

## XINFA Twin 60 tph Rhodax Green Anode Plant - 5 Years Later

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### Abstract

In 2018–19, Xinfa and Fives were commissioning the twin 60 tph Green Anode Plants (GAP) based on the Rhodax process. It was a premiere for such western breakthrough technology in China. These twin GAPs were part of an ambitious brand-new integrated carbon plant from petroleum coke calcination to production of the prebaked anodes feeding 600 kA SAMI technology pot lines.

The start-up and performance of these GAP were presented at ICSOBA in 2021. Xinfa has been operating these plants successfully for more than five years. This paper summarizes the evolution of the performance of this installation, the challenges encountered, and the modifications implemented by Xinfa to maintain the Overall Equipment Effectiveness (OEE) at peak performance and the initial high environmental standards.

**Keywords:** Anode, Rhodax, Xinfa, Fives, Green anode plant

### 1. Introduction

#### 1.1 Xinfa

Founded in 1972, Xinfa group is a modern large-scale enterprise integrating power generation, heat supply, alumina, primary aluminum and aluminum downstream processing industries. Since 2022, Xinfa has also been massively and successfully investing in modern industrial agriculture projects.

Xinfa has an electrolytic aluminum production capacity of more than 4 million tonnes per year based on Chinese high amperage pot technology. This production is distributed over four main sites in the Chinese provinces of Shandong and Xinjiang.

The green anode plant project described in this paper is part of the Aluminum Smelter complex of Chipping city based in Shandong province.

#### 1.2 Fives

With more than 200 years of industrial history, more than 9 000 employees and 100 subsidiaries worldwide, Fives designs and supplies machines, process equipment and production lines for the world's biggest industrial players, in aerospace, automotive and manufacturing industries, cement, energy, logistics, steel, glass and notably in the aluminum sectors.

In the aluminum sector, Fives covers several fields of expertise:

- Carbon with the turnkey supply of green anode plants, crushing recycling units, firing control systems, fume treatment centers, furnace tending assemblies, anode rodding shops, among others equipment and facilities.
- Reduction with gas treatment centers including heat exchangers, pot tending machines, cathode transport cranes, anode changing cranes or beam raising frames, various pot equipment, pot feed and alumina transport systems or Bath treatment plants.

With more than 50 references, the carbon sector flagship is the green anode plant (GAP). It is typically proposed either as turnkey or technology package. For the past 25 years, Fives green anode plant technology has been based on the RHODAX® process.

## 2. Xinfa Aluminium Smelter in Chipping

The twin 60 tph green anode plants were part of a carbon plant project started in 2015. This integrated carbon plant shown in Figure 1 comprises a green coke storage area, shaft calciners, calcined petroleum coke (CPC), pitch and recycled materials storages, two green anode plants, two rodding shops, one green and baked anode storage area, two baking furnaces and one fume treatment center including SO<sub>2</sub> scrubbers.

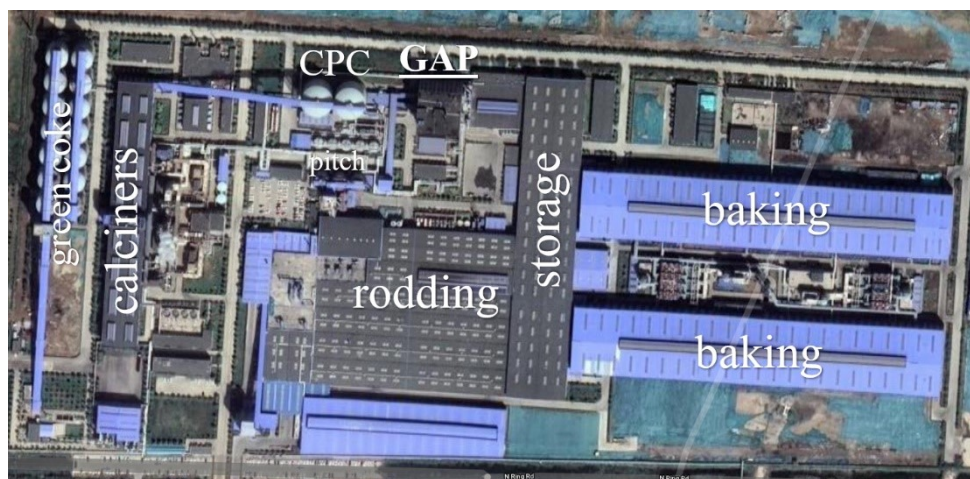


Figure 1. Xinfa, Chipping, new carbon plant (Google maps, satellite view, image ©2021).

This carbon plant can produce 800 kt of baked anodes per year, feeding some of the older existing pot lines and the new SAMI SY600 pot lines commissioned in 2016 with an actual production capacity of more than one million tonnes of aluminum per year.

Fives and Xinfa commissioned these green anode plants in 2018–2019 and the detailed description of this project as well as the first 2 years of operation results were presented at ICSOBA in 2021 [1]. Some key elements are recalled hereafter along with the evolution of the performance of this installation, the challenges encountered, and the modifications implemented by Xinfa to maintain the OEE at peak performance and the initial high environmental standards.

### 3. Rhodax Process at a Glance

The Rhodax process is the result of two parallel developments started in the early 90s. In the 2000s, Fives and Aluminum Pechiney (AP, now Rio Tinto) joined their research and development efforts and co-patented the SCAP-RHODAX® process (Figure 2) which mainly consists of:

- Mixing all solids (raw coke, green and baked scraps) and crush them all together at the same time without any detrimental impact on anode quality under normal operating conditions,
- Producing a recipe based on two grain size fractions only:
  - o Fines with 70 wt.% of particles smaller than 32 µm (< 32 µm),
  - o Grains from 300 µm to 30 mm.

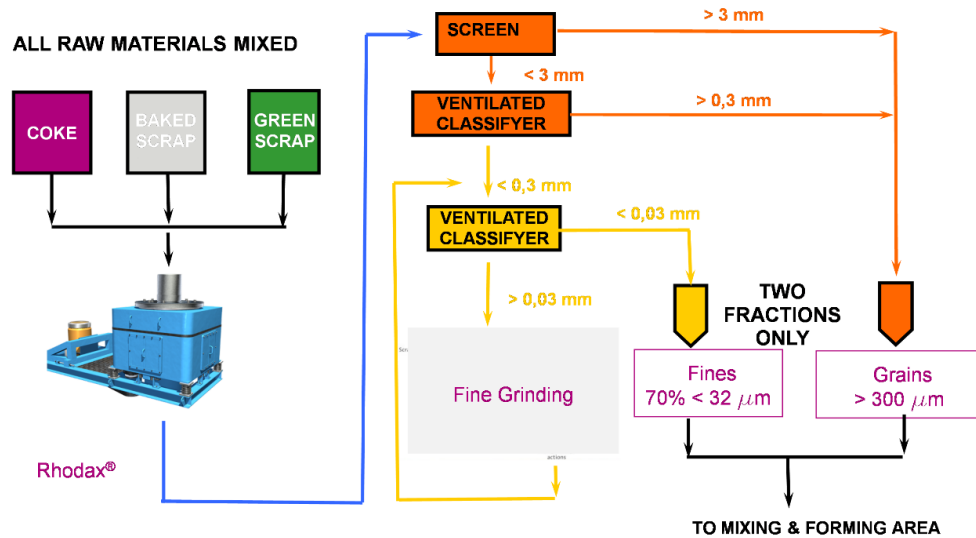


Figure 2. RHODAX® key process features.

The development of the RHODAX® process led to a drastic simplification of the conventional paste plants flow sheet as shown in Figure 3.

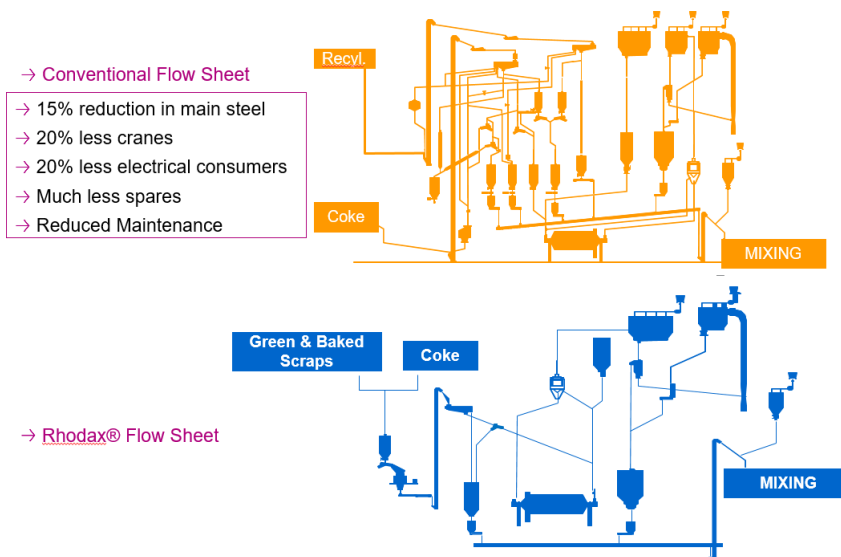


Figure 3. Comparison between conventional and RHODAX® flow sheets.

The key implementation characteristics and advantages of this technology are well known and described in the literature [2]. In addition to the naturally high Grain-to-Sand Ratio (GSR > 4.0), and simplified flowsheet, several other important underlying technical features were recalled in a paper presented at ICSOBA 2024, in Lyon [3], focusing on the recent developments and future challenges of the RHODAX® process, with main evolutions detailed in Section 3.1.

### 3.1 RHODAX® Process Evolution

The initial version of the Rhodax process has strongly evolved over the years, both in terms of process parameters, process control and equipment design.

**On the process side**, the main evolutions deal with the granulometry at various points in the circuit.

Regarding the feed of the circuit, both the fresh coke and recycled scraps size distributions are fluctuating more often and with a much wider range. For the fresh coke, the 80 % passing size (P80) can vary by a factor 2 (10 to 20 mm) which is either due to higher segregation in the huge coke storage silo at the port [4] or due to the variable mixture of both rotary and shaft calcined cokes [5, 6]. For the recycled scraps, the P80 can vary by a factor 3 (20 to 60 mm) which is due to either the variety in the design of the crushing recycling units with different types of crusher technologies or different number of crushing stages.

Regarding the output of the circuit, the maximum grain size of the dry mix material, which was initially set to 30 mm, has been reduced in some cases down to 20 mm and even 16 mm. Good technical reasons motivated this reduction in size:

- The reduction of the preheating screw wear rate
- The elimination of the risk of particle segregation in the green anodes
- Or suspicion of the negative impact on the electrical resistivity of the baked anode [7]

**On the process control side**, various options were successfully implemented in order to improve circuit stability. The earliest one was the concept of virtual fine silo, followed by the development of a coke fine size distribution controller (Optibinder) [5]. Lately, a new circuit design without the first dynamic classifier (Rhodax S circuit) was successfully tested [8] in order to guarantee a GSR close to 4 while improving the controllability of the circuit by adding a mass flow controller on the feed of the fine grinding circuit.

**On the equipment side**, the main evolutions include:

- The Rhodax 4D to increase the crushing capacity and flexibility of the circuit
- The new Rhodax liner design to increase lifetime
- The variable speed drive on the ball mill instead of a hydraulic coupling for a better speed and milling power control
- The new dynamic classifier design to ease the maintenance and increase the lifetime of wear components
- The addition of an eddy current separator upstream to remove the aluminium chips which were causing too many short stoppages of the crushers.
- The new fine dosing system [5] to stabilize the very fine coke fines of the Rhodax process.

### 3.2 Rhodax “S” Process

The Rhodax “S” Process takes into consideration the large experience from the previous installations and aims at further improving the process stability, while maintaining the GSR close to 4 for a full benefit on the thermal shock resistance of the anodes. As shown in Figure 4, the

scalping screen has one more cut size of 1 mm. This new size fraction goes to an overflow feeder coupled with a flow controller. This new arrangement replaces the first dynamic classifier in the Initial version and allows an easier control of the coke quantity sent to the fine grinding unit by adding a mass flow controller on the feed of the fine grinding circuit.

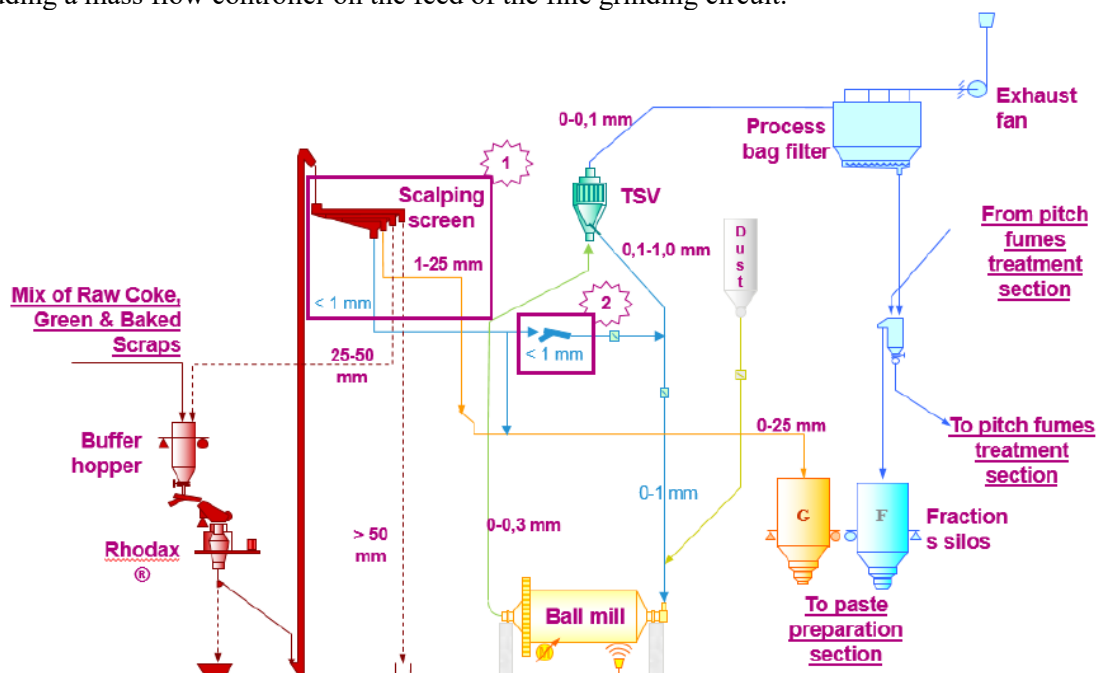


Figure 4. Rhodax S simplified flowsheet.

The Rhodax “S” process is the one used for the twin 60 tph green anode plant installed at Xinfu Chiping carbon plant (Figure 5) in 2018-2019.



Figure 5. Actual building of the twin 60 tph GAP at Xinfu

#### 4. Xinfu Green Anode Plant 5 Years Performance

##### 4.1 Production Performance

Line 1 (L1) runs at 60 t/h to produce up to 380 kt/y of 1 470-kg green anodes feeding 600 kA pots and Line 2 (L2) runs at 50 t/h to produces up to 308 kt/y of 982-kg green anodes feeding 240 kA pots (Figure 6).

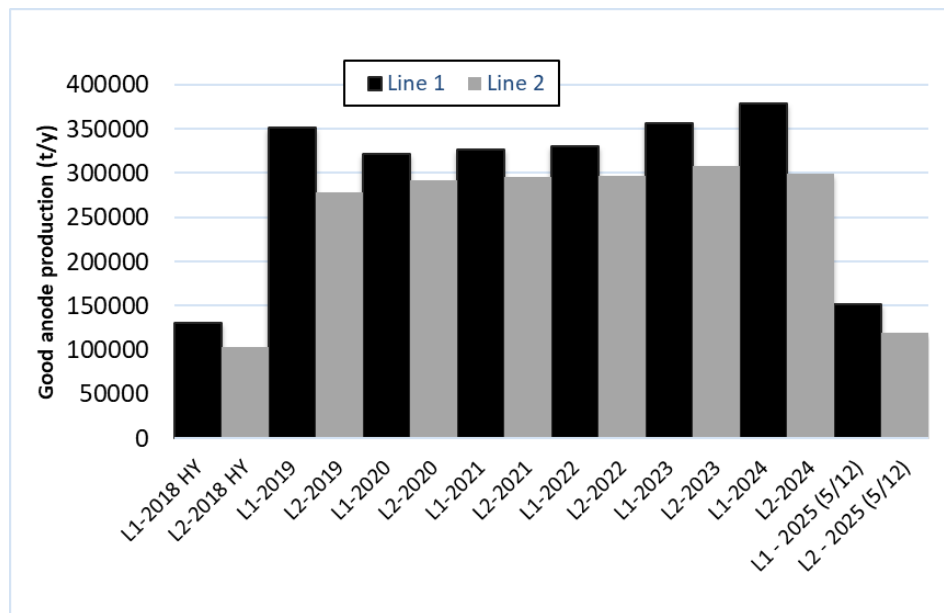


Figure 6. Good anode production for L1 and L2; HY (Half-Year); 5/12 (5 first months of the year).

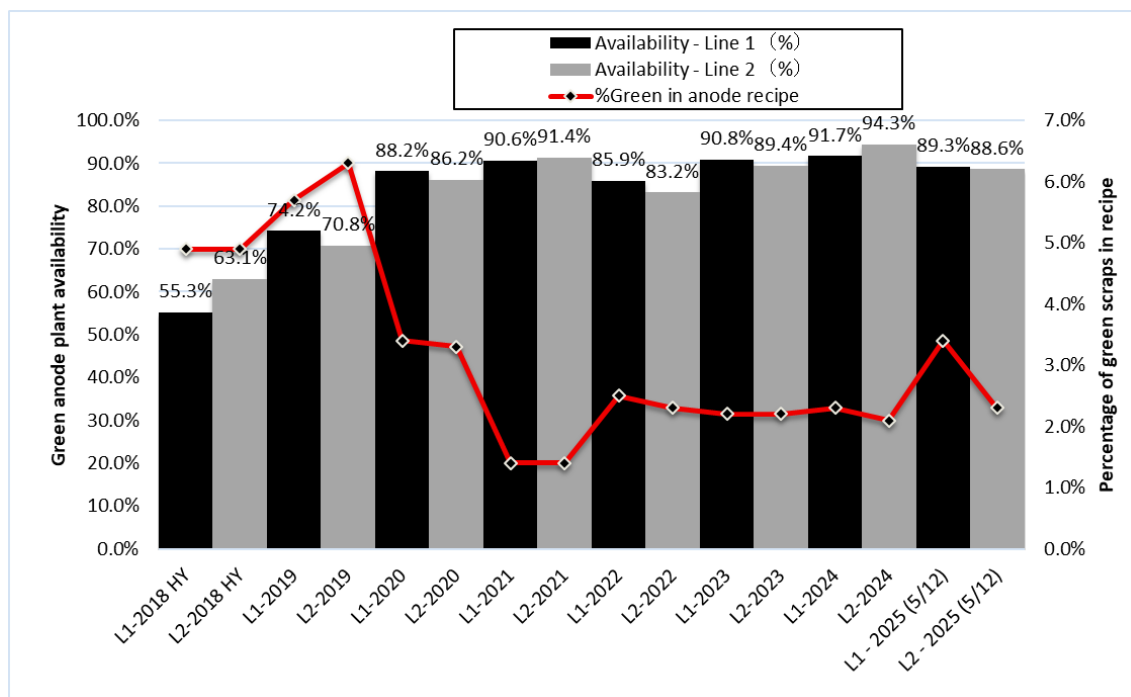


Figure 7. L1 and L2 availabilities (bar graphs) and green scrap percentage in anode recipe.

After a period of ramp-up and stabilization during the commissioning phase in 2018–2019, the GAP availability stabilized around 89 % in average (Figure 7) and the recycled green scrap content in the recipe slightly above 2 %. These performance indexes are among the very best and

demonstrate the good ownership and a high level of mastery of this technology by the Xinfu’s team. The lower availability shown in the first part of 2025 is due to major overhauling in the plant after 5 years of operation with high production levels.

**4.2 Process Performance**

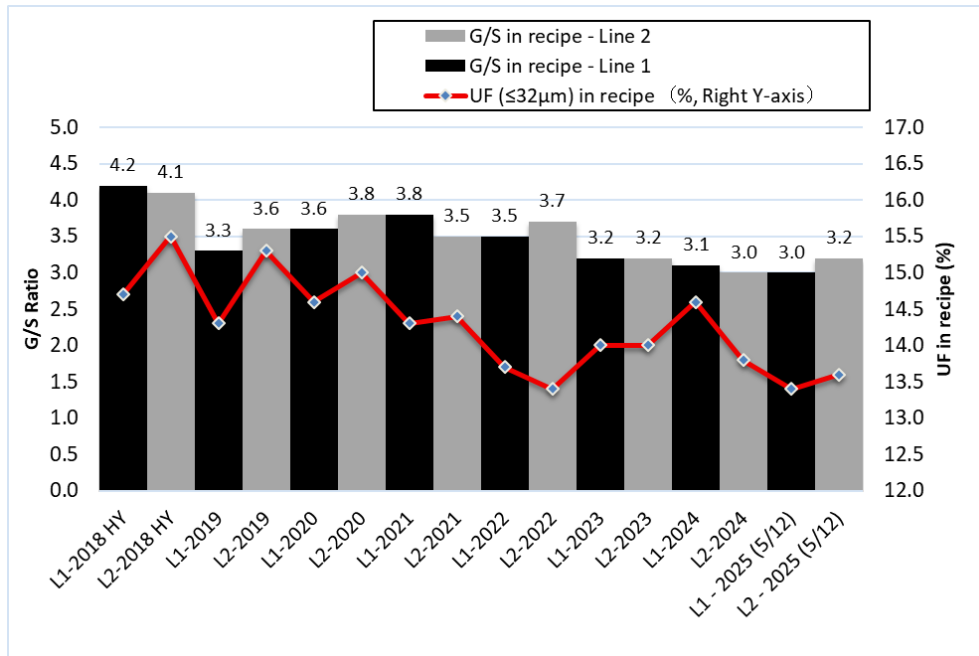
Table 1 includes the evolution of the recipe and coke real density (RD). The coke consumed in the GAP is calcined in shaft calciners. The coke RD fluctuates over the years based on the green coke sources but stays at a rather high level.

**Table 1. Average (L1 and L2) anode recipe & coke real density (RD).**

Property	2018	2019	2020	2021	2022	2023	2024	2025
Coke RD (g/cm <sup>3</sup> )	2.12	2.11	2.10	2.09	2.091	2.087	2.083	2.088
Fines (%)	27.5	30.1	29.7	28.8	28.5	29.1	29.8	29.4
Pitch (%)	13.5	13.6	13.6	13.7	14.0	14.0	13.8	13.7
Recycled Green Scrap (%)	4.9	6.0	3.4	1.4	2.4	2.2	2.2	2.9
Recycled Butts (%)	17.7	9.8	11.7	11.5	11.4	10.9	10.7	11.5
UF in recipe, < 32 µm (%)	15.1	14.8	14.8	14.4	13.6	14.0	14.2	13.6

The Rhodax “S” circuit is designed to produce a GSR close to 4. Along the years (Figure 8), Xinfu implemented various process changes leading to a decrease of the GSR ratio down to 3. This decrease is due to much finer raw material size distribution (coke and butts) and a decrease of the top size of the particles in the recipe from 30 mm down to 16 mm.

Both led to an increase of the sand fraction in the grains and fines fractions. In parallel, the percentage of particles < 32 µm (UF) setpoint is stabilized around 13.7 %.



**Figure 8. L1 and 2 GSR (bar graphs) and UF percentage in anode recipe (line).**

The UF percentage in the fraction < 75 µm in the fines is set at 60 % to target a Blaine of 4 300. The fine grinding circuit, equipped with a fully air swept variable speed ball mill, is very stable as shown in Figure 9 where the process capability index (Cpk) remains above 2 most of the time.

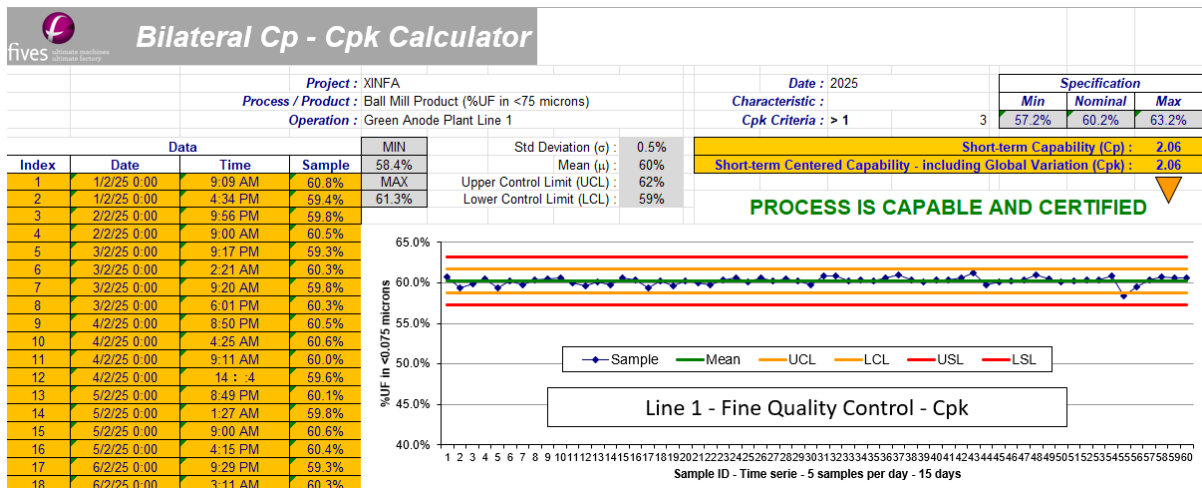


Figure 9. L1 process capability index calculated per period of 15 days.

Thanks to a very good coke density and a well mastered process, the green anode densities (GAD) are maintained at a very high level (Figure 10) with an average around 1.67 g/cm<sup>3</sup>, despite a very low level of butts. This level is around 12 % and fluctuates from 10 to 15 %.

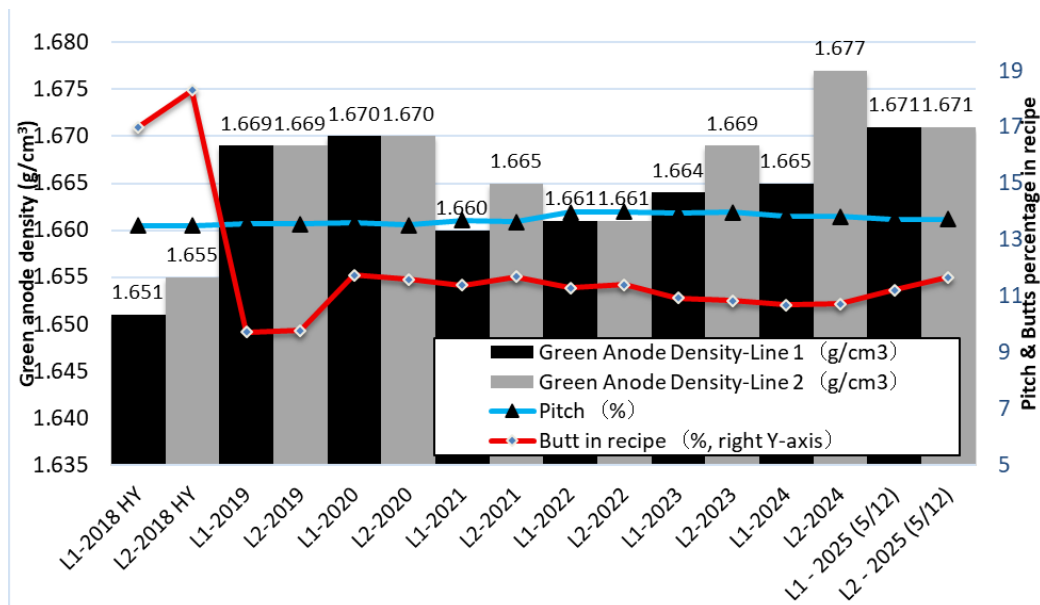


Figure 10. L1 and L2 green anode densities (bar graphs), butts percentage and pitch content in anode recipe (lines).

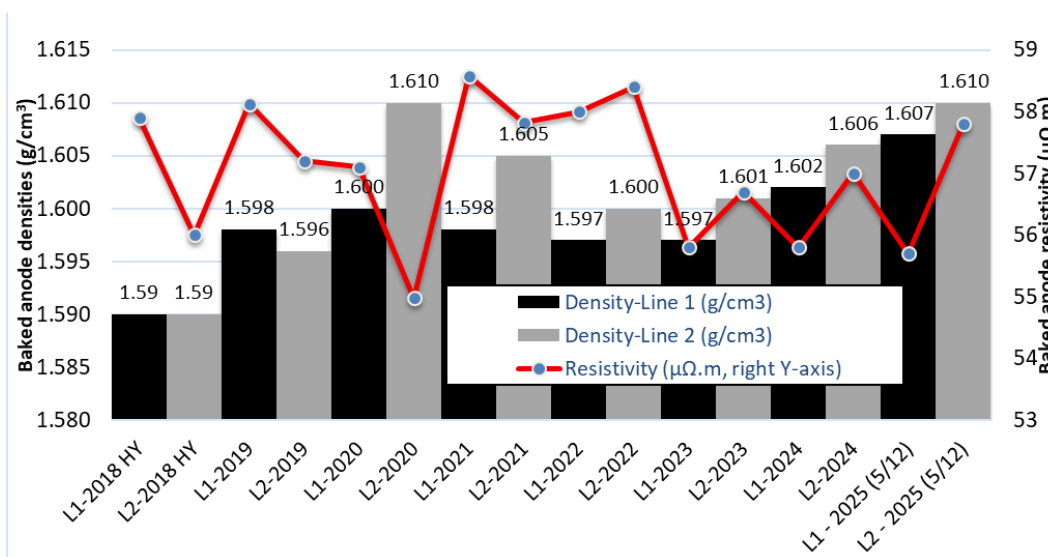
With such a high green anode density, the baked anode density is also on the high side with values in average above 1.60 g/cm<sup>3</sup> and reaching nearly 1.61 g/cm<sup>3</sup> in 2025. Some baked anode properties are presented in Table 2 and plotted in Figure 11.

In 2021, a change in the green coke source led to perturbations in both anode density, electrical resistivity (ER) and permeability. While the anode permeability remains stable for the past 3 years, ER fluctuates in average. Overall ER is slowly decreasing for L1 and remains on the high side with a level of 55 μΩ.m. The ER for L2 keeps increasing despite the same raw material, recipe and process parameters. In that case, over compaction in the former is suspected on L2 and

is currently under investigation. In parallel, deeper investigations of the anode baking process are on-going to cover all the potential root causes of such rather high ER.

**Table 2. Average (L1 and L2) baked anode properties.**

Baked Anode Properties	2018	2019	2020	2021	2022	2023	2024	2025
Density (g/cm <sup>3</sup> )	1.590	1.597	1.605	1.601	1.599	1.599	1.604	1.609
Electrical Resistivity (μΩ.m)	56.9	57.7	56.0	58.2	58.2	56.3	56.4	56.8
Permeability (nPm)	NA	1.0	0.75	0.61	0.82	0.62	0.68	0.68



**Figure 11. L1 and L2 baked anode densities (bar graphs) and electrical resistivities (line).**

## 5. Xinfa Green Anode Plant Process & Equipment Improvements

### 5.1 Process Improvements

Since 2020, a series of actions were implemented by Xinfa to limit the paste segregation in the anode.

#### Action N°1:

The first action was to reduce free chute height between the paste feeder and the paste transfer hopper in the forming section. To do so, an intermediate paste weighing hopper was added which had also the positive consequence of improving the paste dosing accuracy.

#### Action N°2:

The second action was to reduce the anode recipe top size from 30 mm down to 16 mm by decreasing the Mogensen screen mesh sizes. By doing so, the load on the Rhodax crusher increased significantly with a high circulating load. Therefore, it was decided to reduce the raw material size fed to the circuit. Indeed, Xinfa used 100 % shaft calcined coke which was initially very coarse [1] with a top size of 50 mm and an 80 % passing size (P80) of 20 mm (Figure 12). In 2021, it was decided to progressively reduce the size of the coke by crushing it with a roll crusher with the aim reducing the crushing load of the Rhodax. In 2025, the top size is 20 mm and the P80 around 11 mm bringing positive change for the process.

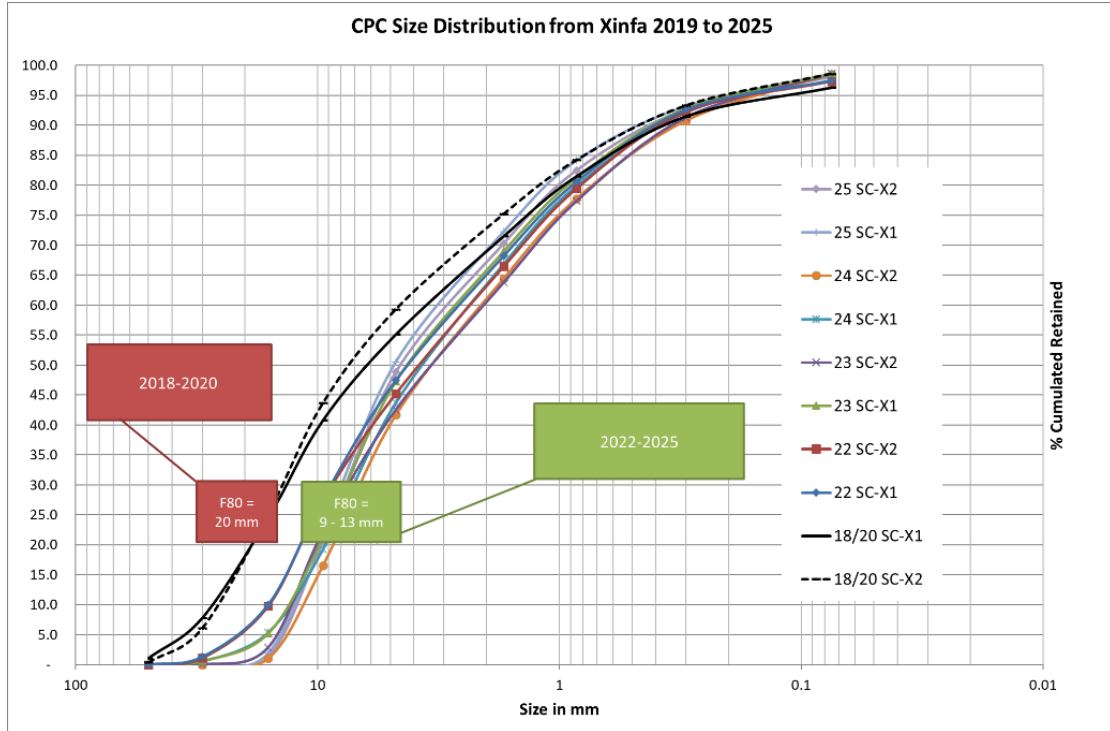


Figure 12. Particle size distribution of Xinha shaft calcined coke.

In parallel, it was also decided to reduce the size of the crushed butts by closing the gap of the carbon recycling unit tertiary cone crusher down to 25 mm. The results are shown in Figure 13 where the top size initially at 60 mm went down to 30 mm and the P80 from 42 mm down to 20 mm. The extra fines generated by this extra crushing were screen-out to prevent from any contamination of the binder matrix with sodium from the crushed butts.

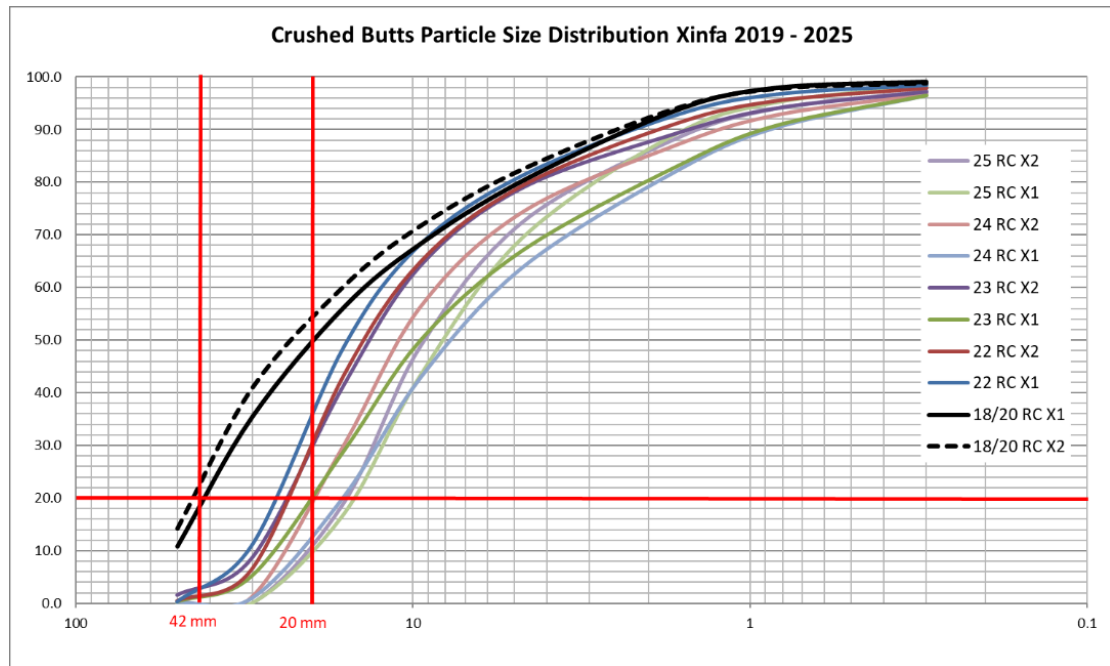
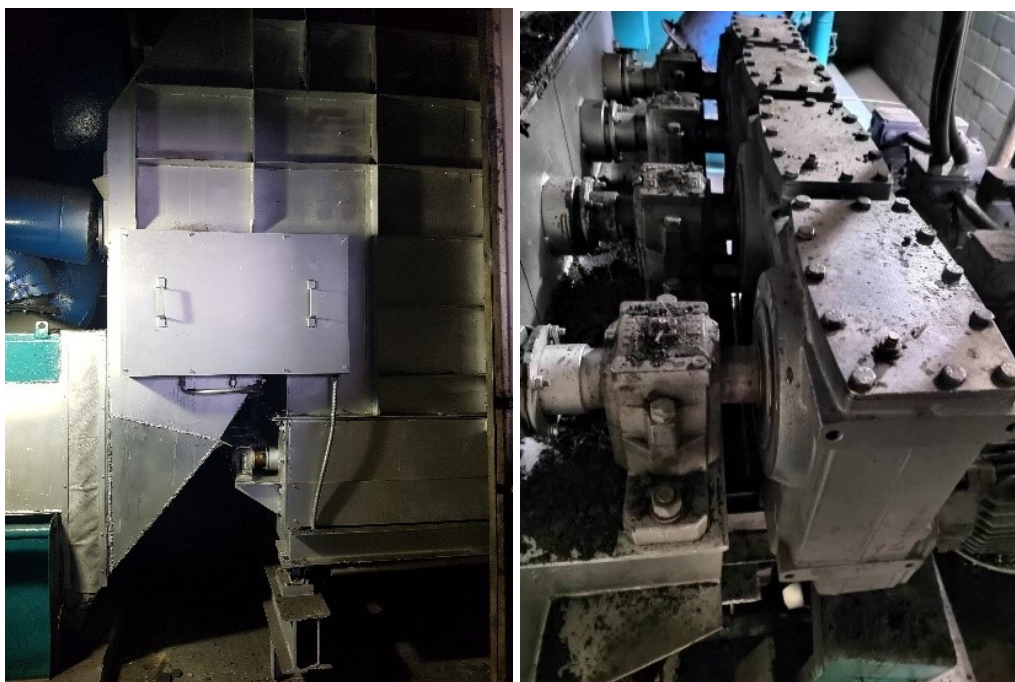


Figure 13. Particle size distribution of the crushed butts.

The butts size reduction went too far leading to too much sand fractions in the recipe causing a decrease in the GSR. Moreover, the fraction 0.3–0.85 mm was in deficit potentially leading to non-optimal particle size distribution and the risk of feeding more butts to the fine grinding circuit. In 2025, the butts crushing circuit was adjusted to keep a lower top size and a lower P80 while limiting the side effects on the finer fractions. In parallel, new settings of the Rhodax circuit are under modifications to help bringing back the GSR close to 4.

Action N°3:

Xinfa identified some paste segregation on the paste feeder itself and decided to redesign the paste feeding section (Figure 14). The new paste feeder includes 4 parallel rotating screws coupled with variable speed drives. The paste is rejected thank to a flap gate located inside the paste chute.



**Figure 14. New paste feeder. Left: back view. Right: front view.**

This new paste feeder limited the segregation during paste dosing and had also the positive consequence of improving significantly the fugitive emission of pitch vapor in the ambiance.

## 5.2 Equipment Improvements

From the start, Xinfa paid particular attention to the environmental impact of the carbon plant. For the green anode plants, it means:

- Stringent emissions at the stack for both dust and VOC
- Special attention to operators' exposure inside the building

For this reason, the EOLIOS pitch fume treatment system [2, 3] combining a dry scrubber and a small RTO (Regenerative Thermal Oxidizer) was part of the initial package. Xinfa decided to add in 2020, an additional dry scrubber of 50 000 Nm<sup>3</sup>/h to double the capacity of the pitch fume suction. This extra suction capacity is used to capture the fugitive emissions between the outlet of the vibro compactor (VC) and the inlet of the anode cooling pool (Figure 15, right). It also includes new suction points around the VCs to improve the ambiance in the forming zone (Figure 15, left).



**Figure 15. New suction points. Left: around VC, Right: between VC and pool.**

To reduce the gross carbon consumption, the upper part of the anode has been modified in such a way that the traditional anode marking device cannot be used anymore due to a too small printing surface. It was decided to install a laser marking device which looks satisfactory so far as illustrated in Figure 16.



**Figure 16. New laser marking device. Left: Laser. Right: Anode top face.**

Finally, to better monitor the fine quality, in 2025, Xinfra installed an on-line fine size distribution sensor from Malvern (Laser type). This device is installed right the fine grinding bag filter and the on-line measurement is reported to the SCADA through the PLC where a control loop manipulates the dynamic classifier speed to adjust the cut size and therefore control the UF percentage in the fine fraction (Figure 17). This is also contributing to the high process capability described in section 4.2.

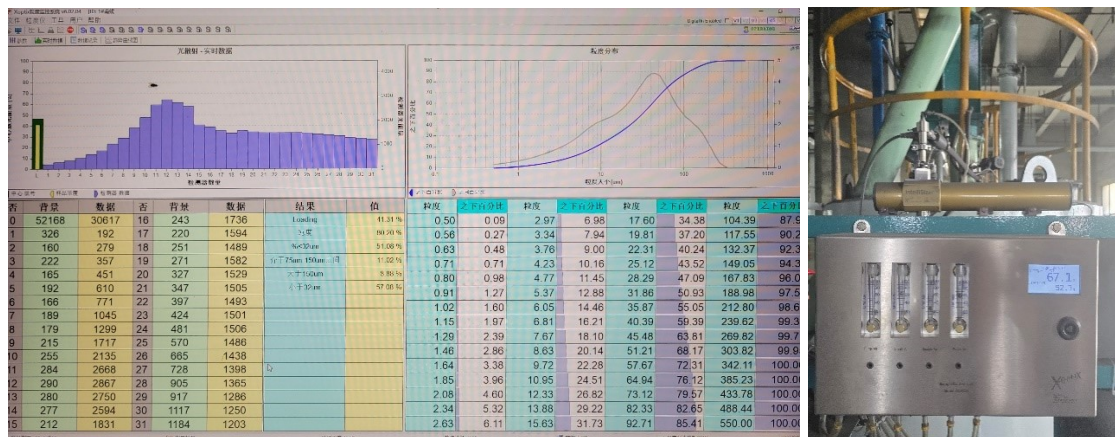


Figure 16. On-line size analyser. Left: HMI, Right: Field device.

## 6. Conclusions

Rhodax “S” process-based technology for green anode plants at Xinha’s Chiping aluminum smelter was a premiere for such technology in China. After more than 5 years of operation and a long period with limited access to the plant due to COVID time, Fives and Xinha jointly reviewed the actual and historical status & performance of the plant. Both appeared to stay at a high level in terms of production, anode quality and environmental control. Few challenges were successfully addressed by Xinha alone, demonstrating a good ownership and high level of mastery of the technology. Few more, like reducing ER and increasing GSR are currently addressed and the results the on-going optimization work will be published at a later stage.

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