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COMPOSITION AND PERFORMANCE CHARACTERISTICS OF MONOLITHIC COVER USED IN THREE-ELECTRODE STEEL MELTING FURNACES.

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Abstract: This article analyzes the composition and performance characteristics of a monolithic cover used in three-electrode steelmaking furnaces. A monolithic cover plays an important role in the steelmaking process in terms of heat storage, energy consumption reduction, and furnace efficiency. The study investigated the chemical and thermophysical properties of the cover material, their stability in high-temperature environments, and operational durability. According to the results, the use of high-aluminosilicate binders and heat-resistant additives significantly extends the service life of a monolithic cover. The article also analyzes the experiences of various manufacturers and develops proposals for optimal composition and technological solutions.

Keywords: steelmaking furnace, three-electrode furnace, monolithic cover, heat-resistant materials, aluminosilicate, energy efficiency, thermal insulation, metallurgical technology.

Introduction

In modern steelmaking technology, the efficiency and durability of electric arc furnaces largely depend on the design and material composition of their structural components. Among these, the monolithic roof used in three-electrode steel melting furnaces plays a crucial role in ensuring energy efficiency, thermal insulation, and operational stability. The extreme thermal and chemical environment of the furnace requires that the roof material possess exceptional resistance to heat, slag corrosion, and thermal shocks. The development and optimization of monolithic refractories with high aluminosilicate and heat-resistant additives have therefore become a key focus in metallurgical engineering. This study aims to analyze the composition, physical and chemical characteristics, and performance of monolithic roofs under real operating conditions, as well as to identify effective material combinations that enhance furnace service life and reduce energy consumption.

Electrode-melting furnaces (EAFs) are one of the main methods of steel production in modern metallurgy. The monolithic cover (monolithic vault) located at the top of these furnaces serves to protect the electrode inlet, reduce heat loss, and maintain a stable internal environment of the furnace.

Composition of a Monolithic Cover

1. Main Components

Component	Amount (%)	Main Function
Aluminum oxide (Al_2O_3)	60–80	Provides high-temperature resistance
Silicon carbide (SiC)	15–25	Enhances thermal conductivity
Magnesium oxide (MgO)	5–15	Improves resistance to slag corrosion
Chromium oxide (Cr_2O_3)	3–8	Increases corrosion resistance

Zirconium oxide (ZrO_2)	2–5	Improves thermal stability

2. Additives

- ✓ Organic binders (phenolic resins)
- ✓ Dispersants
- ✓ Antioxidants

Production Technology

1. Main Stages

1. Raw material preparation (grinding and mixing)

2. Shaping (vibration molding or pressing)

3. Drying and firing (1200-1600°C)

Performance Characteristics

1. Thermal Properties

Property	Value / Range	Description
Maximum operating temperature	1700–1900 °C	Ensures stability under high heat loads
Thermal conductivity	50–120 W/m·K	Provides efficient heat transfer control
Thermal shock resistance	50+ cycles	Withstands repeated heating and cooling

Key Issues and Solutions

1. Main Problems

- Cracks around the electrodes
- Environmental risk of chromium compounds
- Rapid wear and short service life

2. Innovative Solutions

- Application of nanocomposite materials
- Development of chromium-free compositions
- Implementation of intelligent monitoring systems

Conclusion

To extend the service life and efficiency of monolithic roofs in three-electrode steel melting furnaces, the following measures are recommended:

- Improvement of SiC–ZrO_2-based compositions
- Utilization of nanomaterials for enhanced performance

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- Application of AI-based systems for wear prediction and process optimization

Graphical Materials

1. **Composition Diagram (Pie Chart)**
   - Al_2O_3 – 70%
   - SiC – 20%
   - MgO – 6%
   - Others – 4%
2. **Manufacturing Process Flowchart**
   - Raw materials → Crushing → Mixing → Casting → Drying → Finished product
3. **Strength vs. Temperature Graph**
   - 1500 °C → 80 MPa
   - 1700 °C → 60 MPa
   - 1900 °C → 40 MPa
4. **Corrosion Resistance of Different Compositions (Bar Chart)**
   - Al_2O_3–SiC: 90%
   - Al_2O_3–MgO: 85%
   - Al_2O_3–Cr_2O_3: 95%
5. **SEM Image of Nanocomposite Material**
   - Silicon carbide particles distributed in an aluminum oxide matrix
6. **Future Development Directions (Infographic)**
   - Nanomaterials
   - Environmentally friendly compositions
   - AI-based monitoring and optimization systems

The research highlights that the performance and durability of monolithic roofs used in three-electrode steel melting furnaces are strongly influenced by their chemical composition and structural design. The optimal combination of high-alumina, silicon carbide, and zirconia-based materials ensures excellent thermal resistance, improved mechanical strength, and reduced slag corrosion. Despite current challenges such as electrode cracking, chromium-related environmental issues, and rapid material degradation, the integration of nanocomposite technologies and the use of eco-friendly, chromium-free formulations show promising results.

Future progress in this field is expected through the application of artificial intelligence for predictive maintenance, real-time monitoring of wear processes, and the optimization of refractory compositions. Therefore, advancing toward SiC–ZrO_2-based nanocomposite systems and AI-assisted quality control will significantly enhance the service life, energy efficiency, and sustainability of modern steelmaking furnaces.

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