DOUBLE DIGESTION PROCESS: AN ENERGY EFFICIENT OPTION FOR TREATING BOEHMITIC BAUXITES

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Abstract

With depleting gibbsitic or tri-hydrate bauxite reserves and the recent step increase in energy costs, alumina plant operators are looking for ways to process boehmitic or mono-hydrate bauxites that require higher digestion temperatures while keeping the energy costs low. The Double digestion (DD) process, as developed by Alcan provides an economic alternative to standard high temperature digestion process, normally used for treating boehmitic bauxites in Greenfield and Brownfield installations.

The DD process, involves extraction of gibbsite and boehmite in two distinct steps from the bauxite feed at different optimum temperatures with a pressure decanter as a link between the two digestion stages. Pressure decantation is designed to separate the unflashed mud residue containing unextracted boehmite after gibbsitic digestion, and provides feed to high temperature digestion. Depending on the boehmite content in the bauxite feedstock and the equipment layout in a brownfield installation, different flowsheets of DD process are available. The present paper will review some of these flowsheets and their possible application to different bauxite feed and plant equipment layout scenarios.

1. Introduction

Historically bauxite, the main raw material for the commercial scale production of aluminium oxide (alumina) has been categorized as gibbsitic or tri-hydrate ($\gamma Al_2O_3.3H_2O$), boehmitic or mono-hydrate ($\gamma Al_2O_3.H_2O$) and diasporic or another form of mono-hydrate ($\alpha Al_2O_3.H_2O$). Varying rates of dissolution from bauxite and levels of solubility of these three species of alumina in caustic have resulted in three formats of alumina digestion processes i.e. low to medium temperature (105-175°C) for gibbsite, high temperature (220-260°C) for boehmite and very-high temperature (265-280°C) for diasporic bauxites.

Normally, specific energy consumption increases with increase in operating digestion temperature due to inability to recover all the heat energy from digester discharge slurry. Operation of digestion at higher temperature also has an adverse impact on steam/power balance in a refinery equipped with a co-generating station.

Traditional digestion, a two-stream process, was designed to mix separately heated ground bauxite slurry with caustic liquor streams in digester vessels to extract alumina at a target digestion temperature that was achieved with the help of live steam in a direct or indirect manner. In more recent installations, single-stream version of digestion was designed where bauxite slurry and caustic liquor streams are mixed together and heated as a single-stream prior to entering the digestion vessels.

Despite the challenge to maintain the heat transfer equipment in good shape, the heat recovery across the digestion section is much better with a single-stream process than with two-stream process and results in lower specific energy consumption. For a given digestion liquor caustic concentration, a single-stream process also results in lower free caustic concentration than a two-stream process. This allows operating at higher caustics, and hence higher digestion productivity without the use of exotic materials of construction for high-temperature end heat-exchange equipment.

In view of the recent step increase in the cost of energy generated from fossil fuels, alumina operators are looking at ways and means to reduce specific energy as well as raw material consumptions for alumina production. The present paper deals with a concept known as "Double Digestion" for processing boehmitic bauxite using single/mixed/two-stream digestion systems to produce alumina at higher liquor productivity and lower energy, bauxite and caustic specific consumption as compared to conventional single high temperature digestion (HTD) process.

2. Double Digestion Overview

Double digestion (DD) process consists of extracting gibbsite and boehmite in two distinct digestion steps where each step is designed to provide optimum conditions for extraction of each of the alumina species. This in turn results in more efficient plant operations with respect to specific energy, bauxite and caustic consumption.

For a given bauxite containing a mixture of gibbsite and boehmite, digestion at low temperature is carried out to extract gibbsite at relatively high alumina to caustic ratio (A/C). Unflashed digestion slurry, exiting the low temperature digestion (LTD) is processed to separate the solid phase containing unextracted boehmite, and the liquid phase containing dissolved gibbsite with a small amount of suspended mud solids is sent to security filtration. The solid phase is mixed with hot digestion liquor and digested at higher temperature to extract boehmite. The discharge slurry from high temperature digestion (HTD) is further processed to separate the mud residue and liquor having a lower A/C ratio. While the liquor is either sent forward to security filtration or recycled as feed to LTD, the residue is washed in a counter-current manner and disposed at a captive storage site.

The first full plant scale conversion of a single-stream high temperature digestion process to a single-stream DD process was implemented at the Gardanne, France plant of Rio Tinto Alcan (then Pechiney) in 1998 with the objective to increase the nominal production capacity and reduce specific raw material consumption. The plant was retrofitted with DD process by using a conventional decanter for solid liquid separation after LTD. Operation of a conventional decanter at atmospheric pressure necessitates cooling of LT digestion discharge slurry by flashing to atmospheric conditions prior to solid/liquid separation step.

A mixture of decanter underflow slurry and digestion liquor is re-heated for extracting boehmite at HTD conditions. Following the conversion to DD, the plant capacity could be increased by ~15% with ~9% reduction in specific energy and 0.8% increase in extractable alumina efficiency across digestion.

In order to achieve more efficient solid/liquid separation after LTD, Rio Tinto Alcan (previously known as Alcan) developed the concept of a "Pressure Decanter" (1) (PD) that enables the separation of residual solids from LTD discharge slurry at its temperature without flashing, and hence results in:

- Achieving very high settling rates (25 – 35m/h) for residue due to handling of unflashed solids at lower liquor viscosity;
- An underflow that has paste like rheology due to high solid concentration;
- Generation of overflow with clarities similar to those achieved with High Rate Decanters (settlers);
- Higher overall alumina recovery due to lower amount of alumina re-precipitating (boehmite reversion) following the separation of boehmite containing solids from the digestion slurry at higher temperatures;
- Avoids the need to re-heat the solid phase of LTD discharge slurry after liquid/solid separation from atmospheric to LTD temperature.

3. Salient Features of a Pressure Decanter

A full scale pressure decanter has the following salient features (Figure 1):

- A cylindrical pressure vessel having a conical bottom and equipped with a rake and dewatering rods in the cone to facilitate removal of settled residue having high solid concentration;
- Feed system consisting of a feed-pipe and a feedwell;
- Overflow system connected to a flash cooling system;
- Underflow system with dedicated transfer and re-circulation pumps;
- Synthetic flocculent addition system in the feedline and the feedwell;
- Appropriate instrumentation for automatic addition of flocculent and online measurement of overflow turbidity, underflow solids, mud inventory and rake torque.

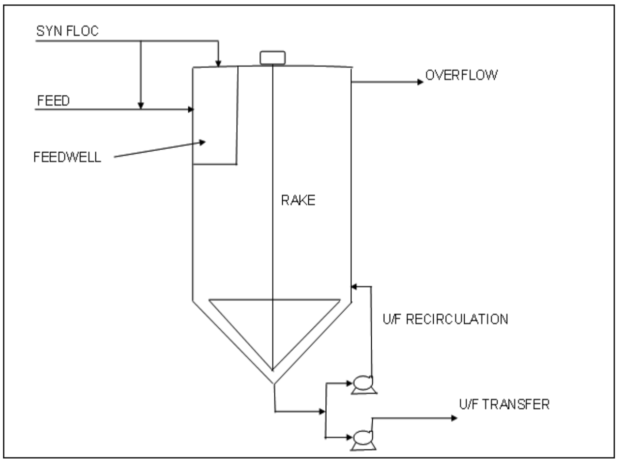

Figure 1. Pressure Decanter

The first plant scale application of a DD process with PD as a link between LTD and HTD was implemented in 2001 at Gramercy plant in USA. Based on the experience shared and reported by Gramercy plant, (2, 3) some improvement in the design of PD has been carried out and will be tested in new full scale applications of this equipment during the current year. These improvements refer to the following:

- Moving of the central feedwell to an off-centre location;
- Installation of an on-line liquor clarity probe;
- Installation of an underflow transfer and recirculation pumps of the same capacity.

4. Versions of a Double Digestion Flowsheet

Three variations of a DD flowsheet have been proposed to provide an optimum solution for a given plant situation depending on:

- Bauxite quality with respect to ratio of gibbsite and boehmite present;
- Whether it is a retrofit of existing LTD or HTD installation or a Greenfield installation.

All the three flowsheets have been installed in three different refineries indicating a flexibility of the concept to suit the specific needs of a plant and these are described below.

4.1 Parallel Double Digestion Flowsheet (Figure 2)

In this version, the overflow from a PD installed immediately after the LTD is flashed in multi-stages while the PD underflow is processed in HTD for boehmite extraction. The cooled slurry from HTD is processed in a clarification stage and its overflow and the cooled PD overflow from LTD are fed together to security filtration prior to going to the precipitation area.

Salient Features of this flowsheet are:

- High boehmitic digestion temperature >240^{o}C;
- Potential to increase flow across LTD flash stages in brownfield retrofitting;
- Minimal chances of boehmite reversion/gibbsite retrogradation;
- Allows separate treatment of HT digestion slurry;
- Reduced volumetric feed rate to the settlers;
- Applicable to bauxites containing medium to high amount (>5%) of boehmite.

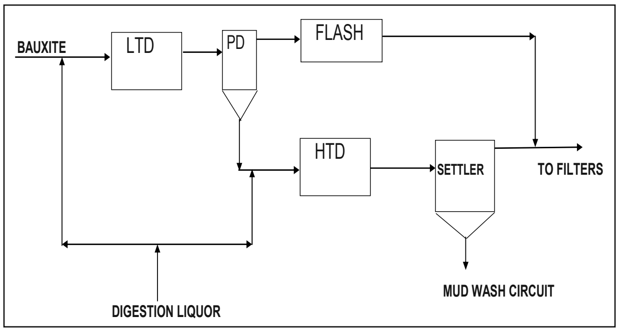

Figure 2. Parallel Double Digestion Flowsheet

4.2 Cross–Flow Double Digestion Flowsheet (Figure 3)

In this version, the overflow from a PD installed after LTD joins with digestion slurry from HTD at an appropriate flash stage and the combined stream is fed to a clarifier for residue and turbid liquor separation. Consequently the flash system for HTD is designed to handle the total digestion slurry from LTD and HTD at the low pressure end of the flash train.

Salient Features of this version of flowsheet are described below:

- High boehmitic digestion temperature >240^{o}C;
- PD overflow clarity is not critical;
- HTD flash train designed to handle the combined digestion discharge slurry;
- LTD flash stage becomes redundant;
- Possibility of boehmite reversion across the HTD flash train;
- Slurry flow to clarifiers unchanged with reduced retrogradation losses;

- Applicable to bauxites containing medium to high amount (>5%) of boehmite.

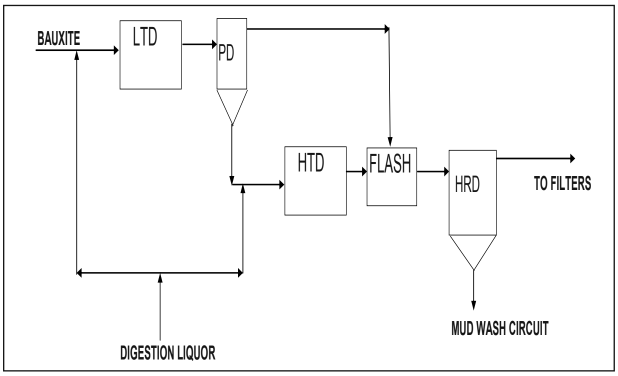

Figure 3. Cross–Flow Double Digestion Flowsheet

4.3 Counter-current Double Digestion Flowsheet (Figure 4)

This flowsheet version consists of separate PDs installed after the LTD and in the HTD flash train. While the overflow from a PD installed after appropriate HTD flash stage is mixed with fresh digestion liquor to extract gibbsite in LTD, the PD underflow containing residue is washed across the mud circuit for caustic recovery and ultimate disposal. Another PD installed after the LTD separates solids in the underflow containing boehmite for processing in the HTD and the overflow for cooling across the LTD flash train prior to feeding the security filtration area.

Following are the salient features of this flowsheet:

- Lower (~210°C) HTD temperature coupled with reduced adverse impact of quartz and titania dissolution;
- Minimal chances of boehmite reversion/retrogradation losses;
- Primary clarifiers (settlers) are made redundant;
- Most energy efficient (steam/power balance);
- Applicable to bauxites containing relatively low amount (~5%) of boehmite;
- Maximize pregnant liquor A/C ratio and precipitation productivity.

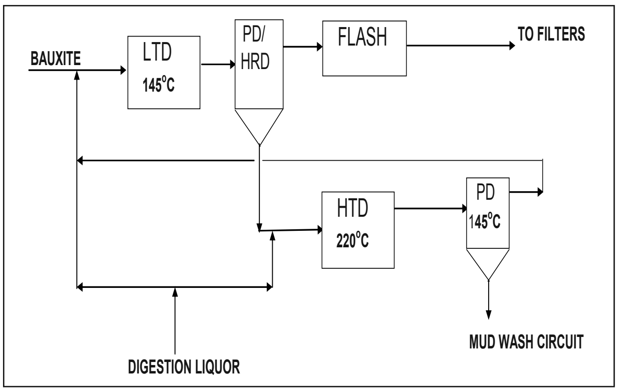

Figure 4. Counter-current Double Digestion Flowsheet

5. Discussion

The three variations of DD flowsheets provide a flexibility to adapt to a given bauxite quality with respect to boehmite and silica content, the steam/power balance situation and equipment layout of a plant for a brownfield retrofitting.

The parallel DD flowsheet was selected for a refinery that has been operating a LTD circuit so far. With depletion of gibbsitic bauxite in the existing mining lease, the remaining bauxite reserves show an increasing trend of boehmite content in the bauxite with future bauxite having an average of 11-13% boehmite in the feed to the refinery. This would have led to already deteriorating operating efficiency parameters like liquor productivity, overall alumina extraction and caustic consumption in an adverse manner. In selecting the parallel DD flowsheet, the existing flash train and heat-exchangers of LTD unit are being partially used while the capacity of the refinery is being increased four-fold.

A Cross Flow DD flowsheet was used for a refinery that was operating a single-stage conventional HTD, but needed to reduce energy consumption and bauxite consumption through improved alumina extraction. The flash tank train for overflow from PD installed after the LTD was merged with the low-pressure end of a new flash train for HTD to reduce capital cost. The plant has been operating since 2001 with DD and reported a ~20% reduction in energy and ~4% increase in digestion extraction efficiency. (2)

In one of the refineries of Rio Tinto Alcan processing gibbsitic bauxite with a LTD system, a decision to install a counter-current DD flowsheet was made due to an increase in boehmite from ~1.5% to ~3% with a possibility of ~100% reversion across the LTD. This was seen to be a cause for lower alumina extraction leading to higher bauxite consumption, which in turn was to increase the caustic consumption and the mud factor requiring a larger residue disposal facility. A drop in liquor productivity and a higher scaling rate of equipment in digestion and mud wash circuit was also envisaged if the boehmite was not extracted.

In view of a low boehmite and high silica in the bauxite, a counter-current flowsheet with HTD operating at a relatively low temperature of ~220°C was selected. A saving of ~9% in bauxite, ~10% in caustic and ~30% reduction in mud factor is envisaged following introduction of this DD process to the existing LTD operation.

6. Conclusions

From the above discussions, it can be concluded that full scale implementation of three versions of the DD process in different plants demonstrate the capability of this concept to efficiently process boehmitic bauxites in order to lower operating and capital costs.

References

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