AUTOMATED PREDICTION OF ANODE EFFECTS IN ALUMINIUM REDUCTION CELLS

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Extended abstract
Aluminium is produced by electrolysis of aluminium oxide (Al_2O_3, also called alumina) dissolved in a liquid electrolyte at temperatures close to 1000^{o}C. The energy efficiency in an aluminium reduction cell depends on several factors, one being the concentration of dissolved alumina in the electrolyte. Both too high and too low concentration of alumina may lead to serious operational problems. One of the limitations of present control strategies is the lack of reliable online information. Due to the harsh working environment inside the cells, no direct measurements of alumina concentration are available. The alumina feed control is today mainly based on change in cell pseudo-resistance calculated from the measured total line amperage and total voltage drop across the cell. No cost efficient alternative alumina concentration sensors for industrial use have yet been developed. According to Bearne (1999) it is probable that the relation between change in pseudo resistance and alumina concentration will continue to be used for control for many years. On these premises, being able to detect and identify abnormal operating conditions at an early stage is important. This paper reports on work done to identify abnormal operating conditions like anode effect using measurements of the individual anode currents in addition to the usual measurements of cell voltage and line amperage. Any new information that can give insight into the distribution of alumina in the cell may help improve control of alumina concentration and reduce variation within the cell.

In the cells in studied in this work, alumina is fed to the electrolyte through two point feeders in each end of the cell. A bar punches a hole in the top crust and allows a controlled amount of alumina to be dropped into the electrolyte bath. Faulty equipment, for example a leak in one of the feeders or a malfunctioning bar, can lead to that the amount of alumina that is actually dissolved in the electrolyte is considerably less than what is assumed by the process control system. If this situation goes on unnoticed over time, it may eventually lead to an anode effect. Anode effect is caused by depletion of alumina underneath the anodes and causes the resistance (and the voltage) to increase dramatically without any corresponding increase in metal production. In addition to causing low energy efficiency and disturbing the cell energy balance, anode effect causes production of significant amounts of CFC gases, which are harmful to the environment and have a very strong “greenhouse effect.”

In a reduction cell with pre-baked anodes, the individual carbon anodes are arranged in two rows and connected in parallel to the horizontal bus bars. When the DC electrolysis current passes from the anodes through the electrolyte to the cathode, liquid aluminium is formed at the bath/metal interface acting as the cathode. The way the current distributes between the individual anodes depends on the resistance in the anodes and in the inter-electrode gap. Since anode resistance is fairly constant over time and the resistance in the electrolyte strongly depend on alumina concentration, the anode current distribution in a cell should give an indication of alumina distribution and concentration profile in the electrolyte. This is motivated by the observations made by Rye et al. (1998) who observed a redistribution of anode current prior to anode effect when the alumina concentration in the electrolyte dropped below a critical level.

In this work both measurement data from normal operation and data from controlled experiments in which anode effect were provoked were studied. Because different faults affect the measurements in different ways, we can characterize and detect an abnormal situation by monitoring the process and comparing with normal operation data. Visual inspection of the anode current data does reveal a redistribution of current prior to anode effect in many cases and a skilled operator may be able to predict anode effect several minutes ahead simply by examining the current distribution. However, in a typical aluminium smelter each potline will have some 200 electrolysis cells connected in series with only a few operators per shift. Relying on manual detection of incipient anode effects is therefore not feasible. Thus, the challenge is to get reliable predictions of anode effects minimizing the number of false alarms when examining the data in an online situation on the computer.

In order to investigate automated methods for anode effect prediction, data from Elkem Aluminium's plant in Mosjøen, Norway, were collected and analysed. Subsequent data analysis shows that for the controlled experiments we get a reliable prediction of anode effect at least five minutes ahead in most cases. For the normal operation data the prediction of anode effect is somewhat later, but still sufficiently early for preventive measures to be taken. However, for normal operation data, the results also show frequent occurrences of false alarms. Many of the false alarms are due to process disturbances such as change in anode cathode distance, manual operations performed on the cell, metal tapping etc. These situations can in most cases be identified by comparing with the process database. A problem however, is when potline operators make adjustment to the cell without notifying the process database. In such cases, false alarms occur. Eliminating such false alarms will be required before applying the anode effect prediction online.

References

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