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Research Article

MODELING THE MELTING RATE IN AN OXYGEN-ENRICHED ERYTHROPHLEUM SUAVEOLENS CHARCOAL-FIRED CUPOLA FURNACE

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ABSTRACT

This study investigates the melting rate of an Erythrophleum suaveolens charcoal-fired cupola furnace with oxygen enrichment. The analysis focuses on the effects of oxygen enrichment on the furnace's thermal efficiency and melting rate. Using a combination of experimental data and mathematical modeling, the study examines the relationship between oxygen concentration and the melting rate of iron in the furnace. Key parameters such as temperature distribution, combustion efficiency, and energy consumption are evaluated. The results indicate that oxygen enrichment significantly enhances the melting rate, reduces fuel consumption, and improves overall furnace performance. This study provides valuable insights for optimizing the operational parameters of charcoal-fired cupola furnaces, promoting sustainable and efficient metallurgical processes.

KEYWORDS

Erythrophleum suaveolens, Charcoal-fired cupola furnace, Oxygen enrichment, Melting rate, Thermal efficiency, Combustion efficiency, Metallurgical processes.

INTRODUCTION

The demand for efficient and sustainable metallurgical processes has driven significant interest in optimizing traditional furnace operations. One such furnace, the cupola furnace, remains a cornerstone in small to medium-scale foundries due to its simplicity and cost-effectiveness in melting cast iron. Traditionally fueled by coke, recent environmental and economic considerations have encouraged the exploration of alternative biomass fuels. Erythrophleum suaveolens charcoal, derived from a tropical hardwood species, presents a promising renewable substitute owing to its high carbon content and favorable combustion properties.

However, the use of charcoal in cupola furnaces introduces challenges, particularly regarding achieving sufficient melting rates and thermal efficiency. Enhancing these parameters is critical for the competitiveness and sustainability of the process. Oxygen enrichment, the practice of increasing the oxygen concentration in the blast air supplied to the furnace, has emerged as a potential solution. By intensifying the combustion process, oxygen enrichment can potentially elevate the furnace temperature, thereby improving the melting rate and reducing fuel consumption.

This study aims to model the melting rate of an Erythrophleum suaveolens charcoal-fired cupola furnace under varying conditions of oxygen enrichment. Through a combination of experimental data collection and mathematical modeling, we seek to elucidate the relationship between oxygen concentration and melting performance. Key metrics such as temperature distribution, combustion efficiency, and energy consumption will be analyzed to understand the impacts and optimize the operational parameters of the furnace.

The findings of this research are anticipated to provide valuable insights into the practical application of oxygen enrichment in biomass-fueled cupola furnaces. This could lead to enhanced operational efficiency, reduced environmental impact, and broader adoption of sustainable fuel alternatives in the metallurgical industry.

METHOD

The methodology for modeling the melting rate in an oxygen-enriched Erythrophleum suaveolens charcoal-fired cupola furnace comprises both experimental and computational components. The experimental setup involved a standard cupola furnace modified to facilitate oxygen enrichment. Erythrophleum suaveolens charcoal was used as the primary fuel due to its high carbon content and energy efficiency. The furnace was equipped with sensors to monitor critical parameters such as temperature, oxygen concentration, and fuel consumption. These sensors provided real-time data necessary for developing a comprehensive understanding of the melting process under various conditions.

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Initially, a baseline experiment was conducted using ambient air to establish the furnace's performance with standard oxygen levels. Subsequent experiments involved systematically increasing the oxygen concentration in the blast air from 21% (ambient level) to up to 35%. The oxygen was supplied using a controlled oxygen injection system, ensuring precise regulation of enrichment levels. During each experimental run, the temperature profiles within the furnace were recorded, alongside the rate of melting and fuel consumption. The collected data served as a foundation for the computational modeling phase.

The computational aspect of the study involved developing a mathematical model to simulate the furnace's operation under different oxygen enrichment levels. The model incorporated key physical and chemical principles governing combustion and heat transfer processes within the furnace. Parameters such as the rate of charcoal combustion, heat release, and heat distribution were included. The model was calibrated using the experimental data to ensure accuracy and reliability. Computational simulations were then performed to predict the melting rate and thermal efficiency of the furnace at various oxygen enrichment levels beyond those tested experimentally.

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Ielting Time (T) (min.)	Fuel Consumed (F) (Kg)
10	2.4
20	4.77
30	7.18
40	8.77
50	11.89
60	14.03
10	2.28
20	4.45
30	6.78
40	8.97
50	10.96
60	13.65

The results from the computational model were validated against the experimental data, ensuring consistency and reliability. Sensitivity analyses were conducted to identify the most influential parameters affecting the melting rate and to optimize the furnace operation. The final model provided a detailed understanding of the impact of oxygen enrichment on the melting process, offering insights into optimal operating conditions for maximizing efficiency and minimizing fuel consumption.

In summary, the methodology combined rigorous experimental procedures with advanced computational modeling to investigate the effects of oxygen enrichment on the melting rate of an Erythrophleum suaveolens charcoal-fired cupola furnace. This integrated approach allowed for a comprehensive analysis, contributing to the development of optimized operational strategies for enhanced furnace performance.

RESULTS

The experimental results demonstrated a clear relationship between oxygen enrichment and the melting rate in the Erythrophleum suaveolens charcoal-fired cupola furnace. At the baseline oxygen concentration (21%), the furnace exhibited a standard melting rate with moderate fuel consumption. As the oxygen concentration increased, there was a significant enhancement in the melting rate. Specifically, at 30% oxygen enrichment, the melting rate increased by approximately 25% compared to the baseline. The highest tested enrichment level of 35% showed an increase in the melting rate of nearly 35%.

Temperature measurements indicated that higher oxygen levels led to elevated combustion temperatures. For instance, the peak temperature in the furnace at 35% oxygen enrichment was

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around 1800°C, compared to 1500°C at baseline conditions. This rise in temperature correlated with the observed improvements in melting rate and efficiency. Additionally, fuel consumption decreased as oxygen enrichment improved combustion efficiency, with a reduction of up to 20% at the highest enrichment levels.

DISCUSSION

The results highlight the positive impact of oxygen enrichment on the performance of the Erythrophleum suaveolens charcoal-fired cupola furnace. The increase in melting rate with higher oxygen levels can be attributed to more efficient combustion processes. Higher oxygen concentration enhances the combustion of charcoal, leading to higher temperatures and faster melting of the iron. This improvement is critical for industrial applications where maximizing throughput and minimizing operational costs are essential.

However, the benefits of oxygen enrichment must be balanced against the costs and practicalities of oxygen supply. While higher oxygen levels improve performance, they also require investment in oxygen generation or supply systems. Therefore, the optimal level of oxygen enrichment should consider both performance gains and economic feasibility. The study's findings suggest that an enrichment level around 30% may offer a good balance between enhanced melting rate and fuel efficiency without excessively high oxygen supply costs.

Furthermore, the reduced fuel consumption observed with oxygen enrichment has environmental benefits. Lower fuel usage translates to reduced carbon emissions, aligning with sustainability goals. This advantage makes oxygen enrichment an attractive option for foundries aiming to reduce their environmental footprint while maintaining high productivity.

CONCLUSION

This study successfully modeled the melting rate of an oxygen-enriched Erythrophleum suaveolens charcoal-fired cupola furnace, demonstrating significant performance improvements with increased oxygen levels. The findings revealed that oxygen enrichment enhances combustion efficiency, leading to higher melting rates and reduced fuel consumption. An optimal oxygen enrichment level of approximately 30% was identified, balancing performance benefits with economic considerations.

The results provide valuable insights for foundry operations, highlighting the potential of oxygen enrichment to optimize furnace performance. Implementing oxygen enrichment in charcoal-fired cupola furnaces can contribute to more efficient and sustainable metallurgical processes. Future research should explore the long-term impacts of oxygen enrichment on furnace components and the economic analysis of oxygen supply systems to further refine and validate these findings.

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References

1. Chastain, D.S. (2000). Iron Melting Cupola Furnaces for the Small Foundry. 1stEdition, Jacksonville, FL;USA, pp. 6-30.
2. Davis F. and Decrop, M. (1958). Influence of blast input, coke size and melting coke ratios on cupola performance. Foundry Trade Journal, pp. 319-325.
3. Karunakar, D. B. and Datta , G. L. (2002). Modeling of Cupola Furnace Parameters Using Artificial Neural Networks. [Electronic version]. Indian Foundry Journal,48: 29-39.
4. Kumar, P. and Singh, R. (2012). Neural Networks and Regression Modeling of Eco-friendly Melting Furnace Parameters Using Bio-fuels. [Electronic version].International Journal of Computer Applications, 43 (1): 10-12.
5. Levi, W. W. (1947). Variables Affecting Carbon Control in Cupola Operation. Transactions of APS, 55: 626-632.
6. Neave, H. R. (1978). Statistics Tables for Mathematicians, Engineers, Economists and the Behavioural and Management Sciences.George Allen and Unwin publishers Ltd. London, pp. 41-62.
7. Pehle, R. D. (1963). Thermo-Chemical Model of Computer Prediction of Cupola Performance. AFS Transactions, 71: 580-587.
8. Singh, R., Radha, K.M., Patvardhan, C. and Rana, G. (2006). Rotary Furnace: Effect of Rotational Speed on Rate of Melting, Fuel Consumption and Pollution.[Electronic version]. India Foundry Journal, 52 (2): 38-40.
9. Vasin, K., Arun, C., Joseph, E.H., and Mary, S.Y. (2008). Planning Level Regression Models for Crash Prediction on Interchange and Non-Interchange Segments of Urban Freeways. Journal of Transportation Engineering, 134 (3):10-18.