DIGESTION STUDIES ON CENTRAL INDIAN BAUXITE

P.K.N. Raghavan, N K Kshatriya, S Dasgupta
Bharat Aluminium Co. Ltd., BALCO Nagar, Korba, India

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Abstract

Indian bauxite deposits are grouped into five categories namely Eastern Ghats, Central Indian, West Coast, Gujarat and Jammu & Kashmir. Each of the bauxites has its own typical digestion and settling conditions due to variations in mineralogy. Bauxite digestion depends greatly on the temperature, pressure conditions, the recycled liquor concentration, bauxite mineralogy and charge quantity. Productivity of the entire Bayer process depends to a large extent on the digestion process. A series of experiments were conducted in an attempt to optimize the digestion conditions for Central Indian bauxite in order to achieve low caustic soda loss coupled with minimum bauxite consumption. Experiments were conducted to find out the best parameters for digestion on a laboratory scale. The effect of digestion temperature, bauxite charge, lime quantity and digestion liquor concentration is discussed in this paper.

Introduction

Alumina extraction from bauxite by the Bayer process requires an efficient digestion. The digestion step in the Bayer process is influenced by the relative amounts of the alumina hydrates present. Atmospheric pressure digestion technology can be used for only Gibbsitic bauxite with negligible or no boehmite content. Low pressure digestion technology on the other hand is used for the Gibbsitic bauxite which contains some boehmite. High pressure digestion (with or without catalyst addition) is exclusively used for the boehmitic bauxite or diasporic bauxite. The digestion process developed by Bayer was designed to treat European bauxite having moderate boehmite and some gibbsitic but negligible diaspore. These latter bauxites need to be digested at high temperature up to 240-2500C and high pressure up to 30-35 atm. Lime addition facilitates the extraction of boehmite.

Caustic soda consumption is controlled by the digestion conditions and the amount of the kaolinite and quartz. The performance of the digestion process is a function of various parameters such as the digestion liquor concentration & Molar Ratio, the digestion temperature, the bauxite charge, residence time and lime addition. In practice, because of the fluctuating operations either all or a few of the above parameters do deviate from the laid down norms causing continuous variations in the digestion efficiency. The productivity of the entire Bayer process depends to a large extent on the efficiency of the digestion process. In this case high temperature digestion (235-245°C) is used for Central Indian bauxites because of the boehmite content.

Plant efficiency requires an optimization of the digestion conditions in order to achieve low caustic soda loss coupled with minimum bauxite consumption per tonne of output alumina. In an effort to achieve the above mentioned goals, a series of experiments were conducted to find out the best parameters for conducting digestion on a laboratory scale. The effect of digestion temperature, bauxite charge, lime quantity and digestion liquor concentration is discussed in this paper.

Experimental

Laboratory digestion tests were carried out in programmable, electrically heated digester, with small autoclave bombs of working volume 150 ml. Bauxite sample of -100 mesh size were dispersed in plant digestion liquor. The bauxite charge to be taken for digestion in the autoclaves was calculated to meet a defined charging molar ratio, which varied in quantity depending on the chemical assay of bauxite. Digestion tests were carried at different temperatures with varying retention time applicable for boehmitic bauxite. The above conditions were selected following the parameters for alumina production at the Bharat Aluminium Company Ltd, Korba (India). The quantity of alumina extracted was estimated by analyzing the bauxite and its corresponding red mud. The major constituents of bauxite and red mud were analyzed by XRF-PW-2440 Philips, Netherlands. The mineralogical analysis were carried out using PANlytical X'Pert Cubix Pro Series diffractometer, equipped with copper target tube, X'celerator detector and operated at 40kVand 30mA. Diffraction data were analyzed using PANlytical X'Pert High Score Plus Version 2.1. The caustic and alumina content of digested liquor were analyzed by potentiometric auto titrator, Mettler Toledo, DL55, Switzerland.

Results

A set of digestion experiments was carried out at 240 °C for 18 minutes with varying target Molar Ratios, the outcome of these tests is given in Table 1. Digestion experiments were carried out at different digestion temperatures with varying target MR keeping constant digestion time and the results of the tests are given in Table 2. The results of digestion tests at different caustic concentration in the plant digestion liquor and for different digestion times are shown in Table 3. Digestion experiments with variation in bauxite quality at two targets MRs 1.42 and 1.45 are presented in Tables 4 and 5 respectively. Table 6 shows the test results obtained after bauxite digestion with various quantities of lime.

Discussion

The digestion studies mentioned above have been carried out in order to optimize the digestion conditions to achieve the highest digestion efficiency, with lowest soda loss.

Laboratory digestion tests were conducted in order to determine the critical Blow off Molar Ratio beyond which the efficiency drops to a very low value. The results (Fig.1 & Table 1) clearly show that with reduction in target MR the digestion efficiency decreases in all cases. But at the same time we may observe that below the target MR value of 1.40 there is a significant change in the slope of the curve indicating the lower limit of the liquor to bauxite ratio. It can be seen from Fig.1 and Table 1, that the digestion efficiency decreases to some extent with decrease in the target MR. But at times efficiency may be sacrificed in order to increase the throughput. This is a clear case of optimization as a techno-economic consideration.

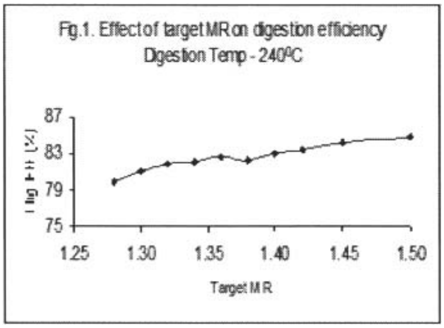


Table 1. Digestion tests at different target MR

Bauxite Quality		Plant Liquor		Digestion Conditions		
	wt %		In gpl	Desili cation	Temp, °C	95
LOI	22.35	Na_2O c	188		Time, hrs	8
SiO_2	3.15	Al_2O_3	90.9	Digest ion	Temp, °C	240
Fe_2O_3	19.43				Time, minutes	18
TiO_2	9.13			Lime	0.75% of bauxite charge	
Al_2O_3	45.00					

Target MR	ML	η	SL	BXT
1.28	49.81	79.89	79.27	2.78
1.30	49.76	81.09	83.45	2.74
1.32	49.17	81.84	81.98	2.71
1.34	48.99	82.17	80.47	2.69
1.36	48.76	82.74	79.61	2.70
1.38	48.33	82.22	87.11	2.67
1.40	48.40	83.15	83.61	2.66
1.42	48.36	83.55	80.80	2.64
1.45	47.97	84.17	78.76	2.62
1.50	48.46	84.78	80.03	

ML – Mud Load (%)
η - Digestion Efficiency (% TA basis)
SL – Soda loss (Kg NaOH/T Al_2O_3)
BXT – Dry bauxite consumption (T/T Al_2O_3)

It is well known fact that digestion efficiency increases with increase in digestion temperature. The digestion efficiency increases about 1% at 244°C (Fig.2 & Table 2), at a target MR of 1.42, which is closest to the plant operating range.

The advantages of operating at 244°C are:
(a) Higher bauxite dissolution hence lower bauxite consumption
(b) Lower soda loss

The disadvantages are anticipated to be as follows:
(a) Higher steam consumption
(b) Increased scaling of live steam heated digesters
(c) Increased chances of impurities going into the aluminate liquor, thus leading to increased impurity in product.

The digestion studies mentioned above have been carried out in order to optimize the digestion conditions to achieve the highest digestion efficiency with lowest soda loss.

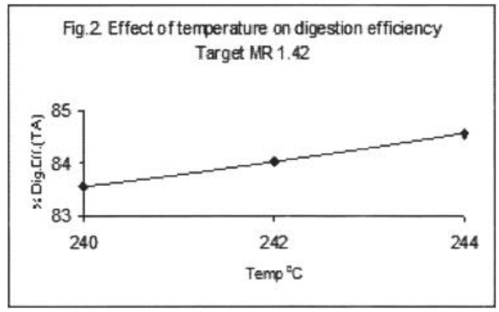


Table2. Digestion test at different temperature with varying target MR

Bauxite Quality		Plant Liquor		Digestion Conditions		
	wt %		In gpl	Desili cation	Temp, °C	95
LOI	Na_2Oc	Na_2Oc	185		Time,hrs	8
SiO_2	Al_2O_3	Al_2O_3	90.9	Digest ion	Temp, °C	240
Fe_2O_3	19.43				Time, minutes	18
TiO_2	9.13					
Al_2O_3	45.00					

Temp, °C	Results	Target MR				
			1.38	1.40	1.42	1.45
240	ML	%	48.33	48.40	48.36	47.97
	η	%	82.22	83.15	83.55	84.17
	SL	Kg	87.11	83.61	80.80	78.86
	BXT	T	2.70	2.67	2.66	2.64
242	ML	%	48.76	48.55	48.12	48.34
	η	%	82.61	83.60	84.04	84.75
	SL	Kg	82.41	82.41	78.29	78.32
	BXT	T	2.69	2.66	2.64	2.62
244	ML	%	48.44	48.18	48.33	48.46
	η	%	83.06	83.93	84.56	85.14
	SL	Kg	83.58	81.78	78.81	77.99
	BXT	T	2.67	2.65	2.63	2.61

Soda loss shows a declining trend when digesting bauxite for 36 minutes instead of 18 minutes (Fig.3 & Table 3).

Bauxite quality plays an important role in the digestion efficiency achieved in the plant, other parameters remaining constant. Of late the bauxite quality for this operation is deteriorating, mainly with respect to recoverable alumina content, whereas the silica content is at acceptable level. In general the digestion efficiency achieved in the plant level is in direct proportion to the alumina content in the bauxite.

Fig.3. Effect of digestion time on soda loss
Dig Temp - 240°C
Target MR - 1.40

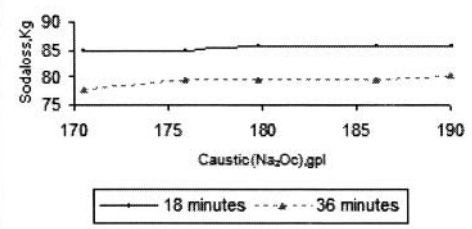


Table3. Digestion test at different caustic and digestion time

Bauxite Quality		Digestion Conditions		
	wt %	Desilication	Temp, ^{0}C	95
LOI	22.42		Time,hrs	8
SiO_2	3.27	Digestion	Temp, ^{0}C	240
Fe_2O_3	17.85			
TiO_2	9.02	Target MR*		1.40
Al_2O_3	46.57	Lime	0.75% of bauxite charge	

Digestion liquor		Digestion Time		Digestion Time	
Na_2Oc,gpl	MR	18 minutes		18 minutes	
		η	SL	η	SL
170.5	2.91	84.88	81.61	85.48	77.94
175.9	2.95	85.04	82.81	85.93	79.62
179.8	2.92	85.64	81.61	86.01	79.58
186.0	2.93	85.73	82.09	86.13	79.65
190.0	3.02	85.78	81.10	86.32	80.31

Though there are some aberrations in the experimental results, in general it can be concluded that digestion efficiency is reduced drastically when the alumina content in bauxite is below 44%. The weight ratio of Al_2O_3 to SiO_2 known as the module of the bauxite, is more pronounced with respect to bound soda loss (Fig.4, Fig.5 & Table 4, 5) as these are more related to the silica of the bauxite processed. From the experimental results it can safely be concluded that for achieving good digestion efficiency accompanied with low bound caustic losses .The bauxite quality requirement should be as follows: Al2O3 > 44% , Module > 15

From Fig.8 & Table 6, it can be seen that the soda loss decreases with increasing lime charge, due to the formation of Calcium Aluminium Silicate and release of sodium hydroxide (Soda in red mud).

Table4. Digestion experiment with variation in bauxite quality at target MR 1.42

Bauxite Quality		Module	η (TA)	BXT	SL			
%Al_2O_3	%SiO_2		%	T	Kg	Deslication	Temp, ^{0}C	95
41.80	3.25	12.9	84.98	2.81	83.88		Time,hrs	8
43.47	3.02	14.4	84.39	2.73	76.59	Digestion	Temp, ^{0}C	240
44.18	2.95	15.0	85.99	2.63	74.36		Time,minutes	18
44.83	2.76	16.2	86.04	2.59	65.21			
46.13	2.69	17.1	84.45	2.57	63.39	Plant liquor	Na_2Oc,gpl	179.0
46.77	2.54	18.4	84.21	2.54	64.76		Al_2O_3,gpl	88.7

Table5. Digestion experiment with variation in bauxite quality at target MR 1.45

Bauxite Quality		Module	η (TA)	BXT	SL			
%Al_2O_3	%SiO_2		%	T	Kg	Dedication	Temp, ^{0}C	95
41.47	3.38	12.3	84.11	2.87	81.79		Time,hrs	8
43.73	2.77	15.8	86.07	2.66	63.67	Digestion	Temp, ^{0}C	240
44.45	2.64	16.8	87.06	2.58	57.10		Time,minutes	18
44.98	2.57	17.5	88.04	2.52	51.05			
45.44	2.57	17.7	87.02	2.53	57.52	Plant liquor	Na_2Oc,gpl	179.0
46.77	2.54	18.4	85.93	2.49	60.65		Al_2O_3,gpl	88.7

Fig.4.Effect of bauxite alumina on digestion.eff
Target MR -1.42

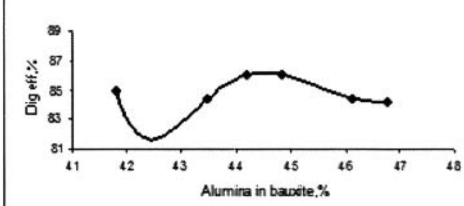


Table6.Digestion with various dosages of lime

Bauxite Quality		Plant liquor				
Constituents	wt %		gpl	Desilication	Temp, ^{0}C	95
LOI	22.67	Na_2Oc	173.6		Time,hrs	8
SiO_2	2.81	Al_2O_3	84.0	Digestion	Temp, ^{0}C	240
Fe_2O_3	17.87				Time,minutes	18
TiO_2	9.31					
Al_2O_3	46.57			Target MR		1.45
		Lime dosage % CaO of bauxite charge				
	No lime	0.50	0.75	1.00	1.25	1.50
ML	44.10	45.40	46.61	46.84	47.78	48.42
η	86.22	86.13	85.90	86.14	86.43	86.40
SL	79.20	80.01	80.72	77.73	78.71	79.32
BXT	2.49	2.49	2.50	2.49	2.48	2.48

Table7.Optimum digestion conditions for Central Indian Bauxite

Digestin liquor, Na_2Oc	185 gpl
Digestion liquor, MR	3.25
Digestion Temperature	240^{0}C
Digestion Time	18 minutes
Target MR	1.45
Lime dosage	0.75% CaO of bauxite charge

Fig.5.Effect of module on soda loss
Target MR - 1.42

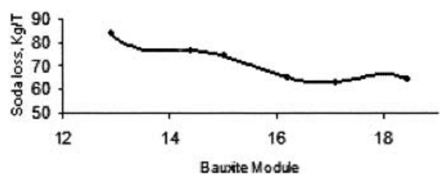


Fig.6. Effect of bauxite alumina on digestion Eff.
Target MR-1.45

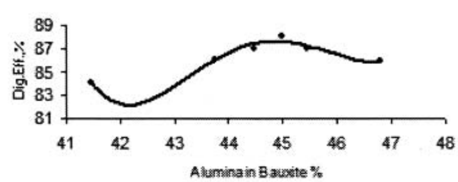
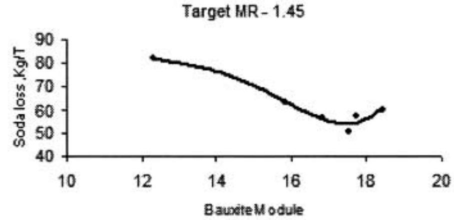


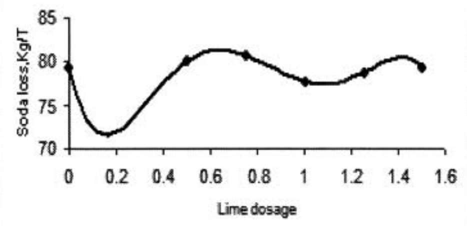
Fig.7. Effect of bauxite module on soda loss
Target MR - 1.45



On Careful observations, it can be concluded that the Digestion conditions given in Table – 7 will be the optimum for high temperature – High Pressure Digestion of Central Indian Bauxites, though the digestion conditions shall vary marginally for those from the central Indian plateau towards the Eastern Ghats are softer, higher Gibbsitic in nature and hence can be digested at temperatures around 230^{0}C, where as those in the Central India and towards the western Ghats are Bohemitic in nature and need higher temperatures and pressure.

The Study of Bauxite reserves from Gujarat which falls under the Western Ghats, the Bauxite Quality is mixed. We get highly Gibbsitic Bauxites (95% Gibbsite) in the regions of Kutch where as those from the coastal Gujarat are hard, highly diasporic in nature and can be best suited for Refractory applications.

Fig.8. Effect of lime dosage on soda loss



Conclusion

While carrying out the digestion studies under the conditions outlined above we can expect a lower bound on caustic loss, coupled with low bauxite consumption. We can also expect significantly lower Fe_2O_3 and SiO_2 levels in the digested liquor, which gets translated in the product hydrate and hence reports in the calcined alumina. While translating these results to plant level operation, some care must be taken on the following points:

(1) The Bauxite used in the laboratory tests was of uniform mesh size, while that in the plant operation are of varying granulometry ranging from very coarse to fine.

(2) The agitation level in the laboratory is not the same as under plant conditions.

(3) In the plant, flashing of the digested slurry is carried out, however this is not available in laboratory scale experiments.

On careful observation of the results, one can observe that the parameters given in Table 7 would be appropriate for the digestion of Central Indian Bauxite.

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