Automated Monitoring of Deformed Anode Baking Furnace Pits

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Abstract

Prebaked carbon blocks are used as anodes for aluminum smelting in the Hall-Héroult process. The baking of anodes takes place in an anode baking furnace. The deflection of the furnace flue walls limits its lifetime. This deflection is promoted principally by the action of the headwalls restraining the free thermal expansion of the flue walls and that of the packing coke. The quality of the anodes used in the aluminum industry depends strongly on the baking process. The condition of a baking furnace is monitored by manual measurements and classification of its condition, a process that has safety and efficiency challenges. This paper proposes an AI-powered autonomous drone for automated pit and flue wall condition assessment. A GPS-guided and camera-equipped drone is programmed to take scheduled trips during which it flies over and records a video of the whole baking furnace floor. The feature corner-based feature points are detected between the video frames and used to warp and stitch the video into a large mosaic. A deep hierarchical object detection framework is used first to detect floor sections and then each pit. A pit is divided into four segments and a final stage classifier is used to assign it to one of the five different deformation levels. The need for a large volume of training data is significantly reduced by designing a data augmentation pipeline to generate training data synthetically. The pit detection has a precision of 99%, and the pit segment classification algorithm achieved an accuracy of 92 %. Also, a 3D model is developed for each pit using its extracted image by segmenting the pit's top and bottom layers and linearly establishing the correspondence between the edge points. The proposed system offers the result monitoring through a user-friendly application that allows operators to visualize the pit deterioration over time and to schedule maintenance.

Keywords: Anode baking furnace, Deflection of flue walls, Automated assessment of flue wall deformation, AI-powered autonomous drone, Deep learning.

1. Introduction

Industrial production of aluminum is carried out by the Hall-Heroult process, an electrolytic process in which aluminum oxide is dissolved in an electrolyte consisting primarily of molten cryolite and aluminum fluoride. During the process, prebaked carbon blocks are used as anodes and are baked up to 1150 ºC in large-scale Anode Baking Furnaces (ABFs) with a certain number of pits per section separated by flue-walls [1]. The dimensions of a single baking pit are around 5.4×0.8×4.6 m^3. After the baking process is done, the baked anodes cool down in cooling sections before entering the fire sections. The entire process takes about 240 to 360 hours. This process is the most expensive step in anode production. The fuel supply and refractory repair represent approximately 15% of the total manufacturing cost of the carbon anodes [2].

Effective extraction of aluminum during electrolysis is heavily dictated by the quality of the baked carbon anodes used. Underbaking, overbaking, or uneven heating of the anode during baking will negatively affect the electrolysis process conditions. Anode sections close to the top and bottom of the pit are exposed to higher heat dissipations and consequently this results in overconsumption of carbon anode throughout the process [3]. Therefore, the anodes must have a homogeneous temperature distribution throughout the baking process [4].

After long periods of continuous operations in the ABF and the frequent exposures of high operating temperatures in the fixed baking pits leading to thermal and mechanical stresses, the pits start to exhibit deformations. In addition, cracks and deflections of the flue walls that are detrimental to the heating process also begin to appear, affecting the baking uniformity and the quality of the carbon anode. The presence of the headwalls inhibits the thermal expansion of the flue walls. As a result, the condition of the pits in an ABF deteriorates over time, limiting its lifetime. The deflections of the flue walls that occur vary in size, altering the width of the pits. Figure 1 shows the different flue wall deflection modes.

Figure 1. Different modes of pit deformations.

Human operators conduct surveys using measuring tape at an ambient temperature to monitor the refractory state. Pits with a width of 760 mm to 840 mm are classified as normal, a width of less than 300 mm as narrow, and greater than 900 mm as wide. Due to the depth of the pits being around 5 m and the large size of the baking furnace, regular monitoring of these pits is challenging and poses health and safety concerns for the inspection team.

through a user-friendly web application that allows operators to track pit condition deterioration over time and schedule maintenance. The proposed system and sub-systems are tested on-site and concluded that they accurately assess a large industrial area despite its difficult characteristics.

5. References

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