Autonomous Intelligent Technology for Three-Steel Temperature Measurement Using Suspended-Rail Infrared Thermometry

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https://doi.org/10.71659/icsoba2025-al047

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Abstract

To address key challenges in monitoring the "three steel temperatures" – sidewall, collector bar, and potshell bottom plate – of aluminium reduction cells, such as high labour intensity, large data dispersion, prominent safety risks, and low efficiency, this study innovatively developed an overhead rail infrared temperature inspection system. By suspending an inspection rail and device beneath the bottom beam of the cell, and integrating spatial positioning, infrared temperature sensing, wireless communication, and adaptive drive modules, the system establishes a triune automated inspection mechanism of "positioning-acquisition-analysis". Industrial tests on a 400 kA electrolytic cell show that the system inspects 144 marked points in just 240 s, achieving a 300 % improvement in efficiency compared to manual inspection. It also delivers a positioning accuracy of ±1 cm and a temperature measurement accuracy of ±1 °C. Compared to manual measurement, the average standard deviation of the collected data decreased from 6.2 to 0.7, reducing data dispersion by 88.7 %. In conclusion, the overhead rail inspection system significantly improves inspection efficiency and accuracy, enhances safe operation and control of electrolytic cells, and meets the monitoring requirements for the steel temperatures of the cells.

Keywords: Aluminium reduction cell, Three steel temperature measurement, Intelligent inspection.

1. Introduction

As the core equipment in aluminium smelting, aluminium reduction cells have three critical temperature measurement points – the sidewall, collector bar, and potshell bottom – collectively known as the "three steel temperatures" [1]. Real-time and precise monitoring of these three key areas is of great importance for analysing the temperature field distribution within the cell, preventing premature cell failure, and extending the service life of the cell [2, 3].

In traditional methods, the three-steel temperatures are measured manually using handheld infrared thermometers, which requires point-by-point inspection. This approach is labour-intensive and inefficient, and poses safety threats to inspectors, especially in emergency scenarios [4]. To address this issue, some studies have explored installing online temperature measurement devices on the sidewalls of electrolytic cells. However, harsh conditions such as high temperature, strong magnetic fields, and heavy dust make it difficult to install and secure temperature-sensing cables and probes. These components are prone to detachment or damage, resulting in substantial measurement errors [5]. Moreover, given the tens of thousands of temperature measurement points in potline the installation and maintenance costs of the required distributed optical cable acquisition devices are too high, hindering large-scale application [6, 7].

Ground robot-based temperature measurement solutions face several challenges. On the one hand, the confined space beneath the electrolytic cells limits the manoeuvrability of large robots. On the other hand, the high-temperature slag produced by the cells can corrode both the robots and their sensors, and also block their paths, affecting normal operation [8]. In addition, the strong magnetic field environment interferes with signal transmission, resulting in inaccurate positioning, frequent equipment failures, increased maintenance costs, and reduced operational efficiency [9].

To solve the challenge of accurately measuring the three-steel temperatures of the cells, this paper proposes an innovative integrated solution that combines an overhead rail inspection device with infrared temperature measurement technology. A dedicated monitoring and control system for the three-steel temperatures is designed and developed to enable real-time, dynamic monitoring and precise regulation of critical temperature points within the cell, providing technical support for achieving intelligent and refined management of aluminium electrolysis production processes.

2. Overall System Design

To meet the temperature monitoring requirements under the complex operating conditions of the cells, this paper presents a inhouse-developed overhead rail intelligent inspection robot system, whose overall control architecture is shown in Figure 1. Centred on a modular design, the system consists of two core modules that work in coordination: the inspection robot and the data processing centre. Serving as the sensing terminal, the inspection robot features a lightweight mechanical structure and integrates a drive system and a low-latency communication module, enabling autonomous cruising along preset rail paths and real-time data transmission. A laser ranging module measures the spatial distance between the robot and the target parts of the cell in real time, feeding the data back to the control system. Intelligent algorithms dynamically adjust the focal length of the infrared temperature measurement lens to eliminate measurement errors caused by distance variations.

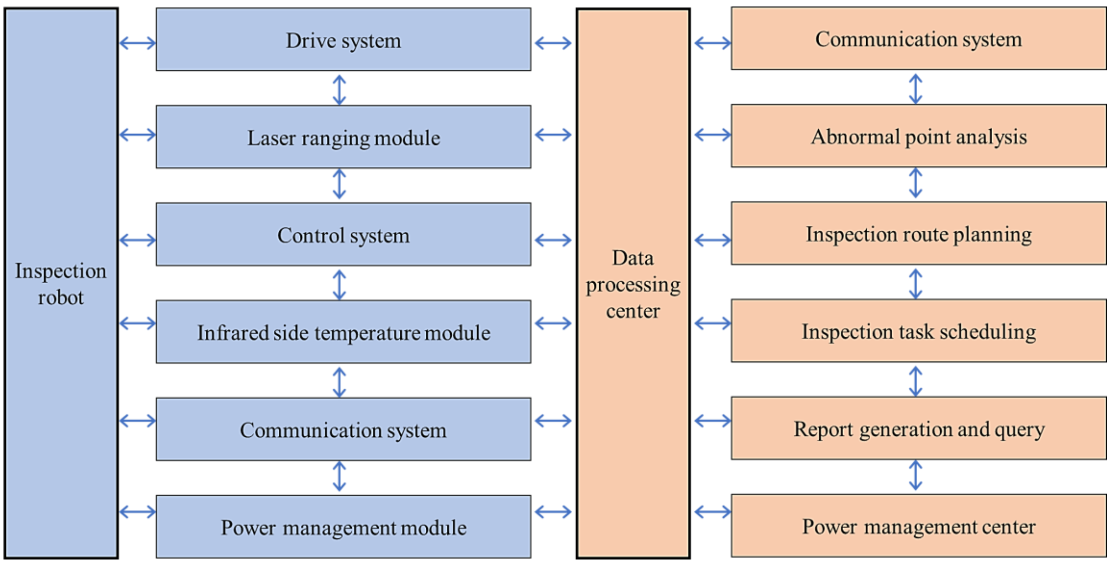

Figure 1. Overall control architecture diagram.

The inspection robot data processing centre serves as the intelligent monitoring hub of the system, integrating core functions such as inspection task planning, data parsing, anomaly detection, and dynamic scheduling. Through industrial-grade data interfaces, the centre receives infrared windows and 144 marked points along the side of the cell is only 240 seconds. Manual completion of temperature measurements at the same points requires two people working in coordination to test and record data, taking approximately 960 seconds. Therefore, the inspection system improves efficiency by 300 % compared to traditional manual inspection.

5. Conclusion and Outlook

The overhead rail inspection robot device and system proposed in this paper address the challenge of measuring the three-steel temperatures in aluminium electrolysis production, overcoming the bottlenecks of low efficiency, poor accuracy, and high environmental risks associated with traditional manual inspection. The device features an innovative suspended rail design, enabling autonomous cruising along a preset path in the narrow space at the bottom of the electrolytic cell. It integrates high-precision infrared temperature measurement and multi-sensor fusion technology to achieve fast and accurate detection of the three-steel temperature. Field test data from a 400 kA electrolytic cell at a certain enterprise show that the inspection system can cover all 48 steel windows and 144 inspection points in just 240 seconds, a 300 % improvement in efficiency compared to manual inspection. It achieves a positioning accuracy of ±1 cm and a temperature measurement accuracy of ±1 °C. Compared to manual measurement, the average standard deviation of the data decreased from 6.2 to 0.7, reducing data dispersion by 88.7 %.

Test results indicate that the overhead rail inspection technology for the cells offers significant advantages over traditional manual and ground-based inspection methods in terms of temperature measurement efficiency, accuracy, and safety. This technology helps improve the intelligence level of aluminium electrolysis production, reduces labour costs and safety risks, and provides technical support for multi-dimensional early warning diagnostics and the optimization of process control for the three-steel temperatures in the cells.

6. References

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