INALUM environmentally friendly strategy by reusing spent anode (butt) management

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Abstract. To implement vision 2025, INALUM should pay attention to environment aspect and one of the strategies is reusing waste material resulted after the process which in this case reusing spent anode or well known as anode butt. INALUM produces \( \pm 40,000 \) ton butt/year as accounted to production cost that is classified to spend money. Anode butt has contaminated Cryolite \((\text{Na}_3\text{AlF}_6)\) during the electrolysis process thus changing the quality. To optimize production cost, those butt materials are reusing as raw material to produce anode. Usage of anode butt as technically lead to deleterious anode quality and electrolysis cell performance. Nevertheless, by internal strategy and well operated by INALUM, not significantly impact gained after using anode butt as anode raw material. Butt cleaning process on the Rodding plant plays an important role in butt quality. By through butt cleaner which has 2 compartment rooms that will be passed through to be cleaned. First room is cleaning room and next room is air blow room are able to produce efficient anode butt to be reused as anode raw material. Butt quality produced by butt cleaning system is highly better than typical range and hence anode quality specifically residual reactivity \((\text{RRCO}_2\text{ and RRO}_2)\) still acceptable to INALUM standard. By using 30% butt ratio to produce anode, INALUM can save production cost by \(\pm 180\) USD/Anode and that is huge saving to average anode production \(112,000\) anode/year.

1. Introduction
INALUM is one and only primary aluminum producer in Indonesia which transformed into a State-Owned Company on December 19, 2013, after it was founded on January 6, 1976, a Joint Venture Company between the Government of Indonesia with twelve Japanese investors incorporated in Nippon Asahan Aluminum. On November 27, 2017, SOE’s Holding of Mining Industry was established with its objectives are as follows:

a. Managing resources and reserve domestic
b. Developing downstream industries
c. Become a world-class company (Fortune Global 500)

As INALUM vision 2025 “to become an environmentally friendly foremost global integrated aluminum-based company” hence INALUM not only focus to produce aluminum but also paying attention to the environment and one of those programs through reusing waste material. During aluminum electrolysis always use carbon anodes in their electrolysis cells. Carbon is a reasonably good electrical conductor and more importantly, it can withstand the action of the corrosive fluoride-containing molten electrolyte at about 960\(^\circ\)C.

In aluminum production, there are two basic anode technology usually used namely Prebaked Carbon Anode and Soderberg anode. Prebaked anodes are dominating type now. A typical prebaked anode is made from a mixture of calcined petroleum coke (CPC), coal tar pitch (CTP) and spent anode (hereinafter called by “Butt”) [1]. The prebaked anode, it is not possible to consume the whole anode
during electrolysis due to potential metal contamination problems. The remainder of the anode, called “Butt” is thus recycled by being added to the new anode formulation. Reusing this material eliminates waste material and is economically preferable. Sodium can be present in significant quantities if bath (Na$_3$AlF$_6$) is not properly removed from the recycled butt. This contaminates new anodes. The degree of cleanliness of the butts influences anode physical properties including mechanical strength, air permeability and carboxy reactivity behavior [2].

1.1. Anode production process

Inalum uses prebaked anode technology during aluminum production. A typical anode of such a process is made by mixture CPC (60 – 57%), CTP (13 – 15%) and butt (25 – 30%). Anode manufacturing in INALUM consists of 3 integrated plants (Green, Baking and Rodding plant). Anode paste is produced in a batch mixing plant with currently anode size (1600 mm x 920 mm x 630 mm) that called by large anode generation 4 (LA-4) as described in figure 1. Anode dimension is greatly determined by the amount of line current used during aluminum electrolysis. INALUM operates on 195 – 235 kA.

![Figure 1. INALUM large anode generation 4 (LA-4).](image)

The output of green plant called by Green Block (GB) which is transferred into the Baking plant to be baked. Anode baking process is aiming to enhance physical, mechanical and chemical properties. Anode baking process requires heating anodes up to 1100 ºC to carbonize CTP (serves as a binder). After baked about 15 – 20 days, Baked Block (BB) is discharged and then transferred into the Rodding plant to assembly with anode rod. Besides as anode assembly plant, the Rodding plant also serves as butt cleaning system[3].

1.2. INALUM optimization effort

Based on the last 5 years, anode butt ratio to produce anode has been an upward trend as INALUM effort to reduce waste material (figure 2). This matter will continue to optimize butt ratio consumption by considering anode quality to keep operational excellence.

![Figure 2. Last 5 years reduced metal, anode butt production, butt ratio consumption.](image)
1.3. Anode butt quality
A large amount of solid waste consumption drives INALUM’s vision to become environmentally friendly Aluminum producer. It is well known that high sodium in butts severely affects subsequent anode reactivity, baking furnace refractory life and other consequences. Consequences of inefficient butts cleaning:

- Increase in air and CO2 reactivity.
- Increase of carbon consumption in the electrolysis cell.
- Generation of dusting in pots, upset cell operation and reduce current efficiency.

Anode butt quality is defined as the condition of the spent anode after their removal from a cell. A goodbutt, after cleaning needs to be free of any bath material and have a good residual cross-section.

To be processed successfully in the Green plant, a good butt after cleaning should be free of any bath material as it contains Sodium which is detrimental to anode quality (as it is a strong catalyst that makes the anode very reactive) [4].

The amount of CO2 reactivity is critically influenced by Sodium content. A correlation between Sodium level and Carbon dioxide reactivity directly impact to carbon consumption and energy consumption. Using the below equation [5], such matter can be defined as follows:

\[
\text{RCO}_2 (\%) = 4.0 + \frac{(0.0411 \cdot Na (ppm)+0.101 \cdot Ca (ppm))}{S (\%)}
\]  

Clean and dirty butt are simply classified as presented in table 1. Sodium is strictly becoming concern impurities, meanwhile other parameters only supporting analysis parameters such as Iron and Fluorine level. Iron affects metal purity but can be considered to be an evaluation parameter or not since mostly Iron content contributed by operation in electrolysis cell (not comes from the material). Just like Iron, Fluorine can be considered to be an evaluation parameter or not since fluorine contributes to HF concentration during the electrolysis process. But, since INALUM has a well gas cleaning system and periodical analysis always shows the result is below the threshold value.

| Parameter       | Unit | Good Anodes | Clean Butts | Dirty Butts |
|-----------------|------|-------------|-------------|-------------|
| Sodium          | ppm  | 200         | 500         | 3000        |
| Aluminum        | ppm  | 100         | 200         | 1000        |
| Fluorine        | ppm  | 100         | 700         | 4000        |
| Iron            | ppm  | 300         | 700         | 2000        |
| Ignition Temperature | °C  | 660         | 640         | 600         | 550        |
| CO2 Reactivity  | %    | 15          | 20          | 30          | 40         | 50     |

2. Method
Butt cleaning process on the Rodding plant plays an important role in butt quality. Even though this process mostly through mechanical processing (figure 3), but intensively monitoring specifically butt cleaner should be maintained. Butt cleaner determines whether butt produced in a clean or dirty condition. Either clean or dirty butt is classified based on chemical impurities specifically Sodium content. Clean butt is classified that butt should be not attaching the rest of Cryolite on the surface cause more Cryolite presence meaning more Sodium and other impurities presence on butt material. Inefficient cleaning is really avoided since potential negative effects both anode and pot performance.

Anode butt is unloaded from special vehicle hereinafter called Anode Transport Car (ATC) and sent to Return Crust Removal. After crust is removed from anode butt, it is then next to butt cleaner which has 2 compartment rooms that will be passed through to be cleaned. First room is cleaning room and next room is air blow room. Butt is cleaned physically in cleaning room through blowing out of
shot particles (steel ball Ø 2 mm) and simultaneously butt revolves 3 times. Then, cleaned butt is pushed into air blow room and then surface of butt is blown by air nozzle (figure 4).

Figure 3. Flow chart butt processing system.

Figure 4. Butt cleaner.

3. Result
3.1. Butt quality
Butt cleaning system in INALUM well operated and it is proven by INALUM butt quality compared to worldwide typical range. Sodium and other parameters are within typical range as described on table 2. Referring to those results, anode quality specifically parameter which is affected by Sodium should has been acceptable. Nevertheless, cleaned butt is not always efficient but sometimes inefficient as well as described on figure 6 & 7.

Figure 5. Anode butt (anode changing activity).

Figure 6. Butt after inefficient cleaning with bath remains on the bottom surface.
Table 2. Typical range of anode butts properties [3].

| Impurities  | Unit | Typical Range    | Inalum   |
|------------|------|------------------|----------|
| Sulphur    | %    | 0.8 - 3.0        | 1.15 - 1.90 |
| Vanadium   | ppm  | 30 - 350         | 75 - 160 |
| Nickel     | ppm  | 70 - 220         | 100 - 230 |
| Silicon    | ppm  | 50 - 300         | 30 - 360 |
| Iron       | ppm  | 100 - 1000       | 160 - 1000 |
| Sodium     | ppm  | 200 - 2000       | 75 - 1830 |
| Calcium    | ppm  | 50 - 500         | 25 - 540 |

3.2. Anode quality

Based on INALUM butt quality is highly better than typical range and upward trend of butt usage certainly gives impact to anode quality specifically reactivity (Residual Reactivity CO₂ and O₂). As predicted calculation, higher butt ratio on similar Sodium concentration will elevate Sodium content of anode. As described in figure 6 that RRCO₂ reactivity is getting lower and RRO₂ applies the opposite. Nevertheless, both of parameter are well acceptable since the analysis results still far above to minimum INALUM standard (RRCO₂ and RRO₂ minimum 88%). There is still room to optimize anode butt consumption to reduce waste and optimize production cost.

Figure 8. Butt ratio vs anode residual reactivity.
3.3. Financial benefit
By reusing anode butt, saving production cost is gained. Refer to the amount of produced butt by $\pm$ 40,000 ton and butt is substitute CPC material hence anode butt price equal to CPC price. Anode composition which uses 30% butt ratio can save production cost by $\pm$ 180 USD/Anode and that is huge saving if multiplied to average anode production 112,000 anode/year.

4. Opportunities to optimize anode waste
Since the good result of anode reactivity while using anode butt, currently INALUM tries to increase anode butt ratio consumption to be 33% and still not significant impact to anode until now. In the future, if there is no significant problem hence it may be optimized to a higher anode butt ratio. By supporting a well process approach and INALUM experience $\pm$ 43 years in anode production, hence this is a highly opportunity to optimize anode butt ratio consumption and INALUM real action to become an environmentally friendly foremost global integrated aluminum-based company.

The highly mechanized nature of the rodding room lends itself far better to automation than it does to manual operation. State of the art of butt cleaning process has been commercial with white and black detection that easier to get cleaner anode butt.

5. Conclusion
Spent anode (anode butt) that classified to solid waste material in primary aluminum production has been reused to optimize anode production cost as well as supporting INALUM environmentally friendly. Supported by well-operated during butt cleaning process thus such material can be acceptable to be reused as anode raw material. Anode butt produced by $\pm$ 40,000 ton/year certainly deteriorates anode quality than fully using calcined petroleum coke (CPC) that one of those qualities is anode reactivity. Nevertheless, through a well process approach hence anode reactivity is acceptable and still highly far above INALUM standard (min. 88 %). By using 30% butt ratio to produce anode, a huge saving production cost around $\pm$ 180 USD/Anode becomes a beneficial cost.

Reference
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