

STUDYING PROCESSES OF HIGH-TEMPERATURE DIGESTION OF SUBR AND TIMAN BAUXITES

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High-temperature digestion (HTD) of monohydrate bauxites is currently becoming the prevailing tendency in Russia in the reconstruction of existing and creation of new alumina refineries based on the Bayer technology. The advantages of the high-temperature digestion process (HTD process) are obvious. They include: high speed of the process and increased extraction of bauxite alumina, as well as significant reduction of the impact of recycled liquor concentration if the temperature is increased.

The main type of alumina-containing raw material at Bogoslovsk and Urals aluminium smelters are bauxites from SUBR (North Ural Bauxite Mine) and Timan (Bezhayuborykvinskoye Bauxite Mine) deposits. With the lapse of time, the quality characteristics of the used bauxites change. Thus, for proper application of the HTD process at Urals plants, it was necessary to specify the process parameters for bauxites in current shipments and forecast bauxites.

We have conducted laboratory studies of the HTD process for bauxites from the SUBR and Timan deposits. During these, we determined the major process parameters of this process, demonstrated the performance of bauxite impurity components at high (260-265°C) digestion temperatures. We made a special focus on the issue of digesting Timan bauxites with a high content of chamoisite, which degrades the performance indicators of alumina refining from this type of raw material.

For studying these bauxites, the temperature of 260°C was selected. Further increase of temperature is not practicable due to the fact that higher supersaturation of liquor occurs at higher temperatures, which leads to increased alumina loss in subsequent desilication and thickening within the flow diagrams existing at the plants.

The chemical properties, structure and mineralogy of bauxite have a considerable impact on bauxite extraction (process efficiency) and alkali loss with waste red mud.

SUBR bauxite has the following mineralogy characteristics:

- main alumina-containing mineral: diasporite characterised by the lowest solubility (leachability);



- silica-containing minerals: kaolin and chamoisite with prevailing content of the first component;
- significant content of impurity components: carbonates (calcite and siderite) and sulphur sulfide (pyrite).

Middle-Timan Bauxite Mine (STBR) bauxite has the following mineralogical characteristics:

- main alumina-containing mineral: boehmite;
- silica-containing minerals: chamoisite and kaolin with prevailing content of the first component;
- insignificant content of carbonates (calcite) with almost zero sulphur content.

It was determined that during processing of STBR bauxites in the HTD process, the optimal fineness is $-0.315 \text{ mm} - 100\%$, whereas for SUBR bauxites, finer grinding is required ($-0.1 \text{ mm} - 100\%$). This is related to the differences in the bauxite structure, which is mainly oolitic coarse powder for SUBR diasporite and polymorphic boehmite for STBR bauxite.

We determined equilibrium caustic modules of aluminate liquor in high-temperature digestion (260°C) of SUBR and STBR bauxites with recycled liquor, whose caustic alkali concentration is $C = 200\text{--}220 \text{ g/dm}^3$. For STBR bauxites, the caustic module of liquors obtained (α_k) was 1.3-1.32. If the amount of ferrous iron was increased, the equilibrium module of liquor increased up to 1.33. In HTD of SUBR bauxite, the values of the equilibrium caustic module (α_k^{equil}) reached 1.37. The determination of the maximum alumina extraction allows us make the conclusion that conducting high-temperature autoclave digestion allows almost all alumina contained in SUBR bauxite to be extracted.

Studying high-temperature digestion of SUBR bauxite demonstrated (see Table 1) that for efficient extraction of alumina from it, it requires quite concentrated recycled liquor ($C_{\text{NazOk}} \sim 220 \text{ g/l}$ – caustic alkali concentration). This is related to the fact that increasing C_{NazOk} in the digestion area increases the intensity and depth of the calcite decomposition process $\text{CaCO}_3 \rightarrow \text{CaO}_{\text{active}}$, which requires input of a less activating calcium-containing additive from the outside. The lime dosing should be at least 1% to the bauxite weight, since if there is not additional input of calcium oxide, alumina extraction decreases rapidly by $\sim 5\%$.

It was noted that the HTD process for SUBR bauxite, compared to the similar processing of Timan bauxites ensures low content (loss) of alkali in waste red mud: The ratio of $\text{Na}_2\text{O}:\text{SiO}_2$ is 0.24 units with CaO dosing = 1.0% by weight and 0.18 units with CaO dosing = 2.0%, respectively, while in the HTD process of Timan bauxite, the value of $\text{Na}_2\text{O}:\text{SiO}_2$ is twice higher and averages 0.45-0.50 units.

Using thermogravimetric and X-ray-structural analysis techniques, we studied the performance of silica minerals (chamoisite and kaolin) in the temperature range of $100\text{--}280^\circ\text{C}$ and determined the degree of their decomposition, i.e. the content of reactive silica in SUBR and STBR bauxites, and also studied the performance of titanium and temperature intervals of perovskite generation for SUBR and STBR bauxites.

It is interesting that aluminate-alkali liquor after the HTD process for SUBR bauxite has a lot higher silica module (μ_{Si}) than the same



liquor after the HTD process for STRB bauxite. μ_{Si} values are 280-300 and 150-180, respectively. This is related, firstly, to a high content

Table 1

Impact of process parameters on alumina extraction and sodium oxide loss with red mud during high-temperature digestion of SUBR bauxite

Parameter measured	Other process parameters	Analysis of liquid phase, g/dm ³						Analysis of solid phase, mass %						Extraction of Al ₂ O ₃			Ratios in red mud		
		Na ₂ O	Al ₂ O ₃	Al ₂ O ₃	SiO ₂	M ₆₀	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	CaO	Na ₂ O	η _{chemical}	η _{theoretical}	(η _{chemical} - η _{theoretical}) / 100	CaO/SiO ₂	Al ₂ O ₃ /SiO ₂	Na ₂ O/SiO ₂		
Post-desilication slurry dosing module	t = 260°C, τ = 1 hour, C _{baux} = 200 g/dm ³ , C _{CaO_{active}} = 2.0 wt %	187.5	219.1	1.41	0.59	369.8	10.5	46.3	6.47	14.7	1.12	90.72	93.92	96.59	2.27	1.62	0.173		
		184.2	214.2	1.41	0.68	315.0	15.6	43.9	6.25	14.0	1.17	85.46	93.92	91.0	2.24	2.50	0.19		
		184.5	211.7	1.43	0.60	306.8	20.5	40.3	5.69	14.2	1.08	79.19	93.92	84.20	2.50	3.60	0.19		
Lime dosing, %	t = 260°C, τ = 1 hour, C _{baux} = 190 g/dm ³ , α ₀ = 1.40	175.1	187.0	1.54	0.81	216.2	16.45	42.75	6.50	9.7	1.95	84.50	93.92	0.900	1.49	2.53	0.30		
		174.2	194.9	1.47	0.70	278.4	14.61	43.27	6.53	12.4	1.56	86.43	93.92	0.920	1.90	2.24	0.24		
		173.7	198.4	1.44	0.62	320.0	12.69	45.06	6.71	14.6	1.20	88.70	93.92	0.944	2.18	1.89	0.18		
Alkali concentration in recycled liquor, g/l	t = 260°C, τ = 1 hour, α ₀ = 1.40, C _{baux} = 200 g/dm ³ , C _{CaO_{active}} = 1.0 wt %	164.8	172.7	1.57	0.60	288.0	18.7	41.8	6.15	11.4	1.67	82.04	93.92	0.874	1.85	3.04	0.272		
		184.2	211.9	1.43	0.68	315.0	13.4	46.4	6.63	12.8	1.72	88.84	93.92	0.946	1.93	2.02	0.260		
		198.1	238.8	1.40	0.84	284.3	10.0	48.5	6.79	13.1	1.69	91.70	93.92	0.976	1.93	1.473	0.249		
Duration of digestion, min.	t = 260°C, C _{baux} = 220 g/dm ³ , C _{CaO_{active}} = 1.0 wt %, α ₀ = 1.40	198.6	230.1	1.42	1.02	225.5	11.0	46.9	6.56	12.9	1.61	90.60	93.92	0.965	1.97	1.682	0.245		
		198.0	231.0	1.41	0.93	248.4	10.6	47.9	6.64	13.1	1.64	90.94	93.92	0.968	1.97	1.600	0.247		
		198.1	238.8	1.40	0.84	284.3	10.0	48.5	6.79	13.1	1.69	91.70	93.92	0.976	1.93	1.473	0.249		

of kaolin in SUBR bauxite, which easily transforms into desilication products; secondly, to sulphur impurity present in SUBR bauxite, which leads to higher liquor desilication.

It was determined that during the HTD of SUBR bauxite, transfer of sulphur into aluminate-alkali liquor significantly increases – up to 50-55% during digestion. It was found that prolonged pre-soaking of raw slurry, notably, 4 hours (degree of sulphur transfer to liquor is about 10%) will promote the reduced transfer of sulphur.

Thus, high-temperature digestion of SUBR bauxite allows, with high degree of chemical alumina extraction ≥ 91% (>97% of theoretical value) and low alkali loss with waste red mud (Na₂O:SiO₂ ~ 0.25), to obtain aluminate liquor with caustic module 1.40, which is even more advantageous for obtaining coarse-grained (sandy) aluminium hydrate.

The following HTD process conditions for SUBR bauxite are sufficient and necessary:

- temperature: 260°C;
- concentration of Na₂O_k in digestion liquor ~ 220 g/dm³ (in the digestion area ~ 200 g/dm³);
- post-desilication slurry dosing module: 1.40;
- additional dosing of CaO_{active}: 1.0% by weight;
- duration of digestion process: 1 hour;
- bauxite fineness: content of 0.1 mm grain content – 100% (60-90 μm category – at least 70%).

Due to the fact that at present,



Table 2

Studying process parameters during digestion of STBR bauxite with a varying content of chamoisite

The chemical properties, structure and mineralogy of bauxite have a significant influence on alumina extraction and alkali loss with waste red mud.

	Bauxite sample No.	Variable parameters	α_k of aluminium silicate liquor	Alumina extraction (to theoretical), %	Alkali loss with red mud, $\frac{Na_2O}{SiO_2}$	
Digestion temperature, °C	STBR (9% of chamoisite)	250	1.36	97.0	0.48	
		260	1.35	97.6	0.47	
	STBR (13% of chamoisite)	250	1.42	95.8	0.47	
		260	1.37	96.3	0.48	
Dosing of CaO_{active} , % to bauxite weight	STBR (9% of chamoisite)	0	1.38	96.5	0.48	
		1	1.35	97.6	0.47	
		2	1.35	97.1	0.46	
	STBR (13% of chamoisite)	3	1.36	96.2	0.41	
		0	1.39	95.6	0.51	
		1	1.37	96.3	0.48	
		2	1.35	96.4	0.46	
		3	1.38	95.0	0.46	
		0	1.39	95.6	0.51	
	Concentration of $C_{Na_2O_k}$ in recycled liquor, g/dm^3	STBR (9% of chamoisite)	165	1.38	97.1	0.47
			180	1.35	97.3	0.47
			200	1.34	97.6	0.46
STBR (13% of chamoisite)		165	1.45	92.3	0.51	
		180	1.38	96.1	0.50	
		200	1.34	97.0	0.51	
Duration of digestion, min.	STBR (9% of chamoisite)	30	1.37	97.0	0.45	
		45	1.34	97.5	0.47	
		60	1.35	97.6	0.47	
	STBR (13% of chamoisite)	30	1.42	92.7	0.46	
		45	1.39	94.7	0.44	
		60	1.37	96.3	0.48	

the silica module in STBR bauxite is gradually decreasing from $\mu_{Si} = \sim 9.0$ to $\mu_{Si} = \sim 7.5$ due to increased content of the main silica-containing mineral chamoisite, the process parameters of the HTD process for this bauxite were specified depending on the content of chamoisite therein.

Table 2 presents the data on the impact of variable parameters on alumina extraction and alkali loss with cryolite mud during hydro-chemical processing of STBR bauxite with a varying chamoisite content. Changing one of the process parameters, the other parameters were adopted as follows:

- duration of process: 60 min;
- synthetic recycled liquor with $C_{Na_2O_k} \sim 180 g/dm^3$;
- caustic module of recycled liquor $\alpha_k^{r.l.} = 3.15$;
- dosing caustic module $\alpha_k^{dos.} = 1.35$;
- 1% addition of $CaO_{active+}$ to the bauxite weight;
- process temperature: 260°C.

As one can see from Table 1, a high content of chamoisite requires more rigid digestion conditions. At the same time, it was determined that the content of Al_2O_3 in chamoisite was $\sim 15\%$, and in sodium hydroaluminium silicate formed during chamoisite decomposition, its content is $\sim 34\%$. Thus, it is obvious that full decomposition of chamoisite will lead to high

alumina loss. Therefore, it is necessary to perform further research into the issue of chamoisite decomposition in production.

Laboratory research of high-temperature digestion of SUBR and Timan bauxite was performed. Process parameters were determined for the optimal processing of this raw material. Positive and negative sides of the digestion process at 260°C were singled out. These studies can be used for modernisation and construction of new alumina refining capacities of UC RUSAL.

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