AA21 - The Influence of Process Parameters on Removing Iron, Zinc and Copper Impurities from Synthetic Bayer Liquor

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Abstract

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The chemical quality of precipitated aluminum hydroxide, and consequently the final alumina product in the Bayer process directly depends of the level of impurities in a refinery's Bayer liquor. To reduce the concentration of these impurities below the level which affects the quality of final product, impurity removal processes are necessary. Most of these rely on the treatment of Bayer liquor to decrease the level of dissolved impurities, and this study examines impurity removal rates as a function of temperature, alumina trihydrate seed concentration and reaction time. The objective of this study was to identify the optimum process parameters to remove as much iron, zinc and copper from liquor as possible, while minimizing aluminate precipitation. A synthetic Bayer liquor (sodium aluminate solution) was used. Results revealed that with optimized process parameters, it is possible to decrease the starting concentration of iron, zinc and copper in the prepared sodium aluminate solution by up to 100 %. Results showed that even 25 min after seed introduction, concentrations reached 1.12 ppm of zinc, 1.43 ppm of iron and 1.04 ppm of cooper, i.e. almost 90 % removal was achieved. A starting temperature of 40 °C gave zinc and copper concentrations below their detection limit, while 84 % of iron was removed. The best results were obtained with 3 g/L of seed, where the concentration of all three impurities were reduced to below detection limit. The study results indicate that the impurity removal rate is correlated to the precipitation of alumina hydrate from solution, as expressed by the change in molar ratio between caustic (Na_2O) and alumina (Al_2O_3) in the liquor (α_K).

Keywords: Bayer process impurities, sodium aluminate, seed crystals, alumina, alumina hydrate.

1. Introduction

The Bayer process is the most widely used process for alumina and alumina trihydrate production. The alumina produced by this process is most commonly used for the production of aluminum metal, but the Bayer process product can also be used (for example) as a catalyst carrier, filler, abrasive, and as a raw material for the production of many other compounds. There are certain requirements regarding the level of impurities in alumina for all of these applications, since the quality of precipitated aluminum hydroxide, and consequently the final alumina product directly depends of the level of impurities in the Bayer liquor. To reduce the concentration of these impurities below the level which affects the quality of final product, impurity removal processes are necessary.

Leaching (or 'Digestion') is the first stage of the Bayer process. Ground and homogenized bauxite is mixed with a NaOH solution (Bayer liquor) at high temperatures and pressures, whereby selective dissolution of aluminum compounds occurs, and the vast majority of other compounds (i.e. impurities), remain in the solid phase [1,2,3]. Beside aluminium, other undesirable Bauxite elements which are soluble in Bayer liquor under the given conditions, are also extracted into the liquor phase.

Depending on the dominant alumina mineral in the bauxite, the leaching conditions differ. The easiest to leach is gibbsite, followed by boehmite and diaspore, the latter requiring the highest temperatures and pressures, which results in relatively higher processing costs and therefore generally poorer economics than for gibbsitic or boehmitic bauxites [4,5,6,7].

The main reactions occurring during the leaching process are [8]:

$$Al(OH)_3 + NaOH \rightarrow NaAl(OH)_4 \quad (1)$$

$$AlOOH + NaOH + H_2O \rightarrow NaAl(OH)_4 \quad (2)$$

The leaching operation is followed by filtration, which separates the red mud from the aluminate rich Bayer liquor [9, 10, 11].

Industrial Bayer liquors almost always contain impurities that affect its productivity, as well as the quality of hydrate and alumina products for different applications [12, 13]. However, the optimum processes and conditions for economic impurity removal remain a subject without cheap, easy or perfect answers, and an area for further investigation, and the motivation for this study.

2. Experimental

The experimental work was performed using standard glassware, A.R. chemicals, instruments and methods of the research laboratory at "Alumina" d.o.o. Zvornik, Bosnia and Herzegovina.

This study's focus was on removing iron and zinc impurities from synthetic Bayer liquor (sodium aluminate solution), by adding specially prepared alumina trihydrate seed crystals at an optimum ratio [14,15]. Apart from this method, many other ways of removing the nominated impurities from Bayer liquor have been investigated and reported in the open literature. These methods include (for example): removal of Zn and Cu by filtration through a layer of granules containing iron trioxide [16], removal of Zn by addition of ZnS seed in the presence of sulfide ion [17], removal of Fe by filtration through a layer of sand [18].

Removal of iron and zinc from Bayer liquor is achieved in this study by adding specially prepared aluminum hydroxide seed crystals. Chemical analysis of the prepared seed was carried out before the test work. A synthetic Bayer liquor was prepared by dissolving a non-metallurgical alumina trihydrate in a sodium hydroxide solution. The sodium hydroxide solution was prepared by dissolving granular NaOH solid in water. It was empirically determined that 204 g of solid NaOH per liter of demineralized water is needed to dissolve 260 g of non-metallurgical hydrate. The concentration of the resulting solution and the molar caustic to alumina ratio (α_K) are adjusted to the level of Bayer process liquor.

The experiments were performed by monitoring the effects of time, temperature and seed crystal concentration on impurity concentrations:

- The time varied from 15 to 75 min. at constant temperature (50 °C) and seed crystal concentration (5 g/L).

4. Conclusions

When reviewing the scientific and technical literature, it was concluded that the current processes of impurity removal in Bayer liquor are not efficient enough, are too complex and/or economically unacceptable. In this paper, the effect of seed added, under different process conditions and concentrations, to remove iron, zinc and copper from Bayer liquor was investigated.

Based on the results presented here, it can be concluded that:

- Increasing the time of contact between liquor and seed crystals has a positive effect on the removal of iron, zinc and copper liquor impurities.
- Increasing the temperature reduces the impurity removal efficiency from the sodium aluminate solution indirectly because with higher process temperature rate of precipitation is lower and solubility of all impurities is higher. At a temperature of 40 °C, good impurity removal results are achieved.
- The effect of seed crystal concentration is most significant, with 1 g/L it is possible to remove iron and copper completely with negligible increase in α_K, which is most interesting because of the minimised productivity losses and therefore the most positive economics. With further increases in seed concentration it is possible to remove zinc from the solution but with increased alumina losses (indicated by an increase in α_K). Removal of zinc from Bayer liquor is directly correlated with the precipitation of alumina trihydrate.
- It is possible to remove iron, zinc and copper from Bayer liquor with an efficiency of more than 90%, in such a way that the treated solution is still economically usable in the following stages of processing while obtaining different types of aluminum trihydrate

5. References

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