Trends and development of slotted anodes

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Historically, aluminium producers have been using slotted anodes for smelter technologies that require large size anodes. These slots help to reduce the thermal stresses in the anodes, and thus to reduce the risk of cracking, and also help the gas bubbles to escape from the anode bottom surface. Today slotted anodes are widely used also in smelters with midsize anodes.

The major benefits of using slotted anodes are that they reduce cell resistance and improve cell stability. The right depth of the slots is important so as to ensure that these benefits last throughout the entire life of the anodes (full-life slots), while slot shape, which determines the gas escape direction and related factors, is also important to achieve benefits in pot management.

Smelters using slotted anodes report savings between 0.11 and 0.17 kWh/kg of aluminium produced. If the energy saved is used to produce additional metal units, production increases from 1,1 to 1,7%.

T.T. Tomorrow Technology is a world leader in anode slotting technology, with a long record of references in manufacturing equipment for slotting anodes. In-house R&D and long experience in the design and production of dedicated equipment for anodes processing have formed the basis for developing the latest generation of automatic slot-cutting machines.

In the last ten years the company has supplied and successfully commissioned several anode slotting lines. Each of them achieved a short payback time after a short supply lead time between the contract award and the start of production at the client site.

The role of slots

The growth of the aluminium industry in the last decades has been extraordinary. By using of the best available technologies the industry gained strategic advantages, so ensuring a better use of production capacity and energy resources. To achieve optimum electrical performance in the cells, anodes play a very important role; anode dimensions and their physical characteristics are both the strength and the weakness at the same time.

New greenfield smelters with up-to-date design and technology as well as old smelters in operation since long time are both often affected by major structural constraints. Both are applying slotted anode technology to enhance performance and to achieve economic and production improvements.

As is well known, carbon anodes are produced by mixing, forming and baking calcined petroleum coke and pitch. Anode dimensions are extremely important to enhance productivity of the cells; anode density is important to achieve proper production performance and efficiency. Increasing the anode dimensions is therefore a common path, which unfortunately can lead to increased pot resistance due to the accumulation of gas bubbles underneath bottom surface. Anodes with lower or non-uniform density penalize production and economics of smelter electrolysis. The slots cut in the bottom surface of the anodes provide an effective escape passage for gas bubbles which are continuously formed during the reduction process.

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450 mm deep slots cut in baked anodes

Comparison of formed slots vs. cut slots

Traditionally there are two methods of introducing slots into anodes:

- Forming the slots in the green anodes by mean of special moulds in the anode vibro compactor or press;
- Cutting slots in the anodes after the baking process.

The first method – while only apparently cheaper – results in increased waste of anodes for unsatisfactory quality before they even reach the cells. They suffer from the intrinsic limits in dimensions: these relatively short and wide slots reduce current density and they suffer from limited slot life in the cells. Less effective pressing also causes lower and non-homogeneous bulk physical properties.

The second method (i.e. cutting slots in the anodes after the baking process) allows overcome these limits of the slots formed in the green anodes.

Often anode slotting machines have been installed where previously slots were formed in the green anodes; comparing with slots cut in baked anodes we note the following key differences, see Table 1.

It is easy to calculate how the weight of carbon lost with slots formed in green anodes is much higher than carbon lost when anodes are slotted after baking. If we compare the same slot heights, then the carbon lost when slots are formed at the green phase may be up to three times the amount which is lost by cutting slots in baked anodes. The impact on cell performance and management is therefore considerably in favour of slots cut in baked anodes, which furthermore do not suffer any density problems.

Slots cut in baked anodes help reduce carbon consump-

Table 1: Slots formed in green anodes versus slots cut in baked anodes

	Slots formed in green anodes (typical)	Slots cut in baked anodes
Orientation	Tied to anodes exit direction from the mold	No limitation
Slot width	25 - 40 mm (at base) to 10 - 20 mm (at top)	12 - 10 - 8 mm (constant)
Slot height	150 - 300 mm	Up to 450 mm
Anode density	Not homogeneous (affected by friction on plates to form slots), lower	Higher, homogeneous (not affected by slots)

tion, if compared with anodes slotted while green, since they avoid the typical disadvantages of lower and non-uniform density in slotted green anodes; also CO and CO_2 attack is higher in slotted green anodes due to the reduced apparent density and to the increased air permeability.

Advantages from slots cut in baked anodes, importance of depth and thickness

T.T. Tomorrow Technology has achieved accumulated much know-how in manufacturing anode cutting / slotting equipment. Internal R&D, together with long experience in designing and manufacturing dedicated equipment for cutting and slotting anodes, and for the handling in the carbon area, formed the basis to develop the latest generation of automatic slots cutting machines.

All the anode slotting lines designed and supplied by T.T. Tomorrow Technology represent investments with short payback times for the customers. Reduced supply lead-time from the contract award to the commencement of the production at client sites means that the economic advantages start even sooner.

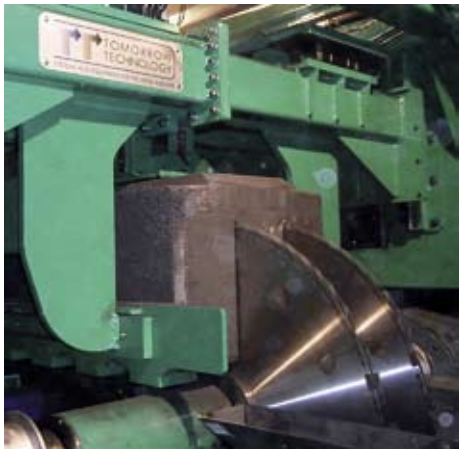
It is easy to forecast the economic benefits coming from the use of slotted anodes.

Typical payback calculations for the implementation of a new anode slotting line, even in smelters with production capacity in the range of 250,000 to 300,000 tonnes per year of aluminium, show pay back between 7 and 12 months.

Since short pay back times (i.e. less than one year) are usually more difficult to realize at 'small' production capacities, the results above represent a very profitable investment, also for smelters whose production capacity is not so big. Smelters with bigger production enjoy further positive scale factors.

As mentioned, the main economic benefits a smelter obtains from using slotted anodes are:

- Energy savings ranging from 0.11 to 0.17 kWh/kg of aluminium produced
- Increased production, which may be computed as 1,3 to 1,7% extra aluminium production, by increasing line current while keeping the original voltage constant; alternatively, they can use the saved voltage drop to (1) reduce energy costs and (2) increase the current so as to maintain the original energy input, with an intermediate gain in production.



Anodes being cut with two slots 450 mm depth

The amount of improvements achieved can vary depending on some 'plant factors'; among these the anode quality and related proprieties play an important role. Nevertheless, the slot height has a direct impact on specific benefits, since their total benefit depends directly on the slot height.

This is the crucial difference for smelters when moving from the (short and wide) slots formed in the green anodes to the higher and narrower slots cut after anodes are baked.

The recognized benchmark is now to have slots whose height prolongs their positive effects during the entire anode life.

Slot width (often called 'thickness') is, as a matter of fact, a measure of the carbon 'lost' (i.e. not going to the pots). Reducing the of slot width (or thickness), therefore, maximizes productivity in the cells.

It is now possible to cut slots in baked anodes up to 450 mm deep and only 8 mm wide.

In addition to the economic benefits directly resulting from the reduced ACD distance, smelters using anode slot cutting machines report that the slots give also the following operation improvements: improved current efficiency, better alumina dissolution and reduced (almost eliminated) number of anode effects.

Industrial background

Management of the coarse carbon and dust coming from the slotting machine is a requirement that may become an additional strength of this technology.

Integrated management and recovery of coarse carbon and dust is a typical extension of the anode slotting lines designed and manufactured by T.T. Tomorrow Technology. Proprietary design and dedicated solutions maximize the value of recovered material and optimize the benefits from recovered carbon.

Anodes slotting machine with safety fence

This coarse carbon and fines recovered from the slotting saw is high value material, to be collected and delivered to the raw material warehouse.

Anode input materials are typically calcined petroleum coke, pitch and recycled material from baked anodes. This last component usually comes from recycled anode butts that have not been consumed in the reduction process. Unfortunately these butts are contaminated with undesirable elements adsorbed with cryolite bath from the pot. By contrast, when using carbon collected from the anode slotting saw is utilized, it is pure, with the best composition.

Proprietary and dedicated solutions for the maintenance and management of the anode slotting machines help to reduce the downtime and to minimize the time for services and ordinary maintenance, making the

operators activities easier and safer.

As usual, after having decided and approved any investment, the lead-time to have it in operation is always critical. This has been properly considered by T.T. Tomorrow Technology where, as standard way of operating, the automatic slot cutting machines are fully pre-assembled as well as fully tested in operation in our factory, using anodes supplied by client. This ensures fine tuning of operational performance and allows the customer to test accept the machine in the supplier workshop before delivery.

This strategy reduces the installation, commissioning and start-up time and related costs at the customer's site, and so ensures smooth and fast commissioning and trouble-free delivery. Once equipment is successfully tested at the T.T. workshop, goods are prepared for shipment and delivered to the client's site.

Conclusions

With the latest generation of automatic anodes slotting machines, short payback time starts quickly after short delivery time and smooth implementation.

Slots are successfully cut on an industrial scale in baked anodes up to 450 mm deep and 12, 10 or 8 mm wide.

In addition to the very high economic benefits which directly result from the reduced ACD distance, smelters using anode slot cutting machines also gain further operational advantages.

The implementation of anode slotting technology allows short payback times, even for smelters with smaller production capacity. It increases production capacity and minimizes production costs. While safeguarding energy resources, it reduces environmental impact by reducing of greenhouses gases and CO_2 emissions.

Author

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