

## Digestion-Evaporation Combined Process in Alumina Refinery

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### Abstract

In the Bayer process, the digestion and evaporation are both processes with high energy consumption. Heat energy is recovered by multi-stage flash in digestion process. In alumina refineries with diasporite as raw material, the temperature of the final flash discharged slurry is usually over 120 °C. Because of the limitation of heat transfer temperature difference, it is difficult to continue to reduce. Multistage falling film evaporation process is often used in evaporation process. All evaporators after four effects are usually vacuum evaporators, the temperature of slurry is usually low. This paper discusses how to achieve better energy cascade utilization through combined process of digestion and evaporation, and then reduce the production cost of alumina.

**Keywords:** Combined Process, Digestion, Evaporation.

### Definitions of terms:

"A/S": mass ratio of Al<sub>2</sub>O<sub>3</sub> to SiO<sub>2</sub> in the solid

"N/S": mass ratio of Na<sub>2</sub>O to SiO<sub>2</sub> in the solid

"Rp": mass ratio of caustic Al<sub>2</sub>O<sub>3</sub> to Na<sub>2</sub>O in liquor

"N<sub>k</sub>": caustic concentration of the liquor (as Na<sub>2</sub>O)

### 1. Introduction

Reducing energy consumption in alumina production is an important research topic in the field of alumina refinery. In China, diasporite is the main kind of bauxite in alumina refineries, which requires digestion temperature is generally above 265 °C [1]. Compared with the refineries using gibbsite, the digestion process of the refineries using diasporite consumes much more energy. According to Z.X. Wang's research [2], the total energy consumption per ton alumina of a certain alumina refinery in China is 11.72 GJ/t-Al<sub>2</sub>O<sub>3</sub>, in which, steam accounts for 60.23 % and energy consumption reaches 7.06 GJ/t-Al<sub>2</sub>O<sub>3</sub>. G. Jin's research shows that 55.27 % of the total energy consumption in the process of diasporite digestion is ultimately taken away by the pulp [3]. Because of high alkali concentration is needed in the diasporite digestion, boiling point elevation is higher. N<sub>k</sub> of test liquor usually reaches 220 - 240 g/L. After multi-stage flashes, N<sub>k</sub> in the solution can reach as high as 260 - 290 g/L. At this concentration, the boiling point elevation of the solution can reach to 18 - 20 °C. Under the condition of such a high boiling point elevation, it is difficult for positive pressure flash to continue to reduce pulp temperature and recover heat energy. Moreover, if vacuum flash is used, the temperature of slurry is too high, and the vapor produced by vacuum flash is difficult to be used effectively. Therefore, we design a new process, which combines the digestion process and evaporation process of Bayer alumina refinery into a new process. The heat of the digested pulp can be further recovered and utilized by using the temperature difference between the digestion process and the evaporation process.

## 2. Process Design

### 2.1. Design Tool

We take the process simulation software SYSCAD from Kenwalt Australia Pty Ltd. as design tool. We use the software to build digestion and evaporation computation model to simulate an alumina refinery. Then we build a digestion-evaporation combined process simulation to calculate the energy consumption saved by this process.

### 2.2. Design Basic Parameters

Our design basic parameters are from an alumina refinery in Guizhou, China. This refinery design capacity is 1600 kt/a, divided into two production lines, capacity of single production line is 800 kt/a. Bauxite used in this refinery is diaspore with A/S of about 5 - 5.5,  $Al_2O_3$  is about 50 %, concentration of test liquor is  $N_k = 249$  g/L, digestion temperature is 265 °C. Evaporative water requirement is about 3.38 t per ton alumina,. The temperature of digestion feed slurry is about 93 °C. For one production line, feed slurry mass flow is 1299 t/h, while volume flow is 817  $Nm^3/h$ .

### 2.3. Digestion Simulation

The digestion process of the alumina refinery is the tube-digestion process. A total of nine-stage preheating tube heat exchanger is set up. The heating medium of the preheating tube heat exchanger is flash vapor. The one-stage live steam condensate tube heat exchanger is heated by live steam condensate. The one-stage live steam tube heat exchanger is heated by live steam. Pressure of the live steam is 6.4 MPa, the temperature is 300 °C. The slurry is heated to the digestion temperature in the tube heat exchanger using live steam. After the reactor, temperature of the slurry is reduced to 126 °C by ten-stage flash cooling. The nine-stages flash vapor is used to preheat the slurry in the tube heat exchanger, and the last flash vapor is used to heat the pre-desilicon pulp.

The simulation model established by SysCAD software is shown in figure 1.

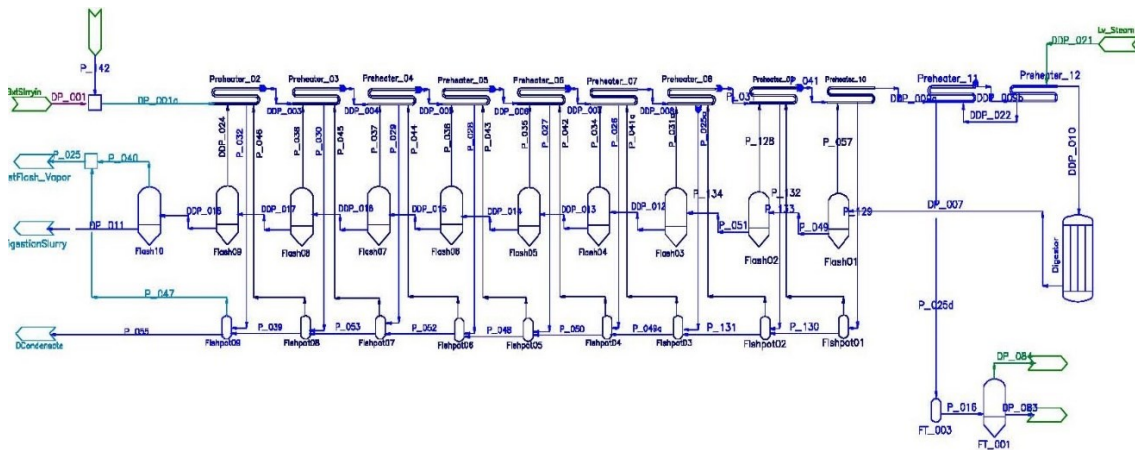


Figure 1. Digestion Process Flow Chart.

The heat balance of the digestion process calculated by the model is shown in table 1.

**Table 1. Heat Balance Table for Digestion Process.**

<b>Heat Income(MJ/t-Al<sub>2</sub>O<sub>3</sub>)</b>			
<b>Number</b>	<b>Item</b>	<b>Heat</b>	<b>%</b>
1	Feed Slurry	3534.49	47.66
2	Live Steam	3881.08	52.34
3	Total	7415.57	100.00
<b>Heat Expenditure(MJ/t-Al<sub>2</sub>O<sub>3</sub>)</b>			
<b>Number</b>	<b>Item</b>	<b>Heat</b>	<b>%</b>
1	Digestion Slurry	3800.78	51.25
2	Reaction Heat	688.68	9.29
3	Live Steam Condensate	1404.47	18.94
4	Vapor Condensate	1019.74	13.75
5	Last Flash Vapor	210.59	2.84
6	Last Condensate Vapor	66.65	0.90
7	Heat Loss	224.66	3.03
8	Total	7415.57	100.00

Through the heat balance, we know that the live steam heat consumption per ton alumina production in the digestion process is 3881.08 MJ, equivalent to about 1.40 t of the live steam.

#### **2.4. Evaporation Simulation**

The six-effects falling film evaporation process is used in the evaporation process of the alumina refinery. For 800 kt/a single production line, a group of evaporators with 330 t/h evaporation capacity is adopted. The mass flow of the evaporator group feed is 1088 t/h, and  $N_k$  of the feed is 177 g/L. Spend liquor feeds into 4th-effect evaporator and 6th-effect evaporator, and the feed proportion of 4th-effect evaporator and 6th-effect evaporator is 60 % and 40 % respectively. The solution feeding the 6th-effect evaporator passes through the 6th-effect evaporator and the 5th-effect evaporator in turn before discharging. The solution feeding the 4th-effect evaporator passes through the 4th-effect evaporator, 3rd-effect evaporator, 2nd-effect evaporator, 1st-effect evaporator and three-stage flashes, then mixes with the 5th-effect evaporator discharge.

The evaporation process simulation model established by SysCAD software is shown in figure 2.

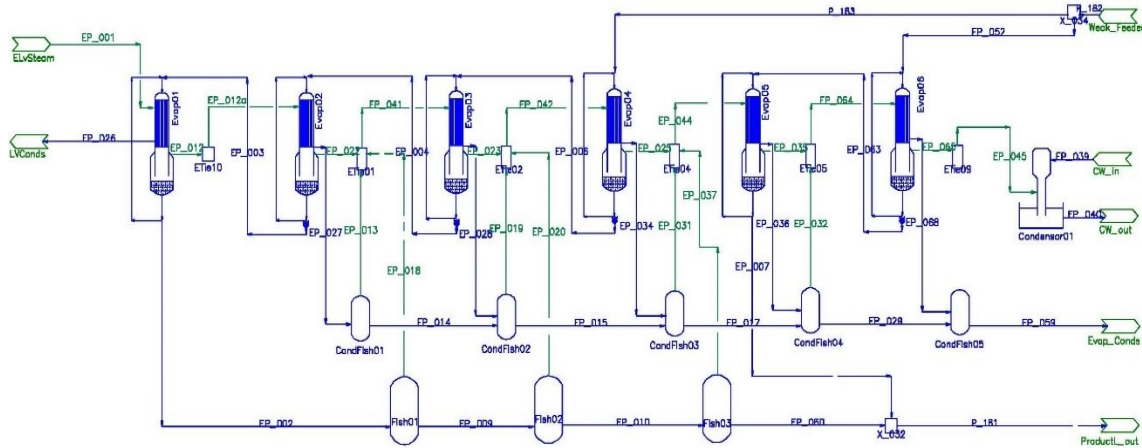


Figure 2. Evaporation Process Flow Chart.

The heat balance of the evaporation process calculated by the model is shown in Table 2.

Table 2. Heat Balance Table for Evaporation Process.

Heat Income(MJ/t-Al <sub>2</sub> O <sub>3</sub> )			
Number	Item	Heat	%
1	Feed Slurry	3467.39	59.82%
2	Live Steam	2328.85	40.18%
3	Total	5796.24	100.00%
Heat Expenditure(MJ/t-Al <sub>2</sub> O <sub>3</sub> )			
Number	Item	Heat	%
1	Evaporative solution	2598.18	44.83%
2	Live Steam Condensate	520.96	8.99%
3	Vapor Condensate	703.78	12.14%
4	6th-Effect Evaporator Vapor	1786.07	30.81%
5	Heat Loss	187.25	3.23%
6	Total	5796.24	100.00%

Through the heat balance, we know that the live steam heat consumed per ton of alumina production in the evaporation process is 2328.85 MJ, equivalent to about 0.84 t of the live steam.

## 2.5. Digestion-Evaporation Combined Process Simulation

In order to further recover and utilize the heat of the leached slurry, a combined process of digestion and evaporation is designed. The design idea of this new process is to reduce the series of preheating in the digestion process and utilize the flash vapor produced by flashes in the digestion process to the evaporation process. By high vacuum and lower slurry temperature in evaporation process, the leached slurry can be reduced to a lower temperature, thus improving recovery and utilization of heat energy and reducing energy consumption in alumina production process.

After many trial calculations, the final process we determined is to set up seven-stage preheating tube heat exchanger in the digestion process. It is built as one-stage live steam condensate heating tube heat exchanger, and one-stage live steam heating tube heat exchanger. The leached slurry is heated to the digestion temperature by live steam in the tube heat exchanger and then feeds into the tube reactor. After the reaction is completed, eleven-stage flash cooling is carried out. The first seven-stage flashes vapor is used to preheat the leached slurry, and the last four-stage flashes vapor enters the first, second, third and fourth-effect evaporators in turn. Spend liquor feeds into 4th-effect evaporator and 6th-effect evaporator, and the feed proportion of 4th-effect evaporator and 6th-effect evaporator is 60 % and 40 % respectively. The solution feeding the 6th-effect evaporator passes through the 6th-effect evaporator and the 5th-effect evaporator in turn before discharging. The solution feeding the 4th-effect evaporator passes through the 4th-effect evaporator, 3rd-effect evaporator, 2nd-effect evaporator, 1st-effect evaporator and three-stage flashes, then mixes with the 5th-effect evaporator discharge.

The digestion-evaporation combined process simulation model established by SysCAD software is shown in figure 2

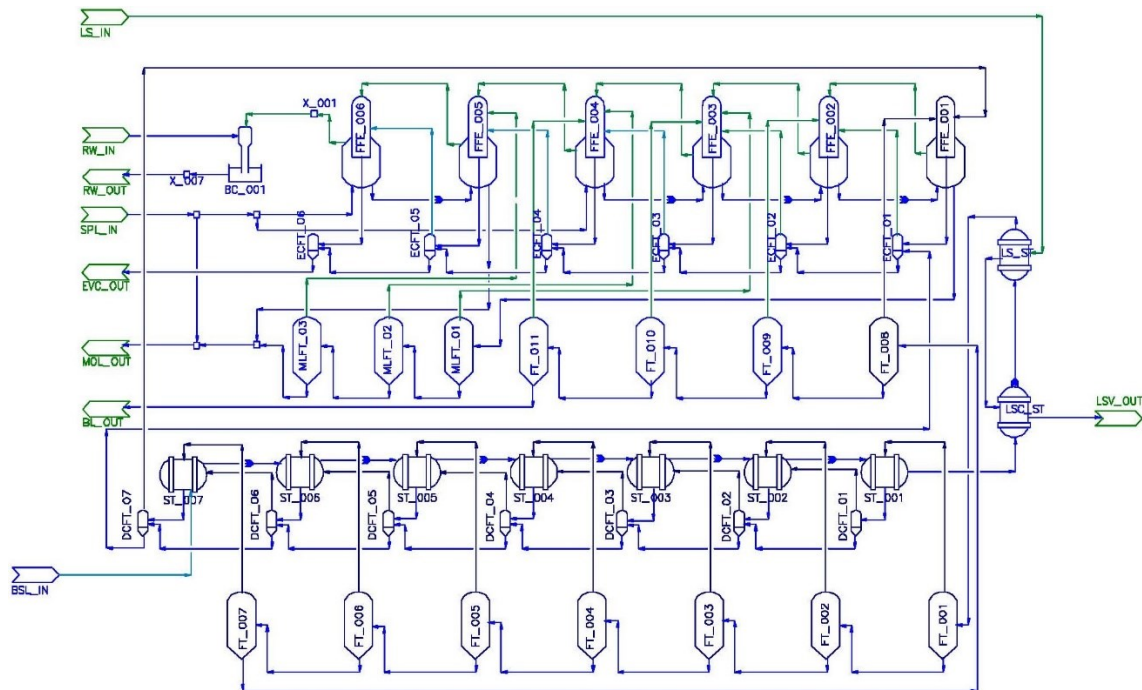


Figure 3. Digestion-Evaporation Combined Process Flow Chart.

The heat balance of the digestion-evaporation combined process calculated by the model is shown in Table 3.

**Table 3. Heat Balance Table for Digestion-Evaporation Combined Process.**

<b>Heat Income(MJ/t-Al<sub>2</sub>O<sub>3</sub>)</b>			
<b>Number</b>	<b>Item</b>	<b>Heat</b>	<b>%</b>
1	Feed Slurry	3534.49	29.46%
2	Live Steam	5497.02	45.82%
3	Evaporation Feed	2966.35	24.72%
4	Total	11997.86	100.00%
<b>Heat Expenditure(MJ/t-Al<sub>2</sub>O<sub>3</sub>)</b>			
<b>Number</b>	<b>Item</b>	<b>Heat</b>	<b>%</b>
1	Digestion Slurry	3542.07	29.52%
2	Reaction Heat	688.68	5.74%
3	Live Steam Condensate	1663.19	13.86%
4	Evaporative solution	1264.21	10.54%
5	Vapor Condensate	2076.07	17.30%
6	Last Flash Vapor	2425.23	20.21%
7	Heat Loss	338.41	2.82%
8	Total	11997.86	100.00%

In the process of simulation, temperature of vapor into the evaporation process can be adjusted by adjusting the area of the preheating tube heat exchanger in the digestion process. Discharging temperature of the digested slurry can be adjusted by adjusting the area of each evaporator. Finally, the final flash discharging temperature is controlled to 118 °C, and evaporation capacity is adjusted to 330 t/h. At the meantime, the evaporation process does not need to consume live steam, and the digestion process consumes 1.98 t live steam per ton of alumina.

In the traditional process, 1.40 t live steam is consumed in the digestion process per ton alumina, 0.84 t live steam is consumed in the evaporation process, 2.24 t live steam is consumed altogether. In the digestion-evaporation combined process, live steam consumption can be reduced by 0.26 t per ton alumina.

### **3. Results and Discussion**

By establishing simulation and heat balance calculating of the digestion process, evaporation process, digestion-evaporation combined process respectively, it is found that live steam consumption per ton alumina can be reduced by 0.26 t after the digestion-evaporation combined process is adopt, which can reduce the energy consumption and cost of alumina production.

At the same time, the digestion-evaporation combined process can also reduce the series of preheating tube heat exchanger. Vapor from digestion process is used in evaporation process, which can effectively improve the heat transfer temperature difference and reduce area of evaporators. The digestion-evaporation combined process reduces the equipment investment and occupancy of the alumina refinery.

In summary, through the joint design of digestion process and evaporation process, the temperature difference between different processes in alumina refinery is effectively utilized. Low-grade heat is fully utilized, while reducing the production cost of alumina, the equipment investment and occupation of alumina refinery are also reduced, the distance of material transportation is shortened, and enormous economic benefits can be achieved for alumina refinery.

#### 4. References

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