Development and Application of an Organic Carbon Detection Device for Sodium Aluminate Solution

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Abstract

The build-up of organic matter in Bayer Process leads to an increase in foam and a decrease in equipment capacity at precipitation stage. It has a great adverse impact on product quality and precipitation yield. Potassium permanganate oxidation method, total organic carbon analyzer and other analytical methods are used in alumina industry to determine the content of organic matter. In this paper, a developed technology for organic carbon detection in process liquor is discussed. First, inorganic carbon in liquor is completely precipitated. Then, the total organic carbon can be detected by an on-line organic carbon oxidation technology. Developed testing equipment and oxidation techniques enable to detect oxalates as well. It has been tested and validated in an alumina plant. It can guide operators to monitor the quality and stable operation of alumina.

Keywords: Bayer Process, Organic matter, Organic carbon, Total organic carbon.

1. Introduction

The organic matter is brought with bauxite and used organic additives into the alumina process. Organic carbon content in liquor accumulates in Bayer cycle. China has been importing large quantity of bauxite due to increased alumina production capacity in recent years. These bauxites have been conveying high content of organic matter into the pure Bayer liquor. Organic matter has a serious impact on production system. It requires comprehensive study and efficient detection of organic carbon in solution. The calculation of organic matter content usually is done from combustion products such as water and carbon dioxide. While the mass of hydrogen is calculated from water, mass of carbon is worked out from carbon dioxide quantity. Considering the oxygen used for oxidation, the mass of oxygen is calculated from both of carbon dioxide and water quantity. Finally, the ratio of carbon, hydrogen and oxygen can be figured out with the simplest formula and molecular weight of organics. In this study, a variety of titration reagents were added to the liquor at different stages to generate CO_2. An external CO_2 detection sensor and integrated mass measurement device were used to analyze and calculate the organic carbon content in the solution[1]. Zhengzhou Non-ferrous Metals Research Institute Co. Ltd of CHALCO has independently developed and produced a fully automatic organic detection device, which comprises an integrated units such as sampling, chemical titration, detection and analysis devices. Titration agents has precisely injected with the plunger pumps. Modern integral algorithms have been applied to get high efficiency and accuracy. This set-up has performed an efficient, accurate and stable detection and analysis of organic matter in the liquor. The set-up has been used on-line for the purpose of getting fast and high detection efficiency, improving working conditions, enhancing product quality, saving energy and reducing pollution.

2. Technological Process

A liquor sample of 100 mL was grabbed from the production process. Then, a 500 mL solution of hydrochloric acid of a certain concentration and 500 mL of catalyst solution containing manganese ions were prepared. A certain concentration of 500 mL NaOH solution was prepared as well.

The liquor to be tested was gradually injected into the reaction tank via a mini peristaltic pump. A precise plunger pump was used to add hydrochloric acid at different times by following the the acidification reaction mechanism. Catalyst solution containing ozone were added to oxidize[3] the organic carbon in liquor and produce CO_2. The carrier gas, N_2 was continuously introduced through the system detected CO_2 produced at different times were recorded. The concentration of organic matter was calculated accordingly. Among them, the precise control of hydrochloric acid reagent is the most important control index in the whole detection process.

At the early stage of test, the Bayer liquor was directly acidified with 1:1 hydrochloric acid. During the acidification reaction, strong acids violently reacted with strong bases. While stirring the solution, most of the inorganic carbon in the original liquor evaporated as carbon dioxide. The solution became free of inorganic carbon when the pH is below 2. CO_2 was continually introduced as a carrier gas to flush out the remaining carbon dioxide in the solution. The rest of the carbon in solution was in the form of organic matter.

Ozone is a strong oxidizing agent. It oxidizes organic carbon into CO_2. In sodium aluminate liquor, CO_2 reacts with NaOH to produce sodium carbonate. Therefore, when organic matter is oxidized, the sodium carbonate content in the liquor increases.

$$C + O_3 = CO_2\uparrow + \tfrac{1}{2}O_2\uparrow \quad (1)$$

$$CO_2 + 2NaOH = Na_2CO_3 + H_2O \quad (2)$$

Ozone generators produce ozone by breaking apart oxygen (O_2) molecules into single atoms, which then attach to other oxygen molecules in the air to form ozone (O_3).. Since ozone decays more easily to give off oxygen, the higher the temperature and the shorter the decay period. Therefore, the reaction temperature is set at room temperature. The whole testing process is shown in Figure 1:

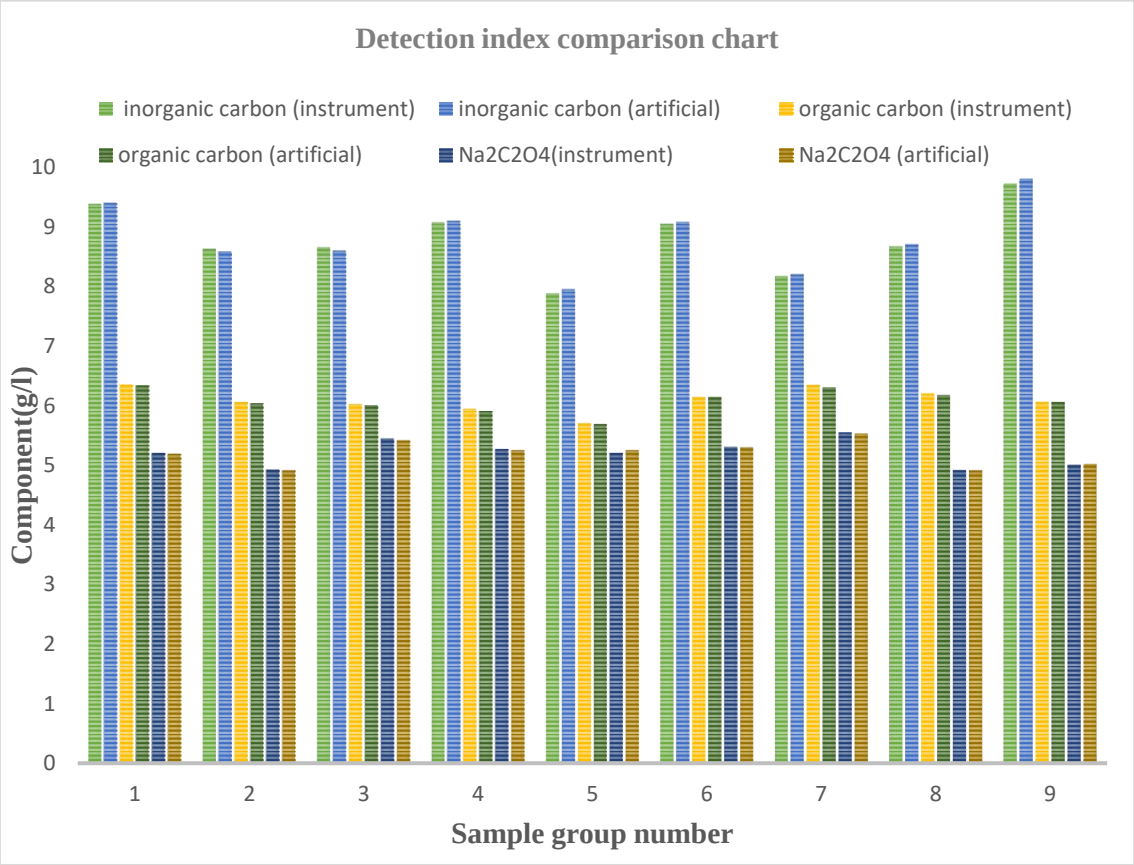

Figure 6. Detection index comparison chart

5. Conclusion

According to the principle of NDIR infrared absorption method, an analysis device of organic carbon in sodium aluminate solution was researched and realized. The sampling unit, reagent addition unit and an analytical unit were designed. PLC based control system was adopted to coordinate the overall monitoring of the machine. At the same time, a man-machine interface of the system was developed. Complete the test of one sample in 50 minutes. According to the test results, the measuring range of organic carbon in this device was determined as 0–50 g/L where, the measurement range CO_2 concentration was between 0–2000 ppm with 1 ppm precision and ≤ 2 % FS(Full-scale), lower limit of measurement:. The measurement range of gas mass flowmeter was 0–10 L/min. The operating temperature was between -10~50 °C. Signal output for Modbus communication was enabled.

The application of this device has solved the problem of rapid analysis of organic carbon in sodium aluminate solution in alumina process. It is convenient for operators to adjust production control parameters in time and ensure high production quality in alumina. The device has friendly interface, simple design and reliable operation. It fills the gap of this kind of testing device in domestic aluminum industry with its low-cost high-performance value.

6. References:

1. Zhang Ni, Behavior research of the organic matter in Bayer Process flow, Central South University, *Master degree thesis*, 2008, 37-45.

2. Song Feng, Bayer Process solution system of high organic matter removal process control, *Shandong Metallurgy*, 2019,45.
3. Chen Ying， Ozone oxidation Bayer Process sodium aluminate solution test research of the organic matter, Kunming: *Yunnan Metallurgy*, 2018, 82.
4. Jian-Song Wang, Organic analysis methods of alumina industry development， *Calculation and measurement technology,* 2013， 15-16.
5. Cao Dianguo, *Computer control technology* [M], Beijing: People's Posts and Telecommunications Publishing House, 2013, 35-36.
6. Zhi-Jun Liu, *Principle of automatic control* (I) [M], Beijing: Tsinghua University Press, 2013, 137.
7. Calculation formula and properties of definite integral, http://www.360doc.com/content/14/0915/14/18578054_409650120.shtml (accessed on 29 October 2020).