A Local Alumina and ACD Observer for Aluminium Electrolysis Cells Using Anode Currents

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Abstract

In industrial aluminium electrolysis cells, the distribution of alumina is often non-uniform. This can be attributed to several factors, such as bath movement, discrepancies in alumina feeding from different feeders and variations in consumption rates, to name a few. Furthermore, the non-uniform distribution of alumina has some effect on the pseudo-resistance of the cell and its variability, which are typically used to control alumina concentration in the cell. However, this can lead to an unpredictable lack of alumina locally in the cell, resulting in localized anode effects that can transform into generalized anode effects. Therefore, to achieve an independent utilization of the feeders for balancing the alumina distribution in the cell, the first step is to have a reliable estimate of the alumina distribution. To realize it, distributed information, such as the anode currents, is required. This study uses a two-step approach for estimating local alumina concentration and anode-cathode distance (ACD). In the first step, an observer uses the cell pseudo-resistance to obtain an initial estimation of alumina concentration and ACD. In the second step, a second observer uses the individual anode currents to correct the initial estimations. This paper is focused on the design of the observers and the required signal processing to obtain reliable estimations. Finally, the proposed method is validated with data from a smelter.

Keywords: Aluminium reduction cells, Alumina concentration, Cell pseudo-resistance monitoring, Observer design, Filtering and estimation.

1. Introduction

In the last twenty years, one of the main objectives of the aluminium industry has been to decrease the greenhouse gas emissions. In aluminium production, a large part of the total greenhouse gas emissions comes from anode effects. When alumina concentration goes under a certain threshold, a more energy-demanding chemical reaction involving the emissions of CF_4 becomes dominant [1]. Moreover, aluminium reduction cells can have significant alumina concentration gradients [2], leading to anode effects starting from a deficit alumina concentration under one or few anodes. The reduction of this phenomenon requires a better control of the alumina feeding: instead of a uniform feeding within the cell, areas with less alumina concentration can be targeted to receive a bigger alumina feeding. The first step for a better alumina feeding distribution is to have an estimation of the alumina concentration gradient in the cell. In this paper, we propose a distributed observer that makes use of the anode currents to estimate the local dissolved alumina and ACD under the anodes.

In the last decade, observers based on a discretized cell model have been proposed for the estimation of the dissolved alumina concentration distribution. In [3], a multi-level Extended Kalman Filter (EKF) for the estimation of local dissolved alumina and ACD, based on discretized cell models, has been proposed. In [4] the authors propose an Iterated EKF that, together with local dissolved alumina and ACD, estimates the bath flow. In [5], the authors proposed a control scheme for the feeder individualization that includes an LQR control based on a EKF distributed alumina estimation. In [6] the authors used a Huber function based Kalman Filter to estimate the local dissolved alumina and ACD.

The common point between the previous estimation algorithms resides in the fact that the anode currents have been used only as input to the discretized cell model, and not to correct the estimation in the observer algorithm. To use the anode currents in the observer algorithm, in continuity with the work proposed in [3-6], a possibility would be to derive an explicit expression of the anode currents, starting from – an affine with respect to the anode current – simplified expression of the voltage. Even though this is the most academically sound solution, some application drawbacks prevent us to use this method: dealing with different anode currents noise, unavailability (or excessive noise) of one or some anode current signals requires the design of a completely new observer, and the sensitivity to non-modelled behaviours becomes difficult to manage with many outputs.

In this work, we propose a two-stage algorithm for estimating local dissolved alumina concentration and ACD. The first stage involves the observer presented in [7], which utilizes the cell pseudo-resistance to estimate *instrumental* dissolved alumina and *instrumental* ACD. The second stage comprises several anode observers equal to the number of available anode currents, which use the anode pseudo-resistance to refine the instrumental estimations from the first stage, thereby obtaining the local dissolved alumina and ACD. The paper is organized as follows: in Section 2 we present the essential information regarding the *instrumental* observer; in Section 3 we show the necessary current pre-processing to apply the local observer that is presented in Section 4; the application of the local observer on industrial data is given at the end of Section 4; finally, some concluding remarks and possible future developments are given in Section 5.

2. Instrumental Alumina Observer

The first stage of anode dissolved alumina estimation consists of the observer of the *instrumental* dissolved alumina $w_d(k)$ and *instrumental* $ACD(k)$. As shown in Figure 1, the observer consists of an algorithm that takes as input the feeding period, the line current and the measured pseudo-resistance and returns the *instrumental* dissolved and sludge alumina together with the *instrumental* ACD.

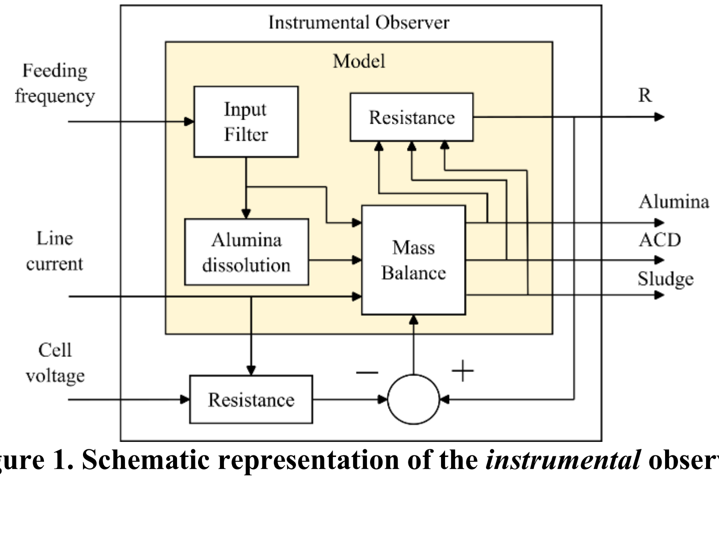

Figure 1. Schematic representation of the *instrumental* observer.

6. References

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