

Low-Cost Improvements to the Sandy DSP Process

Denis Audet¹, James Vaughan² and Hong Peng³

1. Director, Audet Process Audit, Brisbane, Australia

2. Associate Professor James Vaughan

3. Senior Research Fellow Hong Peng

School of Chemical Engineering, Metallurgy Program, The University of Queensland, Brisbane, Australia

Corresponding author: denis_audet@hotmail.com

Abstract

At the same time that there are pressures to reduce the production cost of alumina and aluminium, quality bauxite is becoming more difficult to find, with reactive silica concentration always increasing. Reactive silica is the most costly impurity, because it often accounts for the majority of the need for caustic addition, which is lost via the bauxite residue in the form of a desilication product (DSP). A process aiming at recovering this DSP before it leaves the circuit and then to recover the caustic, hence this cost, has been proposed. The main principle of this process is to crystallise coarse DSP that can be separated from the bauxite residue easily and recycled. New advances of this concept are making use of concentrated caustic solutions, either pure caustic or evaporated liquor, to promote extensive agglomeration during the desilication phase.

Keywords: Bauxite, Digestion, Desilication, Silica, Caustic recovery.

1. Introduction

Bauxite is the main ore-type from which aluminum can be extracted in an economical way. Apart from various aluminium oxides, bauxite is mostly composed of iron, and silicon -based minerals. And these ores are also mainly treated for extraction using the Bayer process in which these aluminium-bearing compounds are dissolved in hot sodium hydroxide solution.

In this process the aluminium and most other compounds in the bauxite remain in the solid phase, as they are insoluble. However, the reactive silica and silicate compounds (referred to as silica in this paper), such as kaolinite, do react significantly as the bauxite goes through digestion the silicate minerals, typically dissolve and reprecipitates as sodium aluminum hydrosilicate, known as the desilication product (DSP).

Desilication is quite variable from one refinery to the other as it depends on the amount of silica in the bauxite and the digestion temperature (dictated by the type of aluminium-bearing mineral in the bauxite). The desilication in some cases is conveniently happening simultaneously with the digestion but in most cases with the current bauxite quality, needs to be done ahead of digestion. This step is important to minimize scale formation on heat transfer surfaces when the liquor will return to digestion in the next cycle, and also to remove other impurities like sodium carbonate from the Bayer liquor.

However, precipitation of DSP is costly, as sodium hydroxide (the key reagent in the Bayer process) and aluminum (element for the product alumina) are lost, being discarded as part of the bauxite residue. It is often said that bauxites with reactive silica concentrations greater than approximately 8 wt.% cannot be processed economically due to these losses. Another negative impact of the DSP in the bauxite residue is the added complexity of during the residue neutralization, tailings area remediation and recycling the residue for iron recovery, etc.

In a recent paper, a new concept where the DSP can be precipitated in a pre-desilication stage before digestion is described (Vaughan et al. 2019). The conventional pre-desilication can be modified to produce so coarse (large in size / sandy) that this DSP can be separated from the undigested bauxite (bauxite residue) after digestion. These solids that are then mostly DSP can be treated in a cost-effective manner (relative to whole bauxite residue treatments), in order to recover the compounds that are normally lost with the residue (Hodge et al. 2020a, and Hodge et al. 2020b). A process flowsheet for the so-called “Sandy Desilication Product Concentrate Sinter-Leach Process” is shown in Figure 1.

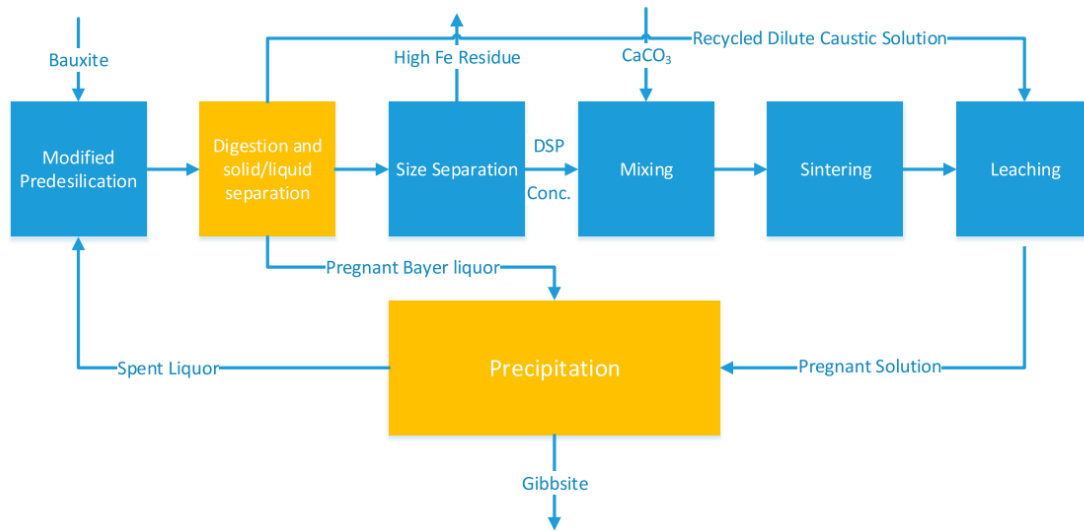


Figure 1: The Sandy Desilication Product Concentrate Sinter-Leach Process [from Hodge et al. 2019].

In this paper will be presented how typical Bayer plants can be modified to produce coarse DSP using streams that are available in their plant.

2. The Coarse DSP Process Advantages

2.1 Standard Pre-desilication

Whether there is a need for pre-desilication or not depends on the amount of silica in the bauxite. If the amount of silica is high with a sufficiently long/hot digestion, desilication can happen during digestion, hence doesn't require a specific section to take care of the silica. However, when the silica is lower than a certain level, during digestion the threshold required to autoprecipitate the DSP cannot be reached, and then specific section is required to carry out desilication fully.

The standard pre-desilication section of a Bayer plant can vary depending of the bauxite type and the amount of silica in the bauxite, but the principle is always more or less the same: allow bauxite to react with the caustic liquor in order to dissolve as much as possible of the silica and also allow it to re-precipitate to a suitably low solution concentration.

In general the pre-desilication circuit (Figure 2) is comprised of a series of CSTR tanks in cascade that are unseeded, especially the first one. The successive tanks may or may not receive some slurry from the last tanks to help increase the amount of seed in the circuit. To help increase the reaction kinetics, generally these tanks are held at the highest temperature that can be achieved at atmospheric pressure. This temperature also depends on whether or not the slurry is preheated. Following pre-desilication, the liquor volume and alkalinity can be increased by addition of evaporation liquor and fresh caustic, ahead of the aluminium (alumina) digestion stage.

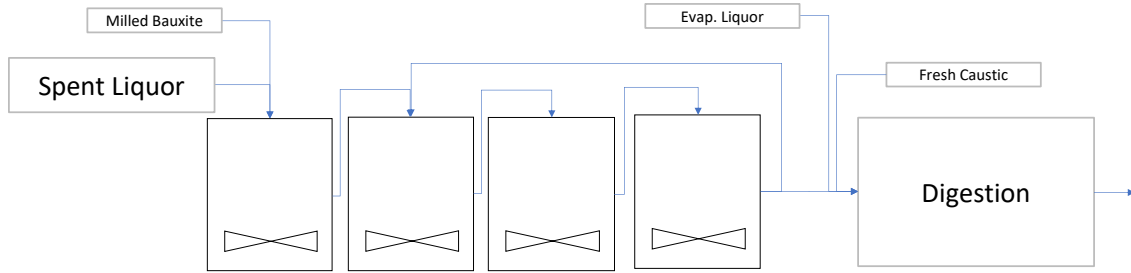


Figure 2. Process Flow Through Bayer Process Pre-Desilication.

2.2 Bauxite Grinding Size and Close or Open Circuit

Depending on the origin of the bauxite, it can be quite coarse and in which case several stages of grinding are required to enable adequate alumina extraction in digestion. The first phase consists generally of dry crushing followed by two stages of wet grinding, typically the first grind size reduction is achieved using a rod mill and the second using a ball mill (Figure 3).

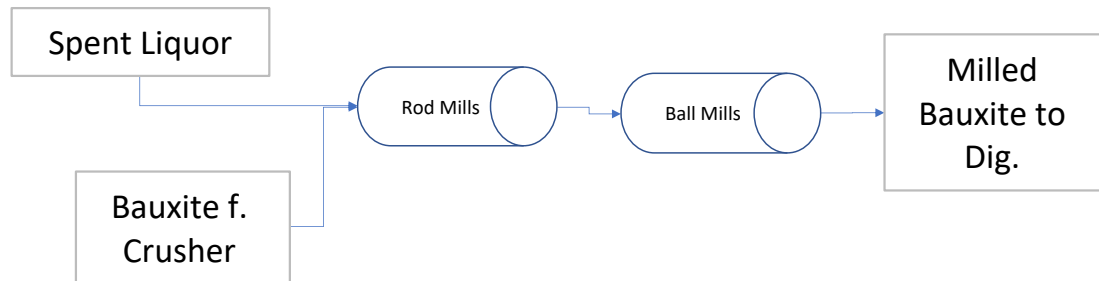


Figure 3. Two Stage Bauxite Grinding Circuit.

Older plants that were designed when the bauxite cost was lower, had an open circuit where the output of the rod mills was sent directly to digestion. The negative aspect of which was that a portion of the bauxite was not well extracted and coming out of digestion coarse enough to be sandy. This sand needed to be separated from the slurry coming out of the digester to avoid having problems in the decanter – sand in decanter significantly increases the torque that need to be applied to the rake to help the residue pass through the underflow. The so called sand (from the bauxite which is actually poorly ground bauxite) is relatively easy to separate from the fine bauxite residue with different types of classifiers (cyclone, rake classifiers, etc).

Nowadays, with bauxite prices being higher, there is economical benefit in ensuring the whole bauxite is ground to a finer size. This is normally achieved using a classifier at the end of the milling circuit to remove the coarse particle (that would have become “sand”) and send them back in the milling circuit (figure 4). By doing so, the amount of sand in the slurry leaving digestion can be minimised.

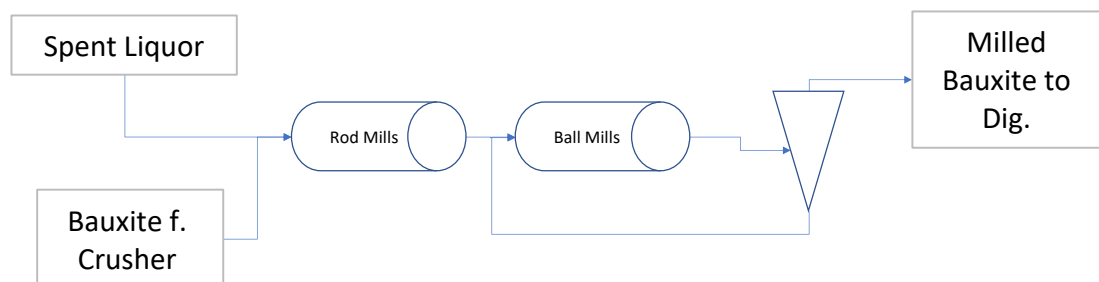


Figure 4. Two Stage Bauxite Grinding Circuit with Size Classification / Recycle Loop.

It is important to understand that to get the full benefits of this Coarse DSP concept, the slurry from digestion should be free of “sand” in order to have only the coarse DSP being separated at that stage. Otherwise, the solids from the classifier would be a mixture of DSP and Sand (undigested bauxite). Iron minerals in the sintering stage can consume limestone due to the formation of calcium ferrite, therefore the cost of the subsequent sintering is increased due to additional energy and reagent requirements as a function of iron content (Hodge et al. 2020b).

2.3 Sandy DSP Process as Developed in Laboratory

Tests that were done significantly outside the normal pre-desilication conditions has led to product much coarser than normally process. The desired caustic concentration is between 50% to 100% higher and the alumina concentration about one third of what of what a typical spent liquor would be (Peng, H et al. 2021).

Using these conditions (and organic additives in some cases), the synthesized DSP particles are much larger sized than the typical DSP with average size of 1~2 μm ; The single crystal phase can be 6~ 10 μm with the agglomerates in some case as big as a 30 μm , as shown in Figure 5. The phase composition is not only sodalite and can be a mixture of LTA and LTN zeolite and sodalite depending on synthesis conditions. The exact recipe to obtain the Sandy DSP size that is desired for later solid liquid separation (after digestion) is most certainly dependent on the liquor composition as we know that organics compounds can play a significant role in slowing down the reaction. Which is why tests would be required to find the optimum for a given refinery.

The bauxite used in the process will also have a great effect as it would raise the silica concentration at different rates depending of the bauxite crystallinity and composition. Another factor that is likely to be important but to a lower extent is the tank geometry and agitation type but this would need to be fine-tuned on site.

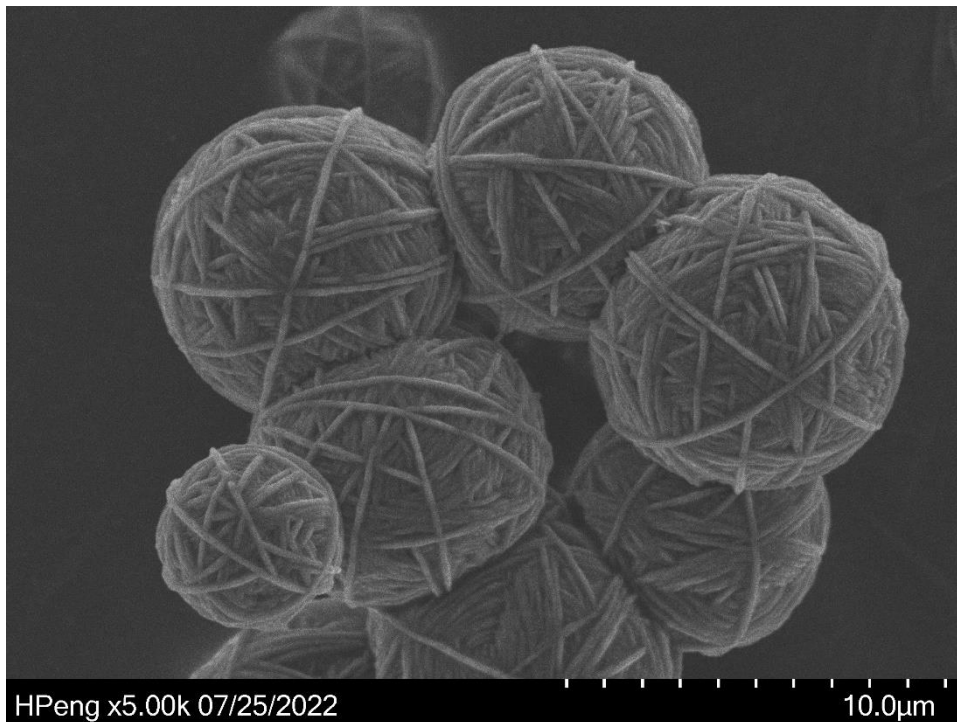


Figure 5. Example of the SEM micrograph of Sandy DSP particles.

3. Application of the Sandy DSP process

3.1 Link of Volume Control to the Caustic Control

In a typical Bayer plant (Figure 6) inevitably, there are many “clean water” inputs to the process mainly for washing the solid residue after digestion and the product at the end of precipitation before being calcined; the other minor inputs are for chemical additives solution.

There are many outputs for water to be removed from the process, like from the Flash Tanks in digestion or possibly in precipitation. And also, via natural evaporation in precipitation open tanks or residue or precipitation decanters; they are at atmospheric pressure.

Depending of the plant though these water outputs can be insufficient to compensate for the water inputs and there is a net input of water that needs to be removed from the process. Without a way of extracting this extra volume of water the caustic concentration of the circuit will go down (by dilution) and the total volume of liquor will increase uncontrollably. Also to make matters worse, a fair amount of the caustic in the liquor is consumed by the DSP during digestion and predesilication and to a lower extent in the alumina product.

For all these reasons, there is a need (in most refineries) to have an evaporator to remove this extra volume of water efficiently and at low cost. In some cases, when the amount of impurities also needs to be under control, this evaporator can be used to precipitate out a range of impurities (sodium carbonate, sodium oxalate, sodium sulfate, and organic compounds with the addition of crystallizers after the evaporator). The caustic concentration of the liquor after evaporation needs to be higher in this case.

The caustic concentration of the liquor going to digestion is important to keep under control as it is one important factor for extraction efficiency, and it is normally done via continuous measuring of the liquor and controlled addition of evaporated liquor and also a source of concentrated caustic to compensate for the losses mentioned before. Using these two streams to control the liquor to digestion concentration enables the whole plant concentrations to be maintained in the target ranges.

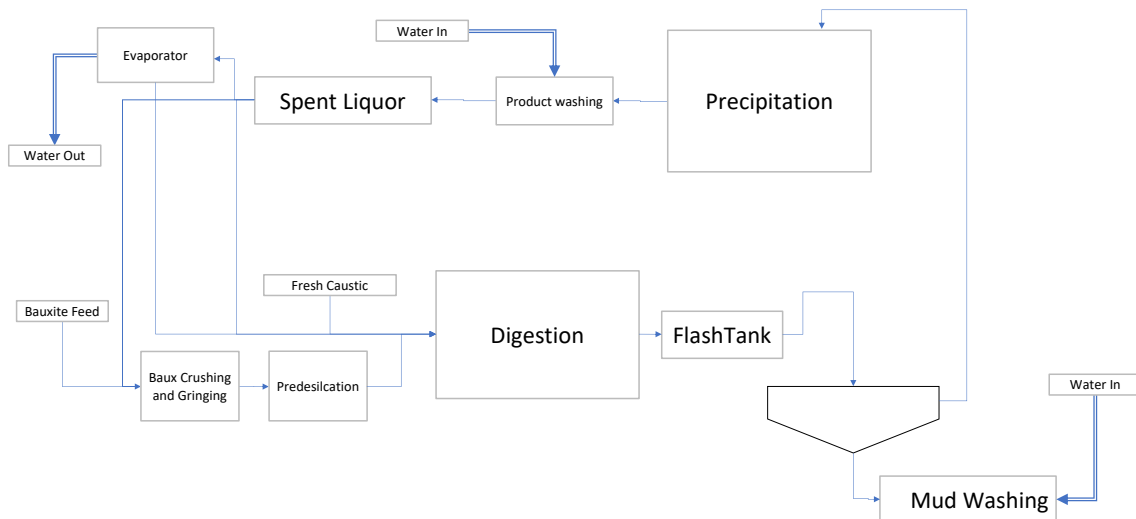


Figure 6. Bayer Plant schematic flowsheet showing the water inputs and outputs.

3.2 Use of Concentrated Caustic Streams with the Integration of the Sandy DSP Process

As mentioned before, the Sandy DSP process requires a much higher caustic concentration than what is normally used for the pre-desilication (typically spent liquor) to achieve the agglomeration and crystal habit needed for the process to work. So, when integrating this process to a typical Bayer plant (Figure 7), some of the concentrated caustic streams can be blended in the right proportion to obtain the concentration required for this process to work. The remainder of the flows is then used to control the caustic concentration of the liquor to digestion, which target would then need to be adjusted as the bauxite slurry will be at a higher caustic concentration.

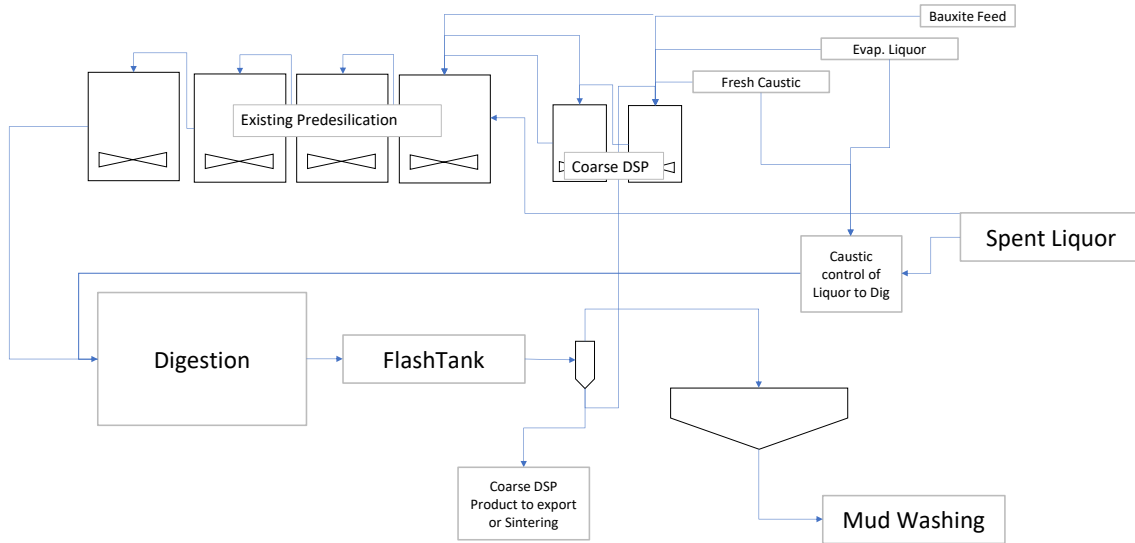


Figure 7. Schematic of the digestion and pre-desilication area after integration of the Sandy DSP process

4. Conclusion

As demonstrated in this paper, it is possible to integrate the Sandy DSP process to an existing plant by making use of evaporated liquor and concentrated caustic streams and by doing so increase the efficiency and profitability of the refinery.

Because this process is still quite novel and has yet to be piloted in continuous mode, it would require research and development efforts to identify the optimum process configuration and conditions. These are likely to be dependent on the liquor composition (particularly the organics, Seneviratne et al. 2017), the bauxite composition and equipment available (agitation is important factor for silica compounds kinetic). DSP seed quality, concentrations and control of the supersaturation during desilication also needs to be considered carefully.

5. References

1. H. Hodge et al., The DSP concentrate sinter-leach process for aluminium and sodium recovery 1. *Mineral Processing and Extractive Metallurgy*, vol. 131(1), 2020, 44-52.
2. H. Hodge et al., The DSP concentrate sinter-leach process for aluminium and sodium recovery 2: leaching behaviour, *Mineral Processing and Extractive Metallurgy*, vol.131 (1), 2020, 69-78.
3. D. Seneviratne, H. Peng, & J. Vaughan, (2017, January). The impact of organic additives on phase transformation and particle size of Bayer process desilication product,

Proceedings of 35th International ICSOBA Conference, Hamburg, Germany, TRAVAUX 46, 229-241

4. H. Peng, J. Vaughan, and J. Vogrin, Effect of Alkalinity on Zeolite LTN Formation under Bayer Process Pre-desilication Conditions, *Ind. Eng. Chem. Res.* 2021, 60, 10119–10128.
5. J. Vaughan et al., The sandy desilication product process concept, *JOM*, vol.71(9), 2019, 2928-2935.