Light Metals 2015
Edited by: Margaret Hyland
TMS (The Minerals, Metals & Materials Society), 2015

BATH TREATMENT PLANT PROCESS AND TECHNOLOGY TRENDS

Christophe Bouché[1], Romuald Daligaux[1], Hervé Hite-Pratt[1], André Pinoncely[1]

[1]Fives Solios SA, 32 rue Fleury Neuvesel, BP24, 69702 Givors Cedex, France

Keywords: Reduction, Bath, Grinding, Cooling, Recycling

Abstract

This paper will review the process and technology trends in bath treatment plants. Indeed, over the past 10 years, potline needs have evolved from fine bath towards coarse bath product size, leading to the introduction of new milling technologies. Moreover, due to more stringent environmental constraints, hot bath continuous cooling processes are nowadays frequently required. As an illustration of these trends, two recent references in the Middle East will be presented: one 62 tph cold bath treatment plant featured with a gravity discharge autogenous mill and one 40 tph hot bath treatment plant featured with an apron cooling conveyor.

Introduction

Nowadays, it is widely recognised that as the bath material is continuously recycled into the pots, the performance of the bath recycling process is also a key factor for an optimum potline operation.

Indeed, as mentioned in [1], the anode cover material (ACM) is one of the largest material flows in an aluminium smelter with nearly 400 kg/tAl and with critical functions like:

- Protection of the anode from airburn and partially to CO_2 oxidation,
- Thermal insulation of the pot,
- Capturing fluorides emissions,
- Balance of bath content in the electrolytic reduction cell.

The high level of expectations from such recycling processes in modern smelters using prebaked anodes have been summarised in previous publications [2, 5]:

- To accept various feeding sources of particularly inconsistent nature, hardness and lump sizes,
- To sort metallic scrap and other rubbish content from the bath material without damage on the equipment,
- To crush the bath material at a given production rate,
- To handle the crushed bath material up to the storage silo(s),
- To ensure all the above operations occur safely without any dust emission,
- To minimise operating costs, by running in automatic mode with minimised maintenance work,
- And of course, to deliver a final high quality product with specifications which fit the critical functions of the ACM.

On top of that, due to more stringent environmental constraints and the constant search for lower CAPEX/OPEX, the bath recycling unit started to process hot feed material with the objective of speeding up the cooling and thus reducing significantly the fluorides emissions. The introduction of a hot bath cooling stage in the recycling process has also had an impact on the crushing process design itself.

Crushed Bath Particle Size Distribution (PSD)

The number one specification to be fulfilled by the crushed bath is the particle size distribution. The particle size distribution is a key quality related parameter as it influences [1]:

- The cell heat balance through the thermal conductivity (Figure 1),
- The stability of the ACM on the anode through the angle of repose,
- The liquid bath level through its ability to melt in the cell.

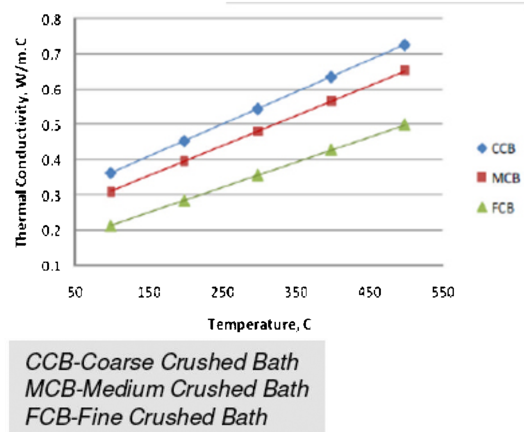

Figure 1 – Thermal Crushed Bath Conductivity vs Size Distribution [1]

Fives have been a major player in this field of the industry with technologies covering the whole range of crushed product specifications and with references including all types of crushing processes like:

- The old conventional circuit with a series of hammer and/or roll crushers and screening stages,
- The "best-seller" air swept autogenous mills,
- And more recently the gravity discharge autogenous mill-based circuit to produce a much coarser ACM.

The particle size distribution (PSD) specifications asked by potlines have been fluctuating within a wide range for the past 30 years, as shown in Figure 2. For instance the percentage retained at 3 mm mesh ranges from 5% to more than 50%. However, in recent years, it seems that the need for a much coarser PSD has been more frequent which forced the technology to shift from the air swept autogenous mill towards the gravity discharge autogenous mill. Indeed, the air swept autogenous mill, which was recognized as the most suitable technology overall, cannot match the coarser PSD requirements, even with an enhanced higher air flow and pre-screening,

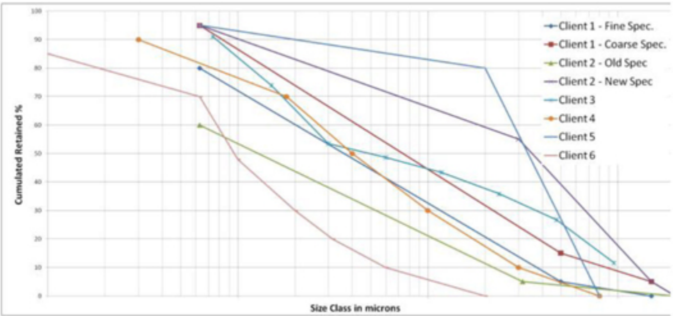

Figure 2 – Crushed Bath PSD Client Specifications received by Fives over the past 30 years

Coarse Bath Production Reference

Fives most recent reference in the field of Coarse Bath production is for a cold bath treatment plant of 62 tph, fed with bath ranging from 0 to 400 mm. The required crushed bath PSD was very coarse and the gravity discharge autogenous mill (GDAM) technology was therefore selected.

Though both GDAM and air swept AG Mill are based on the same autogenous grinding principles, they differ in the way the ground product is discharged.

In an air swept AG Mill, the finer ground particles are discharged through the outlet mill trunnion and transported by the air flow passing through the mill. The final PSD of the ground material is therefore mostly controlled by this air flow.

In a GDAM, the finer particles simply pass through the mesh of the peripheral screening area of the mill (Figure 3) and the final PSD is mostly controlled by the size of the mesh.

Figure 3 – Gravity Discharge Autogenous Mill – Peripheral screening

This difference has a strong impact on the internal classification and internal recycling. When it comes to circuit design, it is necessary to model these differences in other to correctly assess their impact on the external recycling flow of the oversize particles. This is why full steady state simulations are used to validate the design and the global performance of a circuit. For this reference a specific population balance model (Figure 4) was built and calibrated (material breakage rate, breakage distribution and classification matrices) based on our previous knowledge of bath crushing behaviour.

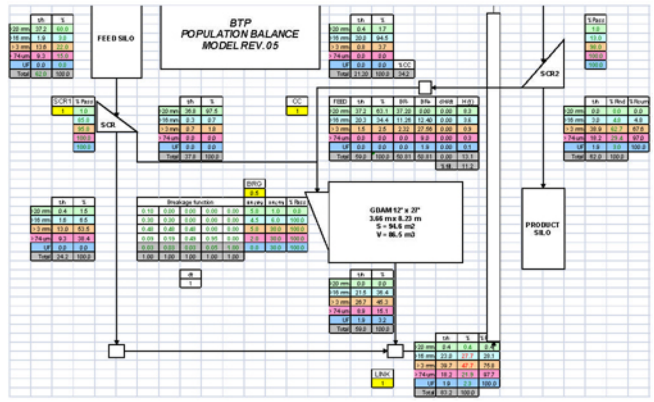

Figure 4 – GDAM Bath Treatment Plant Population Balance Model of the whole Circuit

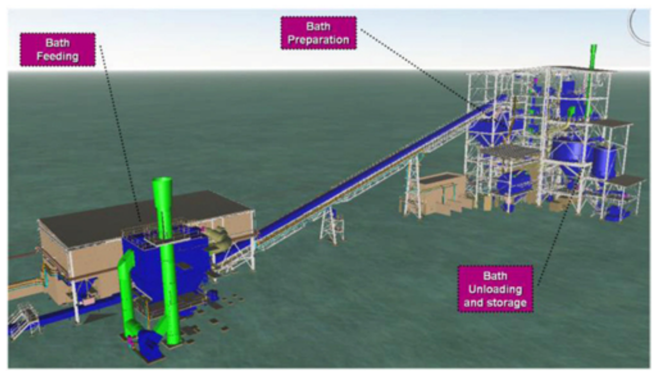

Figure 5 – Birds-eye View of the Cold Bath Treatment Plant with GDAM

Figure 5 shows an overview of the plant design, with cold bath coming either directly on a conveyor belt from the butts cleaning machines located in the rodding shop, or from a storage area where the bath is fed by a loader on a 400x400 mm grizzly feeder. The plant processes standard and pure bath during separate campaigns. To avoid over-grinding and reduce the percentage below 75 µm, the standard bath is pre-screened to send particles greater than 20 mm to the grinding unit. The grinding unit is a 12’ diameter GDAM (Figure 6) running in a closed circuit. The ground product is finally passed through a 20 mm mesh vibrating screen and the final product is stored in a 600 tonne silo. The +20 mm product is recycled back through the GDAM. The pure bath goes through the same process (except pre-screening) and is stored in a 200 tonne silo.

The process is fully automated including a GDAM cleaning sequence to remove scrap material like carbon, aluminium chips and others which get accumulated during the grinding stage. This sequence is triggered when the GDAM power draw exceeds a given limit indicating that the volumetric filling of the mill has become critical.

The de-dusting network maintains the whole circuit under negative pressure. Dust emission at the stack is below 10 mg/Nm^3 (measured as per US EPA Method 5).

The main sources of noise like the GDAM, are noise insulated to guarantee a noise level below 85 dB(A) as shown in Figure 6.

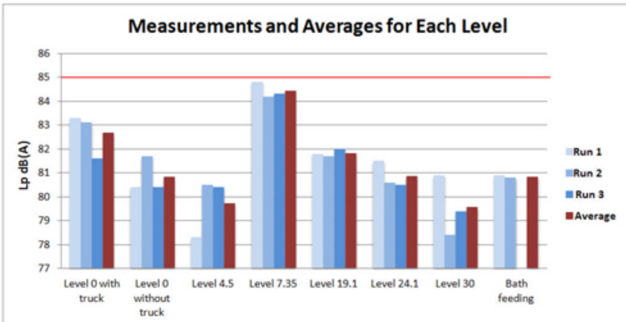

Figure 6 – Noise Level Records for each Floor Level from Performance Test at Site.

As already mentioned, one of the main characteristics of this circuit is to produce crushed bath with a coarse PSD. Table I shows the crushed bath PSD over almost 2 years of operation. Given the accuracy of the sampling and laboratory analysis, these results are considered to meet specification.

Table I – PSD Results vs Client Specifications

Size Class	Client Specification (% Cum. Ret.)	2 Years Results (% Cum. Ret.) Average	Standard Dev.
SC1 - Coarse	0	0	0
SC2	1	0.4	0.8
SC3	5	5.4	3.3
SC4	55	51.6	7.1
SC5 - Fine	90	91.9	3.5

Finally, the detailed measurement campaigns performed during performance tests (including PSD and Flow Measurements) allowed us to validate the population balance model hypothesis considered at design stage.

Hot Bath Processing Challenge

Modern smelters are designed to drastically improve the fume collection on potlines and therefore more attention is being paid to the fluoride emissions emitted by the bath cover in butts pallets and by the crust shovel bins. These emissions represent roughly 30 % of the residual total HF emission in the smelters with single suction on the pots and up to 50 % with the most recent double suction technology (Figure 7). Reducing those sources of HF emissions is the next major step on the road to fluoride free smelters.

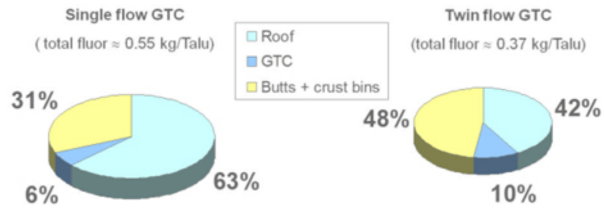

Figure 7 – Typical Fluoride Emission Sources

When cooling down hot bath in open bins, the cryolite is hydrated by the ambient air moisture and generates significant fluoride emissions. HF emissions are very important during the first 10 hours of cooling, still significant up to the 16th hour and almost nil thereafter [3]. When cross-checking those data with the natural cooling curve given in Figure 8, it appears that:

- HF emissions are very important when bath temperature is above 700 °C,
- HF emissions are still significant until bath is cooled down to 550 °C,
- HF emissions are almost nil when bath temperature is below 500 °C.

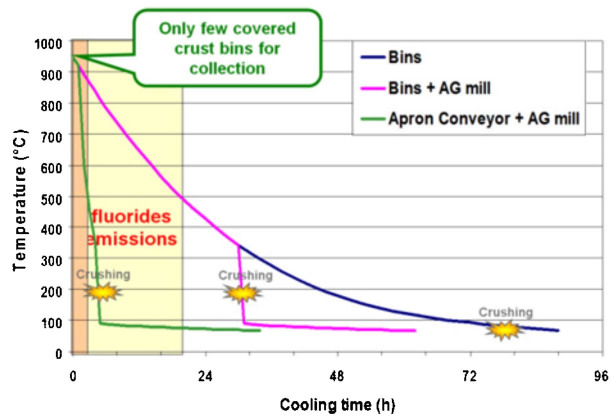

Figure 8 – Bath Temperature over time vs Cooling Technologies [2]

Some smelters choose to inhibit the hydration of the hot crust shovel bath by covering the bins [3]. This appears to be very efficient but increases the cooling time and thus increases the bin inventory and the size of the storage area. This also requires additional handling operations for covering and uncovering the bins, proper sealing between bins and covers and increased maintenance of thesecomponents. Globally it appears to be expensive in terms of operating cost.

Other smelters in Europe have opted for continuous pre-cooling of the hot bath in covered metallic conveyors. The crust bins arriving directly from the potlines at up to 850/900 °C are tilted into a specifically designed pre-crusher delivering a minus 150/200 mm lump size (Figure 9). The pre-crushed product is directly dropped onto a pan conveyor (Figure 10) where cooling is ensured on the bottom and the sides through radiation of the metallic plates in the ambient air, and on the top by direct convection with ambient air. The reduced lump size and the great radiant surface lead to an impressive cooling rate: it takes only about 6 hours to cool the bath material down to 70 °C [4].

Figure 9 – Hot Bath Crusher

The first section of the conveying system where bath is above 500 °C is covered (Figure 10) and kept under negative pressure in order to collect the fluoride fumes. Those fumes are ducted to one of the potline gas treatment centres for dry scrubbing before discharge to the atmosphere.

The final section where bath is below 450/500 °C is not covered in order to maximise the heat exchange with the ambient air.

The pan conveyor runs at very low speeds to operate dust free and act as a movable storage. The conveyor is fitted with a variable speed drive in order to continuously control the bath layer height.

The capital cost of this solution is largely offset by:

- The low maintenance cost,
- The reduction of bin inventory to that only required for filling up and transfer from the potlines to the bath processing shop, without a requirement for a large cooling storage area,
- The corresponding reduction in bin handling and maintenance operations, with associated hazards,
- The possible use of pan conveyors for direct feeding of the mill feeding hopper, without any more required belt conveyors or skip devices,
- The possible use of pan conveyors to cover part of the distance between potlines and the bath crushing unit, and to locate the bin tilting point closer to the potlines: this may allow hot bin transportation to be contained in the immediate vicinity of the potlines with corresponding cost and safety benefits, and to reduce the amount of fluoride emitted during the transfer.

Furthermore, the combination of pre-cooling pan conveyors ahead of a fully air swept AG mill appears as the most optimised solution as it allows a reduction in the cooling requirement by feeding the mill directly at 250 °C instead of typically 80 °C, and a minimised length of pre-cooling conveyor. This is not only attractive in terms of capital cost, but is important when processing high capacities to reduce the length of conveyors for the pre-cooling purpose.

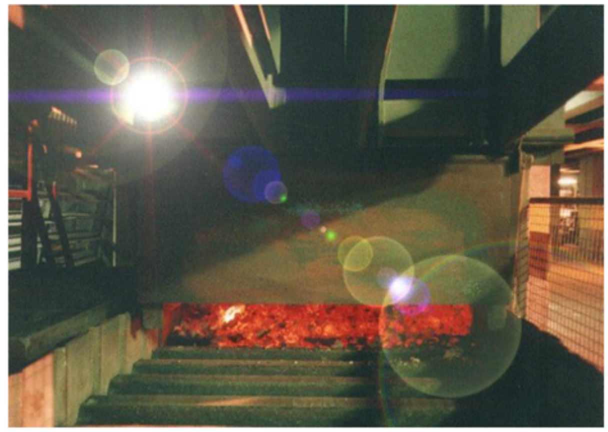

Figure 10 – Cooling Apron Conveyor

Hot Bath Processing Reference

This concept has been applied in our most recent hot bath processing plant reference in the Gulf commissioned in 2009. This plant processes hot bath at a rate of 40 tph with a size ranging from 0 to 400 mm and a temperature up to 700 °C.

The crushed bath PSD required by the client was on the fine side and therefore the grinding circuit was based on an air swept autogenous mill.

Comparing both Birds-eye views of the solutions (Figures 5 and 11), the implantation of the long feeding conveyor looks very similar although they don't have exactly the same functions. In the hot bath processing solution, the function of this conveyor is to transport and at the same time cool down the feed material.

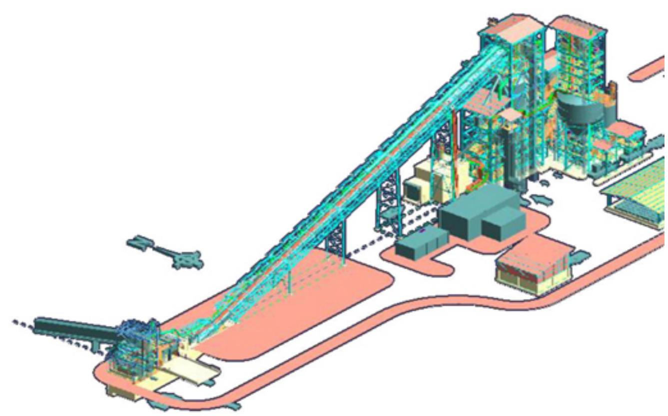

Figure 11 – Birds-eye View of the Hot Bath Treatment Plant with apron conveyor and air swept AG mill

The main two sources of bath are:

- The bin of hot cavity bath (up to 700 °C) loaded on the hot bath crusher at a rate up to 9 tph,
- The hot bath coming from the butts cleaning directly loaded on a cooling apron conveyor (Figure 10) at a rate up to 21 tph.

The hot bath crusher discharge goes to the cooling apron conveyor. The speed of the apron conveyor is automatically adjusted to maintain an even and predefined load to guarantee an optimal bath cooling. The conveyor length has been designed to cool the bath from 700 °C down to 200 °C which is below the maximum temperature allowed in the AG Mill feed. The design is done with an in-house material and thermal balance model which takes into account:

- Characteristics of the conveyor (length, width & speed),
- Properties of the material to be cooled (Heat capacity, PSD),
- Some hypotheses to estimate the global exchange surface and the free convection heat transfer coefficients.

Due to the air flow in the AG Mill (Figure 12), the bath is further cooled down to reach a temperature below 90 °C which is the maximum temperature that the downstream silo devices can withstand.

Figure 12 – Air Swept AG Mill Feed end

In this reference standard and pure bath are processed during separate campaigns and stored in separate storage silos of 1000 tonne and 200 tonne respectively.

Conclusion: What Are the Next Technical Challenges?

It is uncertain whether there is consensus with major primary aluminium producers on the ACM PSD specification (Coarser vs Finer) or on the overall benefit of Hot bath vs Cold bath treatment.

However, Fives bath treatment plant references in that field indicate that there are proven technologies to meet all the required specifications. So what are the next technical challenges?

On both applications described in this paper, there is at least a need to guarantee that the PSD specifications are met at any time. This implies that the following will be required:

- Better crushed product PSD monitoring,
- Better feed material control (garbage in / garbage out) including detection of oversize material (like carbon blocks),
- and probably more advanced control systems to continuously and in real-time adapt process parameters to changes in the feed characteristics.

References

[1] Odd Einar Frosta, “Anode Cover Material – Impact on anodes”, 6th Icelandic Rodding Shop Conference (2014), Session 2.2

[2] A.Pinoncely, “20 years of bath recycling using autogenous mills”, Light Metals (2004) 389-393

[3] M. Gendron & G. Massicotte, “Fumes reduction in potroom area by new equipment design”, TMS (2003) - Proceeding of the symposium on Aluminium Reduction – Potroom Operations, held at the 132nd TMS Annual Meeting, San Diego, California, March 2003)

[4] M. Moritz & M. Coopmann, “A new trend for cooling bath material”, Aluminium (vol. 79 - 1/2 jan./feb. 2003) 23 – 25

[5] A. Pinoncely & P. Podda, “Autogenous grinding for bath scraps recycling”, Light Metals (1996) 609-615