Pot Abnormality Tracking System (PAT) for Critical Pot Detection

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Abstract

Pot tap out is one of the most hazardous condition in an aluminum smelter, posing risk to life as well as business. During pot tap-out metal seepage takes place from the collector bar, side shell or bottom shell of pot, which determines the kind of failure. The main reason for pot tap-out is the metal penetration through cracks in cathode and side lining. Therefore, for critical pot detection, Pot Abnormality Tracking (PAT) system was developed which can aid in shutdown of pots before failure. PAT is a score-based algorithm where selected key performance indicators (KPIs) such as pot age, cathode type, bath temperature, instabilities, historic events, lining vulnerability, etc., are tracked and evaluated against a pre-decided weightage structure. The weightage for each parameter is decided on the basis of historical data and its impact leading to pot failure. PAT system generates separate scores against the possibilities of failure through collector bar and failure through side shell. On the basis of these scores, ranks are allotted to the pot which defines the criticality of pot. Pot shutdown priority can be based on PAT score and hence pot tap outs can be avoided.

Keywords: Pot tap-out, Pot abnormality tracking, Collector bar tap-out, Side shell tap-out.

1. Introduction

Aluminium is produced industrially by the Hall-Heroult process [1]. The aluminium electrolysis process consists of electrochemical decomposition of alumina dissolved in sodium cryolite based electrolyte (Na_3AlF_6) known as bath at 950-970 °C. Faraday's law of electrolysis governs this process. Under the influence of DC current alumina is reduced to liquid aluminium, which collects at the cathode while the oxygen reacts exothermically with anode carbon to form carbon dioxide and carbon monoxide gases [2]. The main reaction in the cell can be expressed by Equation (1):

$$2\ Al_2O_3 + 3\ C = 4\ Al + 3\ CO_2 \tag{1}$$

The carbon is supplied to the reaction by prebaked anode blocks made of a mixture of coke, pitch and recycled anode butts [3]. The process is carried out in reduction cells or pots as shown in Figure 1 [4].

As it can be seen from Figure 1, aluminium smelting consists of a large number of process parameters such as alumina dosage, bath temperature, cathode type, etc. Hence, aluminium smelting is a process, which involves multiple variables and highly complex mechanisms such as mass and energy balances, electrochemical reactions, the supply of reactants and the maintenance of the composition of the reaction mixture [5]. In addition, the large amount of information coming in from such a process, some in real-time and others intermittently at varying frequencies, is challenging for a human brain to process. To control this complex process to achieve high productivity and efficiency requires day to day (and sometimes minute to minute) monitoring of the variables, and a high level of deductive problem solving and decision-making.

As most of the process parameters cannot be monitored online continuously throughout the day such as sudden surge in iron percentage in the metal which may lead to pot failure through the collector bar, a system is required which could predict the criticality of pot based on the critical process parameters analysis. Therefore, a system has been made which is known as pot abnormality tracking (PAT) system. PAT is a score-based system where selected key performance indicators (KPIs) are tracked and evaluated against a pre-decided weightage structure. Separate scores are generated against possibilities of failure through a collector bar and failure through side shell. The highest of the two is considered as PAT score. The pot with the highest PAT score is considered as the most critical pot. The weightage to each parameter is decided based on root cause analysis of pot failure and based on pot autopsies report. For the efficient functioning of the system certain algorithms have been applied on KPIs considered, which enables to predict the correct PAT score.

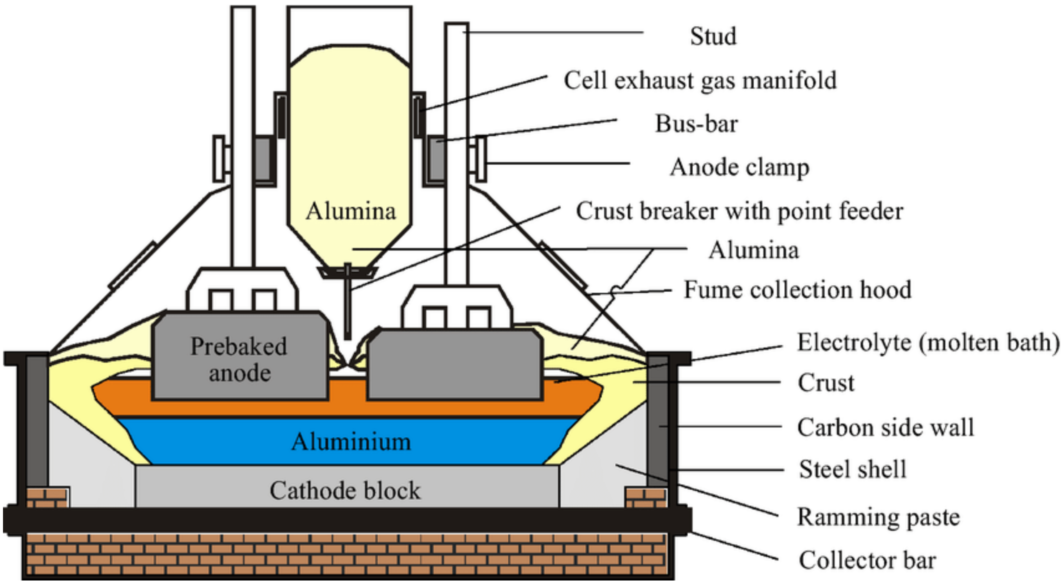

Figure 1. Front view of Prebaked Electrolytic Cell [4].

2. PAT Parameters and Model

Several critical process parameters are considered for developing the PAT System. Selection of correct parameters remains crucial for developing any kind of model; for PAT some known basic process parameters were taken into consideration. Apart from which autopsies of failed pots and shutdown reports of schedule-stopped pots were studied. Root cause analysis (RCA) study was done over all these stopped pots and a set of parameters were finalized along with their contribution (weightage) leading to pot failure.

The major parameters, which play a role in pot tap out are cathode age, iron and silicon increment in metal as an indicator of metal penetration, bath temperature deviation, side ledge melting due to high superheat, anode effect frequency, and critical measurements such as collector bar temperature and side shell temperature. Apart from these parameters information like iron increase due to anodic issue have also been considered to factor-in false metal penetration signals from Fe increase.

As any pot can fail either through sidewall or collector bar, all these parameters were divided into two sets of collector bat temperature (CBT) and hell sidewall temperature (SST). The following is discussion over factors considered in both CBT/SST parameter sets and rationale behind their inclusion.

see the PAT efficiency improvement. It is necessary to carry out correct autopsy of failed pots and determine correct cause and condition of pot failure. These conditions and real cause can change from smelter to smelter and even cathode type to cathode type.

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