

Effect of magnesium aluminate spinel content of porous aggregates on cement clinker corrosion and adherence properties of lightweight periclase-spinel refractories

Guiyuan Wu^a, Wen Yan^{b,c,*}, Stefan Schafföner^b, Xiaoli Lin^a, Sanbao Ma^a, Yaojie Zhai^d, Xijun Liu^d, Linlin Xu^d

^a The State Key Laboratory of Refractories and Metallurgy, Wuhan University of Science and Technology, Wuhan 430081, China

^b Department of Materials Science and Engineering, Norwegian University of Science and Technology, 7491 Trondheim, Norway

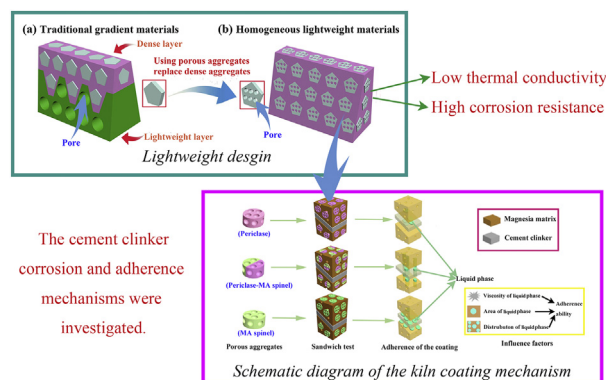
^c National-Provincial Joint Engineering Research Center of High Temperature Materials and Lining Technology, Wuhan University of Science and Technology, Wuhan 430081, China

^d Henan Ruitai Refractory Materials Technology Co., Ltd., Zhengzhou 451100, Henan, China

HIGHLIGHTS

- The cement clinker corrosion and adherence properties of refractories were tested.
- The effect of the spinel content of the aggregate on properties was investigated.
- Cement clinker corrosion and adherence mechanisms of refractories were proposed.
- The optimized product was a specimen whose aggregate contained 25 wt% spinel.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 24 April 2018

Received in revised form 6 July 2018

Accepted 10 July 2018

Keywords:

Lightweight refractories
Porous periclase-magnesium aluminate spinel aggregate
Cement clinker
Adherence properties
Interaction behavior

ABSTRACT

The present study investigated five lightweight periclase-magnesium aluminate spinel refractories containing porous spinel aggregates with a varying spinel content. The cement clinker resistance and adherence properties of the lightweight refractories were analyzed by a static crucible test and a sandwich test, respectively. The effect of the spinel content of the aggregates (SCA) on the cement clinker resistance and adherence properties was investigated with SEM, EDS and with the thermochemical software FactSage[®]. The reaction between the spinel in the refractories with the cement clinker caused the formation of a liquid phase. This liquid phase determined the adherence properties of the refractories and also affected their cement clinker resistance. When the SCA was 0–25 wt%, the refractories had a high corrosion resistance and the cement clinker successfully adhered to the refractories. Yet, when the spinel content was between 50 wt% and 100 wt%, excessive liquid phase formation seriously impaired the refractories. Consequently, the optimized periclase-spinel refractories contained porous aggregates with 25 wt% spinel, which resulted in a high corrosion resistance together with an excellent adherence ability regarding the cement clinker.

© 2018 Elsevier Ltd. All rights reserved.

* Corresponding author at: Heping Road 947#, Qingshan District, Wuhan City 430081, Hubei Province, China.

E-mail address: yanwen@wust.edu.cn (W. Yan).

1. Introduction

Toxic hexavalent chromium (Cr^{6+}) limits the application of magnesia-chrome refractories in the burning zone of cement rotary kilns. In order to reduce the pollution of cement by hexavalent chromium, chromium-free refractories have been therefore widely utilized in the last decades to substitute magnesia-chrome refractories. Of these chromium-free refractories, especially periclase-magnesium aluminate spinel exhibits excellent high-temperature strength and thermal shock resistance [1–8]. However, the high thermal conductivity of traditional dense periclase-spinel refractories not only results in extensive heat loss, but also causes the deformation of the kiln shell at high temperature affecting the kiln safety and operation performance. Moreover, the high bulk density of established periclase-spinel refractories is also accompanied with considerable resource consumption as well as with an increased motor load and thus electric energy consumption of cement rotary kilns.

In order to decrease the bulk density and thermal conductivity of traditional dense refractories, gradient composite bricks were developed in recent years [9–11]. As can be seen from the illustration in Fig. 1(a), these composite bricks usually consist of a dense and a porous layer. The dense layer is directly in contact with the cement clinker and its key properties are cement clinker corrosion resistance and coating adherence strength. The porous layer, on the other hand, is closest to the kiln shell and has the purpose to reduce heat losses. Although this composite structure decreases the thermal conductivity compared to traditional dense refractory bricks to a certain extent, the production process of such bricks is very complicated. Secondly, the thermal expansion mismatch of the dense and porous layers often results in cracks at their interface during the sintering and service. Moreover, the porous layer with its low strength is easily damaged while in use due to the extruding force and shear stress loading on the refractories. These shortcomings of gradient composite bricks severely limit their application in cement rotary kilns. Therefore, there is an urgent need to develop new kinds of energy saving refractories with a homogeneous structure and a low thermal conductivity coefficient.

Traditional dense refractories generally consist of aggregates and a matrix. Compared with aggregates, slags corrode refractory matrices more easily due to their higher porosity. Thus, aggregates with a high density and low porosity, respectively, might not be necessary for all applications [12–17]. Possibly such refractories as shown in Fig. 1(b) prepared by substituting conventional dense aggregates by porous ones not only have the advantage of a low thermal conductivity, but also of a sufficiently high corrosion resistance.

The principle of porous ceramics with micro-sized pores and high strengths prepared by an in-situ decomposition technique has been extensively studied in the last years. The investigated materials include $\text{MgO-Al}_2\text{O}_3$, $\text{Al}_2\text{O}_3\text{-SiO}_2$ and $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$ ceramics, which all could be used as porous refractory aggregates

[18–21]. In one of the first studies, lightweight periclase-spinel refractories used for steel ladles were fabricated by substituting traditional dense magnesia with porous periclase-spinel aggregates, which had a 40% lower thermal conductivity and a higher resistance against steel ladle slags than the dense ones [22]. In a following study, lightweight corundum-spinel castables for steel ladles were also prepared using porous aggregates [23], which again indicated that the corrosion resistance of lightweight periclase-spinel refractories is not impaired compared to traditional refractories containing dense magnesia aggregates.

In the burning zone of cement rotary kilns, lightweight refractories would be in contact with cement clinker as the main corrosion medium. For this application the performance of lightweight refractories depends on their cement clinker corrosion resistance as well as their adherence properties. In a recent study [24], porous periclase-spinel aggregates with varying spinel content exhibited not only a remarkably high cement clinker resistance but also high adherence properties when the spinel content was 15–40 wt%. In other studies [25–27], it was found that dense periclase-spinel refractories with a spinel content of 8–15 wt% also exhibited a remarkable corrosion resistance. However, for porous corundum-mullite it was observed that the aggregates with the highest slag resistance not necessarily also resulted in lightweight refractories with the highest slag resistance [28,29]. Thus, this study wants to find out what spinel content of the aggregates is necessary to achieve lightweight periclase-spinel refractories with a high cement clinker corrosion resistance and adherence strength.

To determine the optimum spinel content of the porous aggregates, lightweight periclase-spinel refractories containing five porous aggregates with varying spinel contents were prepared. Subsequently, the effect of the spinel content of the aggregates (SCA) on the cement clinker corrosion and adherence properties of the lightweight refractories was analyzed in detail.

2. Experimental

For the experiments five lightweight periclase-spinel refractories with magnesia powder ($<74\ \mu\text{m}$, Tongda Refractory Co. Ltd., China), differing porous aggregates (5–0.088 mm) and pulp waste liquid acting as a binder were fabricated. The aggregates were prepared in our laboratory by a previously described in situ decomposition technique [19,23]. The spinel contents of the aggregates were 0 wt%, 25 wt%, 50 wt%, 75 wt% and 100 wt%, respectively, while their apparent porosity was always about 27%. The refractories are referred to as T_0 , T_{25} , T_{50} , T_{75} , T_{100} according to their different spinel contents of the aggregates. The chemical composition of the refractories is given in Table 1.

For all refractory batches the aggregate content (70 vol%), powder content (30 vol%) and pulp waste liquid content (5 wt%) was essentially identical. The refractory samples were prepared by uniaxial pressing at a pressure of 100 MPa. The samples included

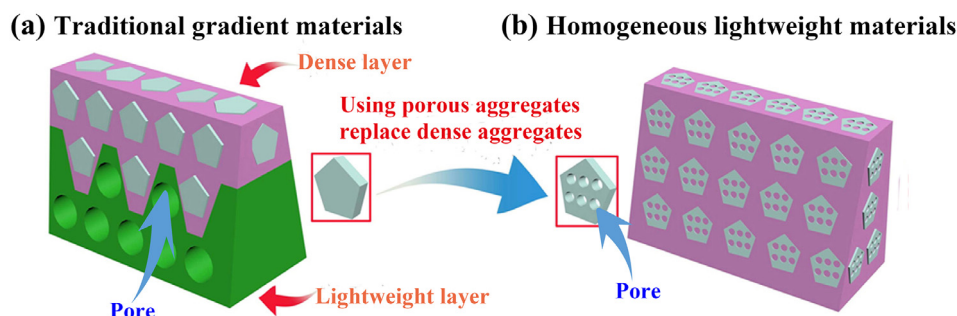


Fig. 1. Illustration of new homogeneous lightweight refractories and traditional gradient refractories.

Download English Version:

<https://daneshyari.com/en/article/6711686>

Download Persian Version:

<https://daneshyari.com/article/6711686>

[Daneshyari.com](https://daneshyari.com)