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Energy and CO_2 Reduction in Steel Reheating and Hot Rolling through Intelligent Furnace Control and Delay-Aware Process Integration

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Steel hot rolling is a critical downstream process in steel production and remains highly energy-intensive due to reheating furnace losses, unplanned mill delays, and insufficient coordination between furnace operation and rolling schedules. While significant progress has been achieved in improving energy efficiency and decarbonization in primary steelmaking, downstream processes such as reheating and hot rolling still present substantial opportunities for reducing fuel consumption and associated CO_2 emissions.

This work presents an intelligent process integration framework aimed at improving energy and material efficiency in steel reheating furnaces supplying blooms to a hot bar rolling mill. The proposed approach integrates real-time thermal monitoring, delay-aware furnace control, and rolling process constraints to minimize unnecessary overheating and idle fuel consumption during mill interruptions. Unlike conventional furnace operation strategies that maintain fixed temperature setpoints regardless of rolling conditions, the developed control methodology dynamically adjusts fuel input and furnace operating parameters based on predicted rolling delays and discharge requirements.

A digital process model representing furnace heat transfer, bloom thermal evolution, and rolling time–temperature constraints is employed to quantify energy losses under conventional and intelligent operating strategies. The model enables real-time estimation of bloom surface and core temperatures, allowing the furnace to operate closer to optimal thermal limits without compromising rolling quality or productivity. Special emphasis is placed on managing energy losses during short- and medium-duration rolling delays, which are commonly encountered in industrial rolling mills and contribute significantly to excess fuel usage and CO_2 emissions.

The proposed framework was implemented and evaluated on an industrial pusher-type reheating furnace with a production capacity of 25 t/h supplying a hot bar rolling mill. Comparative analysis between conventional furnace operation and intelligent delay-aware control demonstrates a measurable reduction in specific fuel consumption and corresponding CO_2 emissions, while maintaining required rolling temperatures and dimensional quality of the rolled bars. The results confirm that intelligent integration of reheating and rolling operations can play a significant role in achieving energy efficiency and decarbonization targets in the steel industry.

The study highlights the importance of extending digitalization and intelligent control strategies beyond primary steelmaking to downstream processing stages. The proposed approach supports sustainable steel production by improving energy utilization, reducing emissions, and enhancing operational flexibility, in alignment with the objectives of EMECR 2026.

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