Kinetics of Quartz Dissolution and Impact on Boehmite Extraction

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Abstract

In the Bayer Process, the dissolution of alumina happens under various digestion conditions. While low temperature digestion dissolves trihydrate alumina phase (THA), high temperature digestion process is required to dissolve mono-hydrate alumina (MHA). In high temperature digestion process, in addition to MHA, the amount of quartz present in bauxite also plays a vital role in the estimation of digestion efficiency. The quartz content is estimated by the difference between the total silica (SiO_2) and kaolinitic silica ($k.SiO_2$) in bauxite. Unlike in the low temperature digestion, wherein the amount of $k.SiO_2$ attacked by caustic liquor is solely considered to estimate the desilication efficiency across pre-desilication tanks and low temperature digestors, in the high temperature digestion, the quartz attack is also considered as a factor in the estimation of overall desilication reaction and chemical extraction. Even though 100 % attack of $k.SiO_2$ occurs for both double digestion as well as high temperature refineries, the quartz attack is low and is dependent on the quartz content, mineralogy, and conditions prevalent in high temperature digestion. Studies conducted earlier with Indian bauxites from eastern region, indicated that the quartz attack can be maximum of 30 %. However, considering the change in bauxite mineralogy over the years and the upgrade of the digestion technology to higher digestion temperatures (~ 280 °C), it is imperative to study the kinetics of quartz dissolution in detail.

The impact of bauxite quality in terms of varying MHA and quartz content have been studied under high temperature digestion conditions to estimate the extent of quartz dissolution and subsequently its impact on digestion extraction efficiency. This paper presents details of the test work done to establish the relationship between kinetics of quartz dissolution and bauxite quality viz MHA and quartz content under high temperature digestion conditions.

Keywords: Bauxite, Digestion, Extraction, Mono Hydrate, Quartz.

1. Introduction

In alumina refineries practicing high temperature digestion, the extraction efficiency is mainly dependent on the extent of mono hydrate alumina (MHA) extraction along with that of alumina tri hydrate phase. The extent of MHA extraction depends upon the concentration of MHA present in the bauxite, its mineralogy, and the conditions prevalent in the high temperature digestion. The mineralogy of the MHA phase is measured through Boehmite Crystalline Size (BCS). The higher the value of BCS [1], the coarser is the size of MHA and lower is the chemical extraction efficiency. In addition to the MHA content, the quartz content and the extent of attack also has an impact on the overall extraction efficiency in a high temperature digestion refinery. The quartz content in bauxite is estimated from the difference between the total SiO_2 and $k.SiO_2$ content. The extent of quartz attack is dependent on the mineralogy, the efficiency of bauxite grinding and the conditions prevalent in the high temperature digestion. Quartz attack can be estimated in terms of the amount of alumina taken from liquor to form sodalite during high temperature digestion. Since there are alumina losses with the sodalite formation, this has an indirect impact on the overall chemical extraction efficiency across the high temperature digestion. Studies conducted earlier, with Indian bauxites from eastern region [2], indicated that the quartz attack can be maximum of 30%. However, considering the change in the mineralogy of the bauxites over the years and with the upgrade of the digestion technology, it is imperative to study the impact of quartz concentration and the extent of dissolution of boehmite.

An attempt has been made in this study to understand the impact of change in quartz and MHA content in bauxite along with the extent of quartz content on boehmite extraction. This paper presents the details of the studies conducted with various bauxite samples from eastern and western regions of India, the results obtained, and the optimum process conditions to achieve the target chemical extraction.

2. Conceptual Approach

Silica in bauxite is present in two major forms namely, kaolinitic silica (k-SiO_2) and quartz. Kaolinitic silica represented by the formula $Al_2O_3.2SiO_2.2H_2O$ is mainly attacked during the desilication process along with low temperature digestion. Approximately 75 to 80 % k-SiO_2 attack occurs during the desilication process, while the rest, 20–25 %, gets attacked at digestion. Caustic losses (25–30 kg) occur for every kilogram of SiO_2 present as kaolinite. In contrast, quartz content in bauxite is represented by the formula SiO_2. Since there is no alumina associated with the quartz, the formation of desilication product (sodalite) at high temperature digestion takes up alumina from the liquor. This loss of alumina to form Bayer sodalite using silica dissolved from quartz reaction with sodium aluminate solution, is referred to as quartz attack.

As in the case of kaolinite [3], the extent of quartz attack depends upon the mineralogy of the bauxite especially w.r.t quartz, the content of quartz in bauxite, free caustic concentration and the prevalent high temperature digestion conditions. The higher the quartz attack, higher is the alumina losses and hence it is imperative to maintain optimum conditions to minimize the attack of quartz. Since the quartz attack occurs mainly during the high temperature digestion, it can have an impact on the extraction efficiency in HT Digester by interfering in the dissolution of MHA. Hence an attempt has been made in this study to understand the impact of quartz attack on the TAA extraction by testing bauxites with varying contents of MHA and quartz.

3. Experimental Details and Results

3.1 Bauxite

Bauxite samples received from the refinery were dried and sampled to nominal -30 mesh and then analyzed by X-ray fluorescence and diffraction (XRF and XRD), for elemental and phase composition. The analysis of the bauxite samples is given in Table 1 and the following observations can be made:

- The MHA content of the bauxite samples vary from 5.60 % which is well above the limit of MHA for economic extraction, to as high as 11.10 %.
- The quartz content is varying from 0.34 % to 1.10 %, which is the normal level observed in the eastern & western coast bauxites of India.
- The k.SiO_2 content in bauxites is varying from 79 % to 93 % of T.SiO_2 content.

Overall, the bauxite samples selected for the study show a wide distribution between the MHA content and quartz content for understanding the impact of quartz attack on the boehmite extraction efficiency.

Table 1. Analysis of bauxite samples.

Element	UoM	Bauxite BX-0	Bauxite BX-1	Bauxite BX-2	Bauxite BX-3	Bauxite BX-4	Bauxite BX-5	Bauxite BX-6
LOI	%	20.60	20.90	20.30	22.10	21.10	20.43	21.12
Al_2O_3	%	45.50	45.80	48.10	47.80	45.70	45.38	44.78
Fe_2O_3	%	20.50	20.20	17.10	17.06	20.17	21.00	21.20
SiO_2	%	2.62	2.54	3.95	4.44	4.25	4.52	4.57
TiO_2	%	9.76	9.62	9.58	7.61	7.92	7.83	7.48
P_2O_5	%	0.25	0.24	0.19	0.25	0.18	0.19	0.20
V_2O_5	%	0.32	0.31	0.35	0.26	0.28	0.25	0.27
THA*	%	33.20	33.40	29.80	33.50	30.40	29.64	30.18
MHA**	%	2.28	2.14	3.67	3.71	3.35	3.67	3.47
k.SiO_2	%	6.50	5.60	11.10	6.70	8.90	8.34	6.90
Quartz	%	39.70	39.00	40.90	40.20	39.30	37.98	37.08

* Trihydrate alumina, $Al_2O_3 \cdot 3H_2O$ or $Al(OH)_3$.
** Monohydrate alumina, $Al_2O_3 \cdot H_2O$ or $AlO(OH)$.

3.2 Optimised Conditions for Quartz Attack

Predesilication (PDS) followed by high temperature digestion (HTD) studies were carried out with the bauxite samples selected for the study. The conditions for the study were selected from the earlier studies [4] carried out with Eastern Coast Process ability studies as given in Table 2.

Table 2. Experimental conditions.

Parameters	Units	Value
PDS Temperature	ºC	92
PDS Residence time	h	16
Digestion Temperature	ºC	245
Digestion Time	min	40

The bauxite samples were sampled to nominal 35 mesh (420 µm) and used for the testwork. Predesilication test was carried out first and then the exit PDS slurry was charged to HTD. The slurry after HTD was centrifuged to separate the bauxite residue and liquor. The liquor was analysed for caustic and alumina by using Potentiometric titrator and the residue was further washed, dried, and analysed for elemental composition using XRF to determine the chemical extraction. Further, the HTD bauxite residue was acid leached to remove the sodalite and then the solid sample was analysed for elemental composition by XRF to calculate the quartz attack.

3.2.1 Experimental Results

The variation of quartz and its equivalent attack is given in Table 3 along with the varying MHA percent in different bauxites. There is an increase in the quartz attack with an increase in the quartz content. However, there is a minimum level of quartz above which the quartz attack becomes significant as highlighted in Figure 1.

Table 3. Results of quartz attack and TAA extraction with different bauxites.

Bauxite	Quartz, %	MHA, %	Quartz Attack, %	TAA Extraction, %
BX – 2	0.28	11.1	0	87.2
BX – 0	0.34	6.50	0	102.2
BX – 1	0.4	5.60	0	105.5
BX – 3	0.73	6.70	12.1	81.5
BX – 5	0.85	8.34	14.8	95.9
BX – 4	0.9	8.90	20.7	83.3
BX – 6	1.10	6.90	19.0	98.4

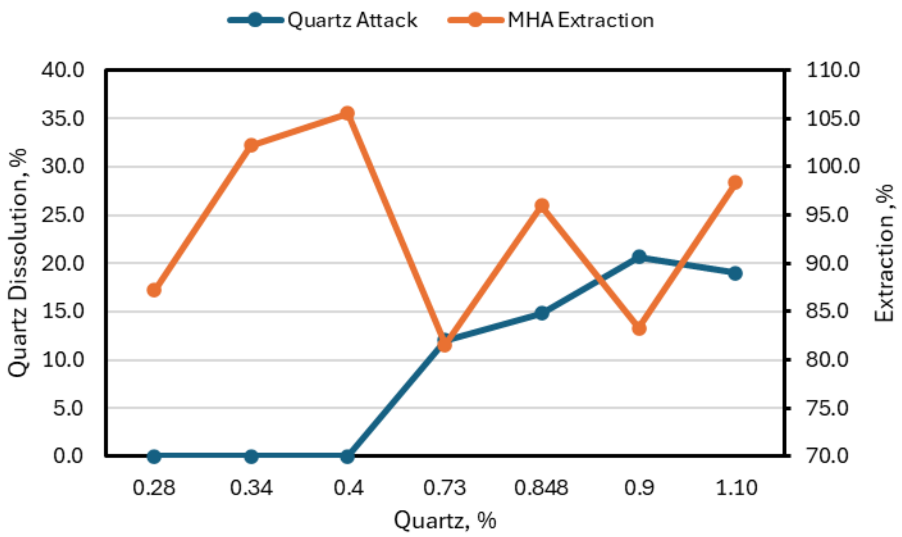

Figure 1. Quartz attack and TAA extraction with different bauxites.

The following observations can be made about the graph shown in Figure 1:

- Quartz attack happens at a quartz content higher than 0.4 %.
- For bauxites with quartz content higher than 0.4 %, the quartz attack increases with the quartz content in bauxite.
- The maximum quartz attack obtained is ~20 %, which is matching with the earlier studies.
- There is a slight drop in the TAA extraction with an increase in the quartz attack.

Overall, it can be concluded that quartz content and the extent of its attack, do have an impact on the overall extraction efficiency in High Temperature Digestion and hence, it is important to also look into the quartz content in bauxite in optimising the conditions in High Temperature Digestion for achieving maximum TAA extraction.

4. Conclusion

This study focusses on determining the impact of quartz content in bauxite and the extent of its attack on extraction efficiency of High Temperature Digestion. Bauxites with varying MHA content (~ 5 % to 11 %) and quartz content (0.3 % to 1 %) from the east and west coast were selected for carrying out the studies. Optimum conditions from the previous studies conducted with east coast bauxites, were used for the testwork. Predesilication followed by High Temperature Digestion tests were conducted under the optimised conditions with all the bauxite samples selected for the study. The bauxite residue samples after HT digestion were analysed for elemental composition to determine the TAA extraction. Further, the HT bauxite residue was acid leached to remove the sodalite part and then the sample was dried and analysed for elemental composition to determine the extent of quartz attack.

It was observed from the testwork that, there exists an optimum content of quartz, above which there is an observed attack of quartz. Results show that above 0.4% quartz content in bauxite, there exists an attack of quartz and the maximum quartz attack obtained is 20% at the conditions used to digest the bauxites used. These results closely match the previous studies carried out with east coast bauxites.

Hence, we can conclude that the content of quartz in bauxite and its extent of attack, do have an impact on the overall extraction efficiency in high temperature digestion. Hence it is imperative that along with the MHA content in bauxite, the quartz content, and the extent of the attack, needs to be taken into account, while optimising the conditions for high temperature digestion to achieve maximum extraction efficiency. Also, the extent of quartz attack will also lead to a reduction in the HT digester productivity, thereby leading to an increase in the specific energy consumption.

5. References

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