

AA14 – Implementation of Filtration Cake Recovery Process

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Abstract

The filtration cake slurry generated during security filtration is usually pumped into the red mud washer for separation. The liquid is recovered, and the solid is discharged as waste. According to the analysis of chemical composition and mineral composition of filtration cake in filtration cake slurry, it is found that it contains Al_2O_3 , CaO , $3\text{CaO}\times\text{Al}_2\text{O}_3$, which is a high-quality additive in alumina production. Recycling of the filtration cake can reduce the unit consumption of alumina and lime and reduce red mud emissions. It is currently one of the important research directions for energy conservation and consumption reduction in alumina production. This article discusses the recovery path of filtration cake, search for a separation method for filtration cake slurry by experiments, and the addition of thickened filtration cake as an additive to the pre-desilication process. The thickened filtration cake can also be dealuminated, pressure filtered, and returned to the pre-desilication process. The recycling of filtration cake is realized through the above process.

Key words: Filtration cake, Recovery, Reparation, Dealumination, Pressure filtration.

1. Introduction

At present, lime milk is commonly used as a filter aid in the security filtration process of alumina production. The solid content of lime milk is 180–250 g/L, and the addition amount is 0.3 %–0.5 % by volume. Before addition, unpolished pregnant liquor is added at a volume of approximately 1:1 for reaction. A fully automatic Kelly filter is used for security filtration operation. When the Kelly filter is depressurized and sludge is discharged, pregnant liquor from the high-level tank is used to backwash the filtration cloth, and then enters the filtration slug slurry tank. The slurry with a solid content of 30-100 g/L is then sent to the dilution tank. The pregnant liquor (filtrate) in the slurry is recovered, and the solid in the slurry - the filtration cake - is discharged with the red mud [1]. The chemical composition of the filtration cake is shown in Table 1.

Table 1. Chemical composition (%) of filtration cake from a certain factory.

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	MgO	L.O.I.	Other
27.98	6.21	1.86	1.39	0.55	2.27	34.17	0.64	24.87	0.06

As seen from Table 1, the main components of the filtration cake are aluminum oxide and calcium oxide, and the A/S is 4.5, which has recycling value.

The recovery of alumina and calcium aluminates can not only reduce the consumption and recovery of alumina, but also reduce the production of red mud, which has good economic and social benefits.

2. Red Mud Separation and Settling Experiment

The experimental material is filtration slug slurry from two alumina refineries.

- a. Tools used: 2500 mL settling tubes, 2.5 mL and 5 mL needle syringes, stirrers, and stopwatches.

- b. Additives X and Y: Prepared to a concentration of 3 %.

The experiment proved that the addition amount increased from 50 g/t dry mud to 100 g/t dry mud. Two additives X and Y were used to test separately where X had a poor effect, while Y had a good effect. The addition amount of 60–80 g/t dry mud was better, and the supernatant was clear, while almost no separation was observed without the addition of additives.

When the dosage of the Y additive was 50 g/t dry mud and 100 g/t dry mud, the effect was good, and the flocs were large. The compression effect was good at 1 min 16 s and 1 min 10 s respectively, with liquid-solid (L/S) weight ratio of 2:3. The supernatant is clear as shown in Figure 1. The experiment data are shown in Table 2.

Table 2. Experimental data.

Additive	Concentration	Additive amount	Settling time	Mud layer volume (5 min)	Settling velocity
		g/t dry mud	s	mL	m/h
X	0.30 %	50.88	296	142	0.51
		59.36	263	145	0.57
		69.53	220	155	0.69
		79.71	201	138	0.75
		89.88	192	150	0.79
		101.75	220	150	0.69
Y	0.30 %	50.88	76	58	1.99
		59.36	75	55	2.02
		69.53	73	64	2.07
		79.71	71	73	2.13
		89.88	77	68	1.96
		101.75	70	70	2.16



Figure 1. Effect diagram of additive Y (not added on the right side).

3. Separation Underflow Dealumination Experiment

Tools used: Constant temperature water bath pot, stirring, measuring cylinder.

The experiment used lime milk as an additive, with a solid content of about 250 g/L and an effective calcium solid content of about 180 g/L. The separation underflow liquid-solid weight ratio was prepared to 2:3, and lime milk was added according to the reaction product $3\text{CaO} \times \text{Al}_2\text{O}_3 \times 6\text{H}_2\text{O}$. Dealumination experiments were carried out at temperature of 60 °C, 70 °C, 80 °C, and 90 °C, with reaction times of 20 min, 25 min, 30 min, 35 min and 40 min. The experiment results shows that temperature conditions have limited influence on dealumination, and the reaction time is 30 minutes. After the reaction, the molecular ratio increases to about 3.0. The results of dealumination experiments are shown in Table 3.

Table 3. Result of dealumination experiments.

Index	Polished pregnant liquor	90 °C Adding lime milk		60 °C Adding lime milk	
		30 min	50 min	30 min	50 min
Na_2O_k (g/L)	168	85.5	91	101	104
Al_2O_3 (g/L)	187.17	40.43	43.12	47.27	48.25
α_k ($\text{Na}_2\text{O}_k/\text{Al}_2\text{O}_3 \times 1.645$)	1.48	3.48	3.47	3.51	3.55

4. Filtration Cake Recovery Plan

Take the alumina refinery with an annual output of 2 million tonnes produced by Bayer process as an example, the unpolished pregnant liquor flow rate is approximately 3000 m³/h. The suspended solid concentration in the unpolished pregnant liquor added with lime milk filter aid is 1.1 g/L, and all of them are filtered by automatic Kelly filters. The solid content of the filtration slug slurry is 35 g/L, and the solid content, Al_2O_3 content, and slurry volume are as highlighted in Equations (1), (2) and (3):

$$3000 \times 1.1 = 3300 \text{ kg/h} \quad (1)$$

$$3300 \times 28 \% = 924 \text{ kg/h} \quad (2)$$

$$3300 \div 35 = 94.29 \text{ m}^3/\text{h} \quad (3)$$

At present, most the alumina refineries transport the filtration slug slurry to the dilution tank to recover the liquid phase, while the solid phase is discharged with the red mud. The filtration cake has not been effectively recovered. Based on the actual situation of alumina production process, two types of filtration cake recovery methods are proposed below.

4.1 Recycling Plan 1

This plan includes settling and separation of the filtration slug slurry, with an overflow back to the unpolished pregnant liquor tank, and underflow back to the pre-desilication system. The flowchart is shown in Figure 2 [2]:

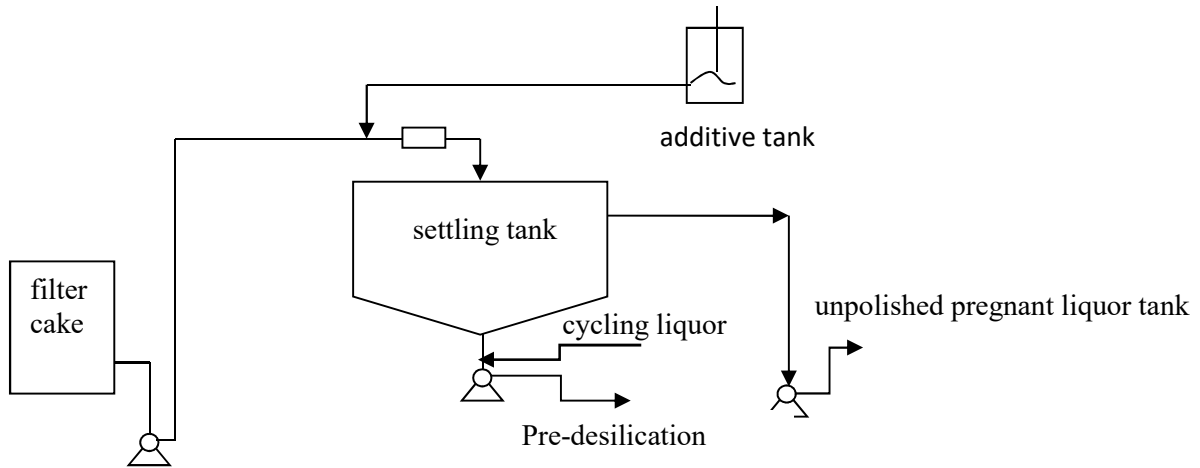


Figure 2. Plan 1 process flowchart.

The filtration slug slurry inside the filter cake tank is pumped to the settling thickening tank, and an optimal amount of additive is added for liquid-solid separation. After separation, the overflow is pumped to the unpolished pregnant liquor tank, and the underflow is pumped to the pre-desilication system. Considering the small amount of underflow liquid, it is considered to partially recycling of liquor to reduce solid content, facilitate transportation, and suppress alumina loss.

It is estimated that the underflow L/S is 3.0, and based on this, 75 % of the liquor contained is calculated, with a solid content of approximately 312 g/L (or kg/m³). Taking the Bayer process, alumina refineries with an annual output of 2 million tonnes as an example, after separation, the underflow flow is as shown in Equation (4):

$$3300 \div 312 = 10.58 \text{ m}^3/\text{h} \quad (4)$$

overflow flow rate is as shown in Equation (5):

$$94.29 - 10.58 = 83.71 \text{ m}^3/\text{h} \quad (5)$$

The actual amount of additive Y added is 50 g/t solid slag, and the additive consumption is as shown in Equation (6):

$$3300 \div 1000 \times 50 = 165 \text{ g/h} \quad (6)$$

The preparation concentration is 0.5 %, so the added amount is as shown in Equation 7:

$$165 \div 0.5 \% = 33\,000 \text{ g/h} \approx 0.033 \text{ m}^3/\text{h} \quad (7)$$

4.2 Recycling Plan 2

Process the settlement underflow in Plan 1, as shown in Figure 3:

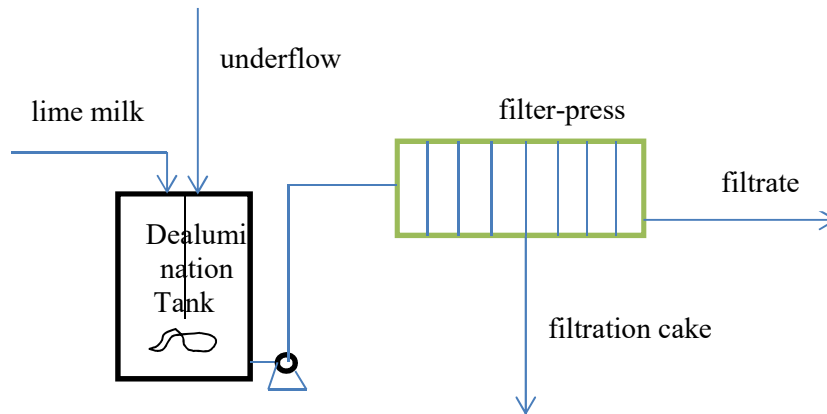


Figure 3. Plan 2 process flowchart.

Based on Plan 1, this plan mainly recovers the settling underflow attached liquid to reduce the impact of low molecular ratio in the attached liquid on digested bauxite slurry. By adding lime milk to remove aluminum and increasing molecular ratio, the aluminum removal slag is easy to filter and less hydrolyzed. After filtering, the filtrate is returned to the spent liquor for evaporation tank, and the filter cake is returned to the pre-desilication system.

Settling underflow flow rate, Equation (4): 10.58 m³/h

Liquor contained capacity: $10.58 - 3300/2800 = 9.4$ m³/h

Lime milk addition amount (reactant based on 3CaO·Al₂O₃·6H₂O): 7.94 m³/h

Reaction temperature in the aluminum removal tank: about 80 °C, time: about 30 min

Composition of filtrate after reaction: NaO_k 88 g/L, Al₂O₃ 48 g/L, α_k 3.02

Filter cake liquor contained after reaction: about 30 %

Filtrate flow rate: 15.95 m³/h

Filter cake quality: $3300 + 3300 \times 30\%/1.2 = 4125$ kg/h

5. Factory Case: Application of Filtration Cake Recycling

A new 600 m³ pressure filter and a new one Ø6 m × 6 m mixing tank is added. After the filtration cake is filtrated, it is mixed with spent liquor after precipitation and sent to pre-desilication. The process flowchart of the application case is shown in Figure 4 [3].

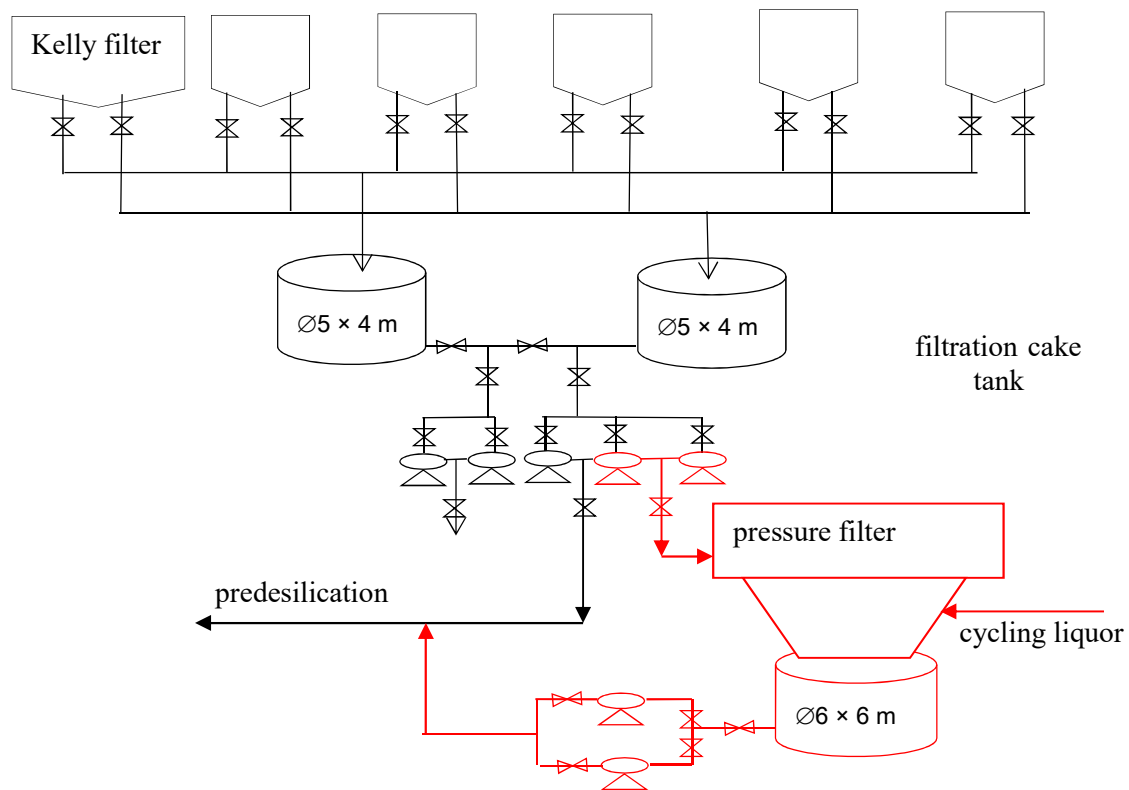


Figure 4. Factory application flowchart.

This process has been applied in an alumina refinery in southern China, with stable production and significant benefits. Every year, 33 000 tonnes of bauxite and 39 606 tonnes of lime are saved, reducing hydrolysis of sodium aluminate.

6. Economic Benefits

After the recovery system is established, lime milk is used as filter aid. Al_2O_3 is 28 %, CaO is 34 %, the relative digestion efficiency is 80 %, and the process loss of CaO is 10 %.

Annual recovery of alumina as shown in Equation 8:

$$3300 \times 28 \% \times 80 \% \times 24 \times 365 \div 1000 = 6475.39 \text{ tonnes} \quad (8)$$

Calcium oxide as shown in Equation 9:

$$3300 \times 34 \% \times (1 - 10 \%) \times 24 \times 365 \div 1000 = 8845.85 \text{ tonnes} \quad (9)$$

The economic benefits vary among different alumina refineries. Taking the northern China alumina refinery with an annual output of 2 million tonnes of alumina as an example, the economic benefits are calculated:

Value of recycled alumina (priced at 407 USD/t) as shown in Equation 10:

$$6475.39 \times 407 \div 1\,000\,000 = 2.64 \text{ MUSD} \quad (10)$$

Value of recovered Calcium oxide (lime priced at 55 USD/t) as shown in Equation 11:

$$8845.85 \times 55 \div 1\,000\,000 = 0.48 \text{ MUSD} \quad (11)$$

Recycling this portion of alumina will increase costs (total alumina production cost - bauxite cost) as shown in Equation 12:

$$6475.39 \times (362 - 104) \div 1\,000\,000 = 1.67 \text{ MUSD} \quad (12)$$

Total annual profit as shown in Equation 13:

$$2.64 + 0.48 - 1.67 = 1.45 \text{ MUSD} \quad (13)$$

7. Conclusion

For the recovery of filtration cake, this article discusses two schemes. Plan 1 involves liquid-solid settling separation of filtration slug slurry, with the liquid phase returning to the unpolished pregnant liquor tank and the underflow containing the liquor being back washed into the pre-desilication system with cycling liquor. In Plan 2, the underflow of Plan 1 is separated and then dealuminated to increase the molecular ratio and reduce the impact of liquor contained on pre-desilication system. Both schemes have effectively recovered the solid phase of the filtration cake. Plan 1 has a simple process and strong feasibility for implementation; Plan 2 has a more complex process, but it can reduce the impact of liquor contained on pre-desilication system.

8. References

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