fig. 3 shows of the latest-generation anode slotting machine cutting slots 450 mm in height and 8 mm in width.

The possibility of cutting baked anodes with deeper and narrower slots (450 mm depth and 8 mm width) also opens up new scenarios and new investment opportunities justified by high economic returns.

Several calculations of the return on investment and the payback period of the investments for new anode slotting machines to replace previous slotting equipment (even if they are still under working conditions) prove the high profitability of choosing to modernize or renew old equipment.

The price-increasing trend of aluminium at the LME increases the economic return on the above-mentioned investments.

Fig. 4 shows anodes with deep and narrow slots before and after use in the pot.

**Conclusions**

The short payback period begins after a short delivery time and smooth implementation, where T.T.’s latest generation of automatic anode slot machines is in operation.

In baked anodes up to 450 mm deep and 12, 10 or 8 mm wide, slots are successfully cut.

In addition to the very high economic benefits of increased aluminium production, smelters using anode slot cutting machines gain further operational advantages.

The implementation of anode slotting technology pays off within a short period of time, even for smelters with lower production capacity. It leads to an increase in production capacity and minimizes production costs; it is important for the conservation of energy resources and leads to a reduction in environmental pollution.

The ability to cut slots with an interrupted profile (to direct released gas to the centre of the pots), to increase slot depth and to reduce width, justifies new investments not only where an anode slotting machine is not yet in operation, but also where old slotting machines already in operation are being replaced.

The evaluation of the investments, which take into account the benefits of deeper and narrower slots, shows a high profitability even when renewing existing equipment in operation at lower performance levels and with limited characteristics.

Fig. 4: Slotted anodes at end of life and before being put in operation