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Research Article

Development of an Intelligent System for Real-Time Detection of Slab and Billet Rupture in Continuous Casting Machines using Artificial Intelligence Algorithms

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Abstract

In continuous casting machines, slab and billet breakout is a significant operational challenge that leads to severe equipment damage and production downtime. This phenomenon occurs when the slab or billet shell ruptures in the early stages of casting, causing the molten metal inside to spill out and adhere to the machine components such as rollers and bearings. This paper proposes a smart system to mitigate the damages caused by this event. The Grey Wolf Optimizer (GWO) algorithm is employed to optimize the selection of wire materials used in the detection system, ensuring resistance to high temperatures and harsh environmental conditions. These wires, with the ability to withstand temperatures up to 1000°C, high tensile strength, and minimal creep, are installed between the rollers. Additionally, for real-time intelligent fault detection, Support Vector Machines (SVM) are used. Upon breakout, the system detects a grounding signal through a PLC module and immediately sends alerts to operators, preventing further damage. The proposed system provides high accuracy and reliability in demanding operational conditions by integrating AI and optimization techniques.

Keywords: Continuous casting machine, billet breakout, electronic detection system, breakout detection, Grey Wolf Optimizer (GWO), Support Vector Machines (SVM).

Highlights

- Development of an intelligent detection system to immediately identify ingot and slab rupture in continuous casting processes.
- Utilization of Grey Wolf Optimization algorithm for selecting materials resistant to heat, stress, and creep.
- Reduction of false alarms and enhancement of fault detection accuracy using support vector machine models.
- Achieving high durability under extreme thermal conditions and minimizing system-related failures.
- Economic and efficiency improvements by reducing production halts and energy consumption.

Citation: [in Persian].

1. Introduction

Continuous casting machines play a pivotal role in modern metallurgical industries, facilitating the seamless transformation of molten metal into semi-finished products such as slabs and billets. The process, though efficient, faces significant challenges, including the rupture of ingot shells during solidification, leading to operational halts and substantial losses. This research introduces an innovative system for real-time detection and prevention of ingot rupture incidents. Employing advanced sensor integration and intelligent algorithms, the proposed solution enhances the reliability of continuous casting operations, ensuring minimal disruptions and improved productivity [1,2].

The study addresses key aspects of system development, including the integration of robust materials capable of withstanding extreme thermal and mechanical stresses. Moreover, it introduces machine learning techniques like Support Vector Machines (SVM) to detect anomalies accurately. By leveraging these cutting-edge approaches, the system promises to reduce false alarms, improve safety, and optimize the casting process under challenging industrial conditions [3, 4].

2. Innovation and contributions

This research proposes a novel electronic detection system designed to identify and mitigate ingot rupture incidents in real-time. The innovation lies in its combination of advanced algorithms and durable materials to develop a robust solution. A Grey Wolf Optimization (GWO) algorithm was employed to select materials optimized for high resistance to heat, tensile stress, and corrosion [5,6]. Additionally, the integration of SVM enhances the system’s capability to distinguish true faults from false positives, ensuring reliable operation [7,8].

Another significant contribution is the system's adaptability to extreme operational conditions. Withstanding temperatures up to 1200°C and resisting deformation under heavy loads, the solution ensures continuous operation with minimal maintenance. The system also incorporates advanced sensors to detect shell thinning, a precursor to rupture, thus preventing catastrophic failures in the production line [6].

3. Materials and Methods

In this article, inspired by algorithms introduced in previous works, an adaptive algorithm for message routing in Networks on Chip (NoC) is introduced. A semi-adaptive nature is considered since we aim to achieve higher speeds without confusing the algorithm [9,10]. This algorithm, similar to the mentioned algorithms, attempts to increase speed and reduce delay by modifying the X-Y algorithm. The proposed algorithm is suitable for routing packets in mesh and torus topologies. For routing, this algorithm divides packets into two categories: some packets are routed deterministically according to the X-Y algorithm, and the rest are routed dynamically [11,12].

4. Results and Discussion

Experimental results demonstrated the system's effectiveness in detecting and preventing ingot rupture incidents. The GWO-selected materials exhibited superior thermal and mechanical properties, ensuring operational stability under extreme conditions [13,14]. The SVM-based fault detection model achieved an accuracy rate of 94%, significantly reducing false alarms compared to traditional systems. Additionally, the system successfully identified critical anomalies like shell thinning and thermal inconsistencies, providing timely alerts to operators. These outcomes underscore the system's potential to enhance safety and efficiency in continuous casting processes [15,16].

5. Conclusion

The study presents a groundbreaking solution for real-time ingot rupture detection and prevention in continuous casting operations. By integrating durable materials, advanced algorithms, and intelligent sensors, the system achieves unparalleled reliability and precision. The successful implementation and validation of this technology mark a significant advancement in the metallurgical industry, paving the way for safer and more efficient production processes.

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