Math Modeling of Soda-Potash Solutions Processing at RUSAL Achinsk

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Abstract

Due to the depletion of reserves of specification-grade ores of the Kiya-Shaltyrsky nepheline mine and the Mazulsky limestone mine, RUSAL Achinsk JSC receives raw materials with a high variability of chemical compositions in terms of Na, K, S, Cl, and Al. The raw materials supplied are heat treated to obtain a semi-product, i.e., sinter. Further on, during the hydro-chemical processing of the sinter by the process solutions of the refinery, an imbalance in ions $2Na^+$, $2K^+$, SO_4^{2-}, CO_3^{2-}, Cl^- occurs. For this reason, there are certain complications in processing a soda-potash solution to obtain commercial products (i.e., calcined soda, potassium sulfate) in the Calcined Soda Shop (CSS) of the alumina refinery. To solve this problem the specialists of RUSAL Engineering and Technology Center developed an app for the on-line calculation of the material balance in the workshop which allows the rapid evaluation of the key technological indicators of the process. The app is able to carry out detailed material balance calculations for the main areas of the workshop (concentration of solution, crystallization of monohydrate soda, crystallization of potassium sulfate, crystallization of anhydrous soda), plot solubility diagrams of salts in the $Na^+|K^+–CO_3^{2-}–SO_4^{2-}–H_2O$ system and provide recommendations on technological process management. In 2021, the app was successfully fully implemented at the production site of JSC RUSAL Achinsk.

Keywords: Math modeling, Salt solubility diagram, Material balance, Soda-potash solutions

1. Introduction

JSC RUSAL Achinsk (AGK) is the Russia's largest enterprise processing nepheline ore to alumina and by-products (raw materials for cement, calcined soda, and potassium sulfate). The refinery uses millions of tonnes of soda and limestone annually. Nepheline ore is characterized by a wide variety of chemicals (Al_2O_3, Na_2O, K_2O, SiO_2, CaO, Fe_2O_3, SO_3, MgO, TiO_2, Cr_2O_3, etc.) and minerals (nepheline, analcime, orthoclase, natrolite, amesite, kaolinite, calcite, goethite, magnesite, pyrite, etc.) compositions [1]. Irregular distribution of these minerals in the ore of the Kiya Shaltyrsky nepheline mine, as well as complexity of raw material blending (millions of tonnes annually), result in an uneven supply of alkalis, carbonates, and sulfates into the production process. Additionally, due to exhaustion of the Mazulsky limestone mine, many detrimental minerals get into the process, e.g., pyrite (FeS_2), kaolin ($Al_2O_3·2SiO_2·2H_2O$), silica (SiO_2), etc. The impact of numerous factors on downstream processing stages (i.e., mix preparation, sintering, sinter leaching, desilication, precipitation, carbonation) results in a high variability of the ionic composition of the soda-potash solution (an intermediate product of alumina production), which is directed to extracting the soda products to the Calcined Soda Shop (CSS).

2. Method of Processing Soda-potash Solutions

A soda-potash solution is an intermediate product of the hydrochemical area of alumina production and contains mainly cations $2Na^+$, $2K^+$ and anions $A1O_2^-$, HCO_2^-, CO_3^{2-}, SO_4^{2-}, SO_3^{2-}, OH^- Cl^- in the water (dissolvent). As per the current process, the soda-potash solution enters the processing unit for neutralization where caustic alkali (special solution with a high con-tent of free caustic alkali, i.e., NaOH, KOH, prepared in the causticization area) is added to the solution to neutralize HCO_2^- ions by an exchange reaction. The composition of the solution from the neutralization unit corresponds to the $Na^+|K^+–CO_3^{2-}–SO_4^{2}–Cl^-–AlO_2^-–OH^-–H_2O$ seven-component system, which is not well studied [2,3]. It is known that only high concentrations of anions $A1O_2^-$ and OH^- in the solution influence the salt solubility [4], but usually when $A1O_2^-$ content in the soda-potash solutions is low: only some sections of the multicomponent system have been studied.

The soda-potash solution, which is directed to the CSS from neutralization, is then preconcentrated (excessive water is removed to achieve the target solution density and salt concentrations). It is further supplied to isothermal crystallization. At 95–100 °C, i.e., slurry temperature in evaporation trains, the solution is evaporated to achieve the required concentration, which is higher than soda saturation, to obtain a wet $Na_2CO_3·H_2O$ product (monohydrate soda, which is dried to anhydrous soda in drum driers). Figure 1 shows the main processes of the CSS.

As can be seen in Figure 1, a mother solution (solution after the removal of monohydrate so-da) is directed to extraction of potassium sulfate (K_2SO_4) by adiabatic isohydric crystallization, i.e., the solution is supersaturated by cooling below 40 °C. However, the precipitation of berkeyite ($2Na_2SO_4·Na_2CO_3$) or glaserite ($Na_2SO_4·3K_2SO_4$) should be avoided, as they are undesirable products and are not required in the salt market.

After sulfate crystallization, the mother solution goes to isothermal crystallization where the solution is evaporated up to a higher concentration than the soda saturation point in order to obtain a commercial product, i.e. Na_2CO_3 (anhydrous soda). After evaporation the mother solution is treated as a spent solution and is mixed with the mother solution from monohydrate evaporation to prepare the feed solution for sulfate crystallization. In other words, the process for salt extraction requires availability of the spent solution and implies balanced operation of the evaporation equipment to ensure complete processing of the soda-potash solutions.

App features and functionality enable the operator to assess the detailed information on the performance of each area at the refinery based on the input data on flow rates and chemical compositions, and thus predict the operation of the equipment.

7. References

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