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Corrosion–erosion wear of refractory bricks in glass furnaces

A.M. Guzmán [a,*], D.I. Martínez [a], R. González [b]

[a] Faculty of Mechanical and Electrical Engineering, Autonomous University of Nuevo Leon, Pedro de Alba S/N, Cd. Universitaria, San Nicolás de los Garza, Nuevo León 66451, Mexico
[b] Faculty of Civil Engineering, Autonomous University of Nuevo Leon, Pedro de Alba S/N, Cd. Universitaria, San Nicolás de los Garza, Nuevo León 66451, Mexico

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ABSTRACT

This paper presents the failure analysis of alumina–zirconia–silica (AZS) refractory bricks located in the glass level in the tank of a furnace for melting glass, since is the region where there is greater wear respect to the base. The wear of the refractory was evaluated after 4 years of campaigning, under thermal and mechanical loading during the glass manufacture. The analysis by scanning electron microscopy shows high porosity and the presence of alkalis is also detected from the glass composition, being the phase alumina–zirconia–silica (AZS),the one that shows better resistance to erosion wear by displacement of the molten glass. The analysis yielded the following mechanisms of chemical wear, removal of the vitreous phase toward the surface of the sample due to the increase in temperature of the furnace, and therefore attack by vapors through the porosity caused by the exudation of the vitreous phase, as well as deterioration of the microstructure of the refractory due to the formation of cracks. Because it is considered as the main problem in these types of furnaces, the erosion wear is related to the flows of convection currents within the tank, this occurs at the level of the glass, as it is at this point, where it has concentration of thermal and mechanical loads due to movement of the molten glass.

1. Introduction

Nowadays, refractory materials are important components in the equipment used for the production of glass; refractory materials are considered mechanically and chemically high performance, being chemically inert at temperatures above 1400 °C. The requirements to be met in the glass manufacturing industry are good physical and mechanical resistance to the thermal shock of the working temperatures, and resistance to attack by molten glass which can dissolve the refractory, modifying its properties [1–4]. The glass industry has made significant progress regarding the type of materials used to manufacture it, this is undoubtedly due to the change of clay-based refractory materials and prepared by pressing and electrocast materials sintering, this change in the manufacturing process was introduced by Fulcher in 1925 based on research conducted at Corning Glass Co. A characteristic of the electro melted manufacturing is that the materials have a minimum porosity (1–2%), this is of great importance to the refractory, since this minimizes the glass-refractory interface [5–8].

Additionally to the typical defects that cause rejections in the glass production like inclusions, bubbles, cracks, etc. are also the failures in the refractory linings. Therefore an alternative in the materials used in the glass production furnaces are alumina–zirconia–silica (AZS) refractory because the ZrO_2 has a high melting point and it is also a thermodynamically stable oxide. These are widely used, although few have been reported about its failure mechanisms, so this paper reports the failure mechanisms of electrocasted refractory type AZS [9–13].

* Corresponding author.
E-mail addresses: anmgh@yahoo.com (A.M. Guzmán), dorairma@yahoo.com (D.I. Martínez), rhodio@hotmail.com (R. González).

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2. Experimental

The evaluation was made in new AZS refractory bricks and AZS bricks extracted from a furnace after 4 years campaigning, Fig. 1a shows a furnace in use during the glass melting process, and the 1b indicates the placement of the samples took for this research.

2.1. Materials

The new refractory was characterized by chemical analysis, X-ray diffraction, physical properties were determined and penetration testing was performed, also a molten glass attack was carried out by the ASTM C621 [14]. The molten glass attack was carried out by a penetration test placing 5 g of soda–lime glass on the sample, the sample was placed inside of an electric furnace to a temperature of 1450 °C at a heating rate of 10 °C/min, keeping this temperature in a lapse of 4 h, subsequent a slow cooling inside the furnace. Samples attacked were cut across and prepared for their observation by SEM (Scanning Electron Microscope) in order to make a comparison with the attack observed in the refractory with 4 years campaigning.

Evaluation of the refractory used in the glass furnace.

In samples from areas where attack occurs (Fig. 2a) microstructural observations were made, through light and electron microscope (JEOL-SEMJSM-6510LV) with semi quantitative EDS (energy dispersive spectrometry) phase analysis. Subsequently, cubic cuts were performed to determine physical and mechanical properties of the refractory according to the penetration profile of molten glass (Fig. 2b)

The material (glass) in contact to the brick walls was soda–lime–silica commercial glass its typical composition is 71.16% SiO_2, 7.8% Na_2O, 7.14% CaO, 0.92 Al_2O_3, 0.23 K_2O and 0.16 MgO. The furnace temperature was 1200–1600 °C.

2.2. Determination of surface wear

Surface images were taken using a stereographic microscope to determine the wear, hot face exposed to fluid (see Fig. 1b). Coupons of 5 by 5 cm^2 were cut from the surface and the images were taken at a 50× magnification, observing cavities and deformation of the material in the liquid glass flow direction, the volume wear was determined through image analysis of the attacked zone, calculating the average loss of wall thickness on each section, once wear was determined in the samples, a correlation between the final microstructure and mechanical properties of the refractory was made.

3. Results and discussion

3.1. New refractory

The chemical analysis results obtained by the atomic absorption technique are presented at Table 1, mineral phases were determined by X-ray diffraction founding alumina as corundum and zirconia as baddeleyite (see Fig. 3), physical property

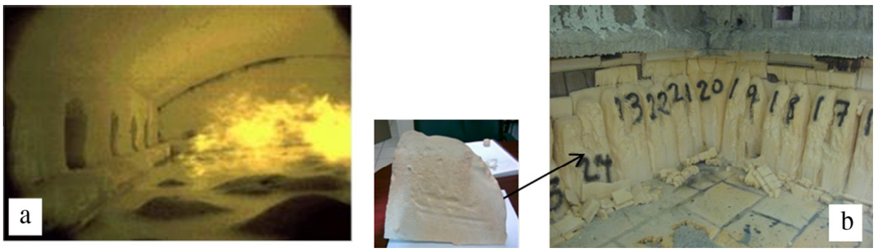

Fig. 1. (a) Glass furnace, during melting process. (b) Brick sample extracted from the furnace (glass flow zone).

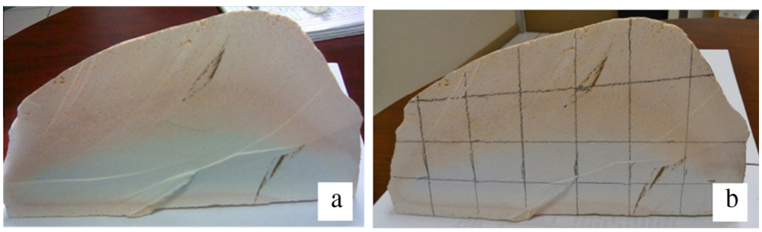

Fig. 2. (a) Transversal cut of the brick and (b) samples analyzed.