Industrial Trials of a Belt Filter for Filtration of Strong Evaporated Liquor at RUSAL Krasnoturyinsk

Dmitry Ovsyuchenko[1], Igor Chetyrkin[2], Elena Mitrofanova[3], Sergey Ordon[4], Maksim Pechenkin[5], Andrey Panov[6], Aleksey Perestoronin[7]
1. Industry Segment Manager, RUSAL ETC, St. Petersburg, Russia
2. Director of Technology and Technical Development Department of Alumina Production
3. Technology Manager, RUSAL ETC, Krasnoturyinsk, Russia
4. Deputy General Director for Alumina Production and Ecology
5. Director of Technical Development Department of Refineries,
6. Director R&D Alumina,
7. Senior Researcher, RUSAL ETC, St. Petersburg, Russia.
Corresponding Author: Dmitriy.Ovsyuchenko@rusal.com

Abstract

Alumina production at RUSAL Krasnoturyinsk includes the precipitation of sodium carbonate in the course of spent liquor evaporation which is then separated from the strong evaporated liquor and sent for bauxite sintering. Due to its fine particle size and polydispersity, these sodium carbonate crystals settle and filter poorly (filter cake moisture is as high as 30 %) causing increased caustic alkali and alumina recycling to sintering resulting in additional losses. Incomplete precipitate separation from evaporated liquor also causes accumulation of carbonate in production liquors reducing performance of the evaporation train and leading to decreased evaporated liquor caustic concentration, followed by further accumulation of sodium carbonate. Consequently, improved sodium carbonate removal from RUSAL Krasnoturyinsk process liquors is an urgent problem, especially in view of a planned increase in alumina production capacity. This paper reports on a solution enabling increased carbonate removal efficiency from RUSAL Krasnoturyinsk evaporated liquors. The results of industrial trials of the filtration of strong evaporated liquors on an experimental belt vacuum filter LON-1.8 are presented. In the course of belt filtration of evaporated liquor, humidity of filter cake was decreased by 8.5 % compared to the drum vacuum filters BOU-20 that are used now, and demonstrated the advantage of using belt vacuum filters in the flowsheet of RUSAL Krasnoturyinsk.

Keywords: filtration, slurry, high carbonate bauxite processing, sodium carbonate removal.

1. Introduction

At RUSAL Krasnoturyinsk alumina is mainly produced from North Urals bauxites that are characterized by high content of carbonate (~ 5 – 7 wt. % CO_2) and sulfur compounds (~ 0.7 - 0.8 wt. % S). These impurities cause accumulation of sodium carbonate and sulfate in recycled production liquors that reduce the liquor impurity removal efficiency of the evaporation train.

The main indicator for the removal efficiency of these impurities from liquors is the evaporation level, indicated by $Na_2O_{caustic}$ concentration in the evaporated liquor. Increased carbonate in the liquor fed to evaporation reduces evaporation efficiency due to increased scale on the heating surfaces of evaporation trains; the same effect occurs with increasing liquor sulfate. The resulting loss of heat transfer leads to a decreased evaporation level and degrades carbonate and sulfate removal from the liquor. This causes further accumulation of carbonate in the recycled liquors and a vicious circle of declining impurity removal efficiency. Incomplete removal of crystallized material from the liquor causes the generation of fine precipitated particles that settle poorly in the settling tanks and then impair filtration of sodium carbonate crystals at drum vacuum filters. Filter cake moistures of up to and above 30 %, and Na_2O and Al_2O_3 content increases to 15 – 16 wt. %

and 8 - 10 wt. %, respectively. Consequently, a significant amount of sodium carbonate in the sintering feed is replaced with caustic soda leading to a decrease in the sintering causticization rate, and an increase in the amount of caustic added to the process to balance the refinery alkali losses. Very often the evaporation and soda removal area cannot process the whole flow of spent liquor from the precipitation area mostly because of unsatisfactory processing properties of sodium carbonate and sulfate separated from the evaporated liquors [1].

Thus, sometimes, the existing evaporation capacity for removal soda and sulfates from the liquors is not sufficient even for current alumina production capacity at RUSAL Krasnoturyinsk. In view of a planned production capacity increase, the soda removal area requires an upgrade to improve its operating efficiency.

Presently at RUSAL Krasnoturyinsk sodium carbonate is separated using thickeners for preliminary thickening of precipitated solids in the evaporated liquor from the evaporation trains followed by thickener underflow filtration on drum vacuum filters BOU-20. Use of the thickeners and drum vacuum filters stems from low sodium carbonate solids content in the evaporated slurry from the evaporation trains (70 - 100 gpl) and the fine particle size of the precipitate.

In 2017 RUSAL ETC's laboratory in Saint Petersburg analyzed the properties of carbonate-sulfate precipitates from the Bayer process spent liquor from RUSAL Krasnoturyinsk. Averaged results of some of the tests are indicated below. Chemical composition of the evaporated liquor is specified in Table 1. Analysis of the precipitate indicates a mixture of sodium carbonate and sulfate, aluminium oxide and sodium oxalate [2].

Table 1. Chemical composition of the evaporated liquor.

Na_2O_{total} g/L	$Na_2O_{caustic}$ g/L	$Na_2O_{carb.}$ g/L	Al_2O_3 g/L	SO_3 g/L	$\alpha_{caustic}$	Υ g/cm^3
310.2	281.3	28.9	154.0	10.1	3.0	1.42

The precipitate was examined by microscope, which showed that the precipitate is rolled roughly rounded particles of 20 – 100 µm, with an average size of 50 – 60 µm [1]. Fine particle size and low solids content of the evaporated liquor cause poor settling and filtration properties of the precipitate.

One of the options to improve the separation efficiency of carbonates, sulfates, and organics from evaporated liquors at RUSAL Krasnoturyinsk is implementation of new advanced filtration equipment, e.g. belt vacuum filter (Figure 1).

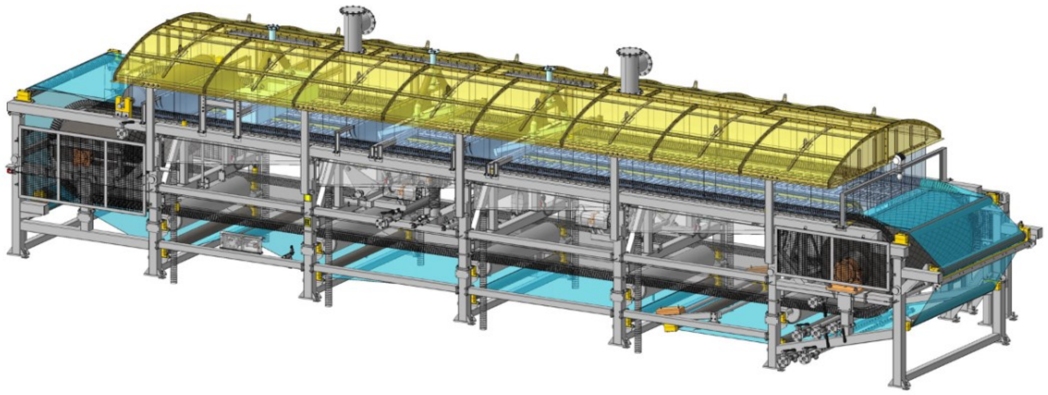

Figure 1. 3D model of a belt filter.

Belt filters are efficient and reliable equipment mainly designed to ensure the continuous mechanical drying of industrial slurries and sludges. Belt filters provide a high degree of precipitate drying. These filters are widely used in various industries: petrochemical, coal, ore mining, metallurgy, food processing and pulp and paper. Unfortunately, they are not commonly used at alumina refineries and currently such filters are installed only to produce side- or by-products of the main production.

2. Experimental

To verify the capability of filtering “red” soda from evaporated liquors using belt vacuum filters under actual process conditions, a pilot unit equipped with belt filter LON-1. 8 (manufactured by “Progress”, Ukraine) was installed at RUSAL Krasnoturyinsk.

The pilot unit is shown in Figure 2. It comprises of the following main elements:

- belt vacuum filter;
- receiver;
- trap;
- pump for filtrate discharge.

The design of the pilot filter allows for adjustment of the belt speed with a variable-speed motor. Speed of the filter belt varies from 0.013 to 0.08 m/s. This feature was used for carrying out pilot tests. The dependences of preciptate cake moisture, solids content in the filtrate and filter specific capacity on the belt speed (filter capacity) were determined.

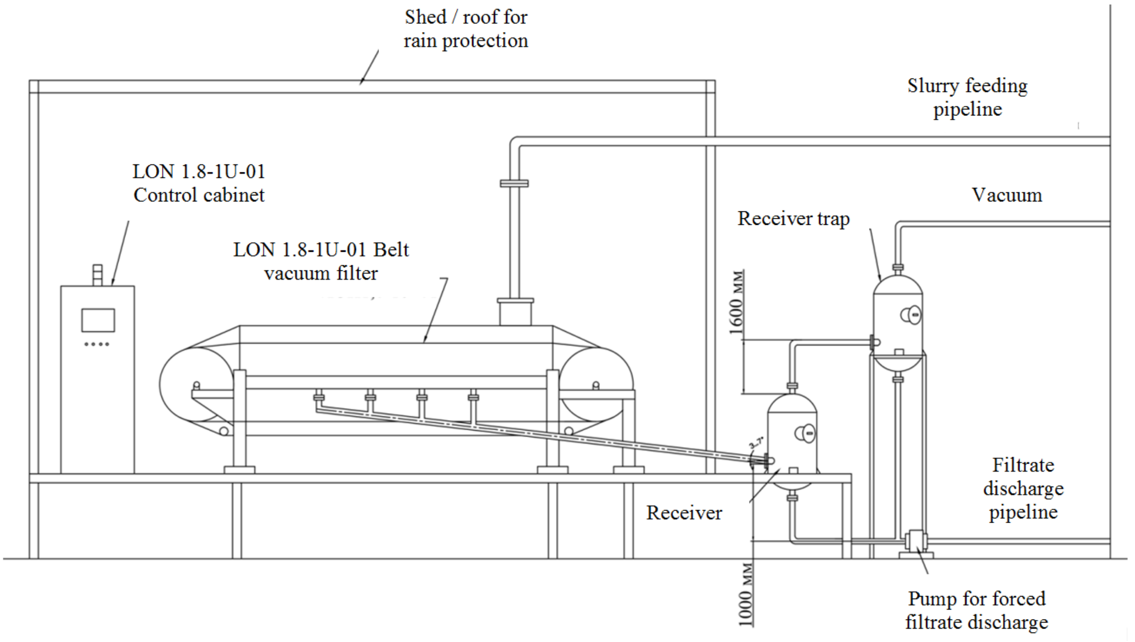

Figure 2. Layout of a trial belt filter.

Pilot testing of belt filter operation comprised two stages. In the first stage the belt filter was fed from the precipitate slurry agitating tank after preliminary thickening of the evaporated slurry from the evaporation train in the settling tank as per the standard process flowsheet. During the testing procedure thickened precipitate slurry was diluted to solids content of 50 – 110 g/L by opening the cone of a settling tank to provide the operation of an agitated crystallizer. A reference filter for a pilot filter LON-1.8 was an existing drum vacuum filter BOU-20 fed with the routine slurry. At the second stage the belt filter was fed directly from evaporation train No 9 without use of a preliminary settling tank.

3. Results

Average values from sampling during the tests are presented in Table 2 and Table 3.

Table 2. Performance of belt and drum filters fed with slurry from the settling tank*.

Product	Belt speed, s/1m	Vacuum, atm g	Solids, g/L	Moisture, %	Cake height, mm	Solids yield, kg/m²*h	Slurry volume, m³/h	Delta moisture, %
feed slurry DF		0.26	369					
filtrate DF			20.5					
cake DF				29.9				
feed slurry BF	92	0.38	247					
filtrate BF			8.3					
cake BF				28.4	14.3	170.6	2.1	1.6
feed slurry DF		0.27	476					
filtrate DF			27.0					
cake DF				31.2				
feed slurry BF	71	0.40	254					
filtrate BF			14.6					
cake BF				26.8	13.8	218.3	1.6	4.4
feed slurry DF		0.19	399					
filtrate DF			22.2					
cake DF				32.8				
feed slurry BF	58	0.43	247					
filtrate BF			13.5					
cake BF				28.7	7.75	146.8	1.6	4.0

Table 3. Performance of belt and drum filters fed from the evaporation train*.

Product	Belt speed, s/1m	Vacuum, atm g	Solids, gpl	Moisture, %	Cake height, mm	Solids yield, kg/m²*h	Slurry volume, m³/h	Delta moisture, %
feed slurry DF		0.20	366					
filtrate DF			11.5					
cake DF				30.7				
feed slurry BF	92	0.33	76					
filtrate BF			7.7					
cake BF				22.0	18.2	256.0	8.0	8.8
feed slurry DF		0.18	428					
filtrate DF			16.2					
cake DF				31.9				
feed slurry BF	71	0.29	94					
filtrate BF			8.5					
cake BF				24.0	17.8	328.4	7.96	8.0
feed slurry DF		0.20	381					
filtrate DF			17.5					
cake DF				32.3				
feed slurry BF	58	0.29	85					
filtrate BF			5.4					
cake BF				23.3	21.8	507.5	15.36	9.0

*Average values for the sampling period.

4. Discussion

The data demonstrates that cake moisture from the pilot filter only slightly depends on filter belt speed, i.e. filter capacity. The best correlation with soda cake moisture values is observed with the initial solids content of the filter feed slurry. It should be noted that when solids content in the filter feed slurry is ≈ 250 g/L (when the slurry is fed from the settling tank), the cake moistures from the pilot filter vary between 27 and 29 %, on average 3.3 % lower than those from the drum filter. If solids content in the feed slurry is reduced to 80 – 85 g/L (when the slurry is fed directly from the evaporation train), the actual cake moisture from the pilot filter reduces to 22 – 24 %, that is 8.5 % lower than the cake moisture from a drum filter BOU-20.

The dependence of the pilot filter cake moisture on the feed slurry solids content from the evaporation train are shown in Figure 3 and Figure 4.

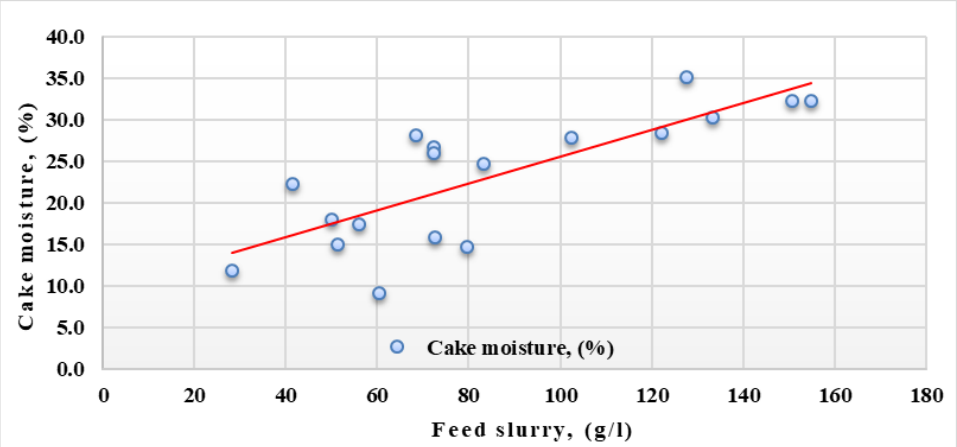

Figure 3. Dependence of the pilot filter cake moisture on the filter feed slurry solids content (from the evaporation train).

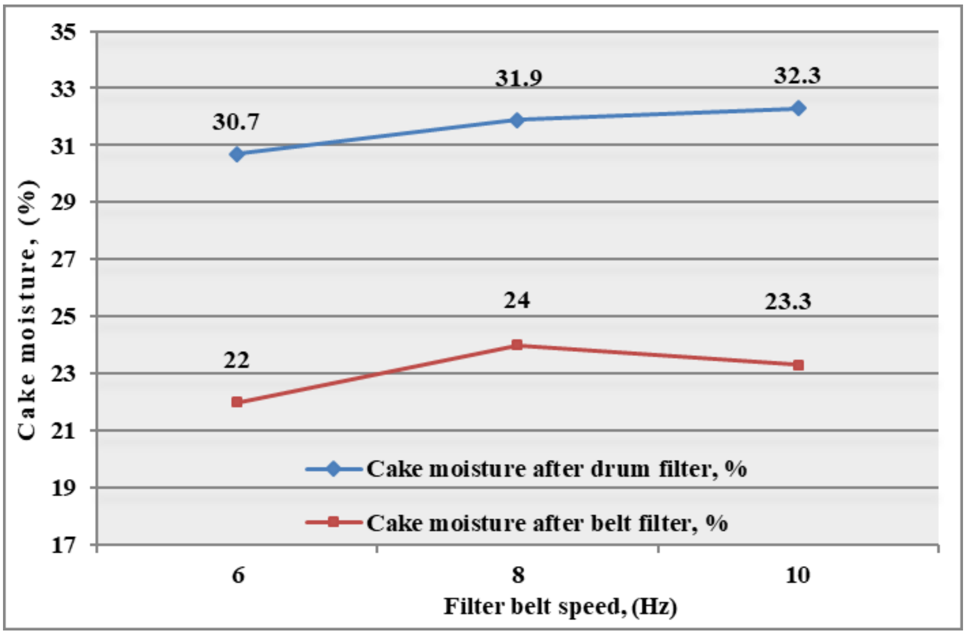

Figure 4. Comparison of pilot belt filter and reference drum filter cake moistures. (BF is fed from the evaporation train).

* Average values for the sampling period.

When the pilot filter is fed directly with the evaporated slurry, the cake moisture reduces by ~ 8.5 % compared to the settling tanks and vacuum filters (BOU-20) currently used.

Further the performance of the pilot filter fed with the evaporated slurry from evaporation train No 9 is presented, i.e. the pilot filter is fed with the evaporated liquor without preliminary thickening.

Based on the test results, the filtrate solids from the belt filter amounted to 7.2 g/L, 52 % less than the filtrate from reference filter BOU-20 which was 15.1 g/L. According to RUSAL Krasnoturyinsk's process control data, from the beginning of 2019 average solids content in the settling tanks' overflow was 13.5 g/L. So a belt vacuum filter produces better filtrate quality compared with the current process flowsheet of drum filters and settling tanks.

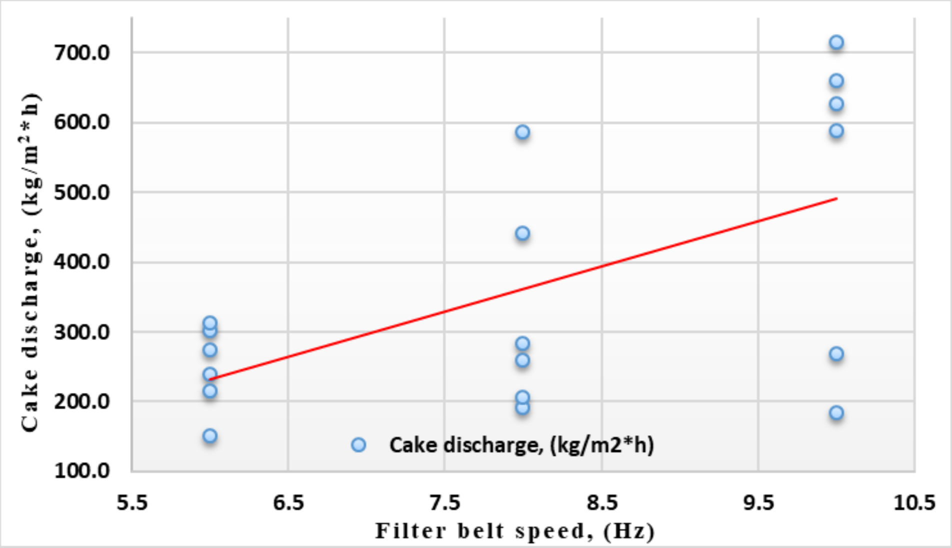

Figure 5. Dependence of filter capacity and cake moisture on the filter belt speed.

Figure 5 shows that if the filter belt speed increases, the specific cake discharge (kg/m^2×h) increases proportionately. The maximum filter capacity of 507.5 kg/m^2×h without degradation of filter process parameters is achieved at a maximum filter belt speed of 10 Hz.

Analysis of the data obtained indicates that if the specific filter capacity increases, cake moisture and solids content in the filtrate from the pilot belt filter remain practically the same. This suggests that the specific capacity of the filter may be further enhanced by using different designs/layouts of belt filters, more efficient filter cloths and optimizing the operating parameters of such filtration equipment [3].

Based on the data obtained for the pilot filter capacity, the required filter belt area has been calculated for the whole flow of the evaporated soda liquor at RUSAL Krasnoturyinsk.

5. Conclusions

Pilot tests at RUSAL Krasnoturyinsk using actual process liquors proved the viability of using a belt vacuum filter for separation of recycled sodium salts from the evaporated slurry both the slurry directly from the evaporation train and the thickened slurry from the settling tank.

In the course of the filtration tests using the evaporated slurry directly from the evaporation train with solids content of 80 – 85 g/L, the cake moisture from the pilot filter was 22 - 24 %. This cake moisture is 8.5 % lower than with the current process flowsheet of settling tanks and drum filters BOU-20.

Based on the test results, the belt filter filtrate solids content amounted to 7.2 g/L, or 52 % less than the filtrate solids content from a reference filter BOU-20 (15.1 g/L), and 44 % less than the overflow from the settling tank (13.5 g/L).

Pilot tests proved that implementation of the belt filter to remove precipitated soda salts from recycled liquors is much more effective than the current process used at RUSAL Krasnoturyinsk in terms of both cake moisture and filtrate quality. This technology appears to be a promising option to enhance the capacity of the evaporation area to remove carbonate and sulfates from the liquors. Currently work on front-end engineering design of a new area for “red” soda removal using belt vacuum filters at RUSAL Krasnoturyinsk is in progress.

6. References

1. A.V. Perestoronin, G.V. Tokarev, M.N. Pechenkin, E.N. Mitrofanova “Study of crystal growth of recycled soda at Bogoslovsk Refinery”. // Aluminum of Siberia – 2017, Book of papers, Krasnoyarsk, 2017, pp. 71-77.
2. Perestoronin A.V. Soda crystallization from aluminate process liquors: thesis for a Candidate Degree in Technology: 05.17.01 / A.V. Perestoronin – Saint Petersburg, 2016. – p. 176.
3. Report on “Improvement of effectiveness of soda removal from recycled liquors of “RUSAL Krasnoturyinsk”: R&D report / “RUSAL ETC” LLC, Saint Petersburg, 2019 - p. 23.