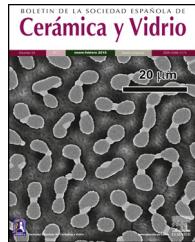




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Influence of bone porcelain scraps on the physical characteristics and phase composition of a hard porcelain body

Ali Arasteh Nodeh

Chemical Engineering Department, Quchan Branch, Islamic Azad University, Quchan, Iran

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ABSTRACT

Hard porcelain is constituted in the alkali oxides-alumina-silica ternary system, and produced by a mixture of clay-feldspar and silica. The most important properties of this porcelain are high mechanical strength, translucency and whiteness. These properties depend on quality of raw material, firing temperature and soaking time. In bone porcelain bone ash was added to body composition up to 50 wt.%. Generally hard porcelain and bone porcelain scrap cannot be reused in body composition. Whereas using these scrap could help natural resources. In this research using bone porcelain scraps in hard porcelain body have been investigated. Results show, this substitution decrease firing temperature, linear expansion and increase glass, probability of deformation and total shrinkage. Using 6 wt.% bone porcelain scraps to hard porcelain body composition besides improving some properties, increases 1340 °C firing mechanical strength two times and helps natural resources.

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Influencia de restos de porcelana de huesos en las características físicas y composición de fases de un cuerpo de porcelana dura

RESUMEN

Palabras clave:

Restos

Porcelana dura

Porcelana de huesos

Sinterización

Resistencia mecánica

La porcelana dura está compuesta por el sistema ternario de óxidos alcalinos-alúmina-sílice y se produce por una mezcla de arcilla-feldespato y sílice. Las propiedades más importantes de esta porcelana son alta resistencia mecánica, translucidez y blancura. Estas propiedades dependen de la calidad de la materia prima, la temperatura de cocción y el tiempo de remojo. En la porcelana de huesos se añadió ceniza de hueso al 50% del peso de la composición del cuerpo. Por lo general, la porcelana dura y los restos de porcelana de huesos no pueden reutilizarse en la composición del cuerpo, aunque el uso de estos restos podría ayudar a los recursos naturales. En este estudio se ha investigado el uso de restos de porcelana de huesos en el cuerpo de porcelana dura. Los resultados muestran que esta sustitución disminuye la temperatura de cocción y la dilatación lineal, y aumenta la probabilidad de deformación y la contracción total del vidrio. Utilizar el 6% del peso de restos de porcelana de huesos en la composición del cuerpo de porcelana dura, además de

E-mail address: aliarastehnodeh@iauq.ac.ir

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mejorar algunas propiedades, aumenta al doble la resistencia mecánica a la cocción a 1.340 °C y ayuda a los recursos naturales.

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Introduction

Hard porcelain is composed of the triple oxide of silica, alumina, and alkaline oxides (K_2O), obtained through firing a combination of Kaolin, Feldspar, and Quartz, whose important characteristics include high whiteness, translucency, and mechanical strength. These characteristics are fully dependent on the quality of raw materials, the firing atmosphere, the maximum temperature, and soaking time at the maximum temperature [1–3].

In bone porcelain, the bone ash which contains hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) is added to the composition of the porcelain body by as much as 50%. The bone ash present in the bone porcelain is degraded to β -tricalcium phosphate [$Ca_3(PO_4)_2$], lime (CaO), and water (H_2O). Produced lime reacts with metakaolin obtained from the clay and creating anorthite [4]. The structure of hard porcelain usually consists of glass, cristobalite, and mullite phases, whereas the phases constituting bone porcelain contain cristobalite, anorthite, and whitlockite [5]. Their firing curves are also different with each other: hard porcelain usually sintered within 1320–1350 °C during 4 h, while bone porcelain is fired within 1220–1260 °C during 11 h [6,7].

Sintered scraps, in both types, cannot be recycled. Their reuse helps the environment from their disposal and less usage of natural resources but may influences the quality of production. Many attempts have been made to use the scraps in body composition. However, in production of porcelain, a slight change in the composition might cause some problems, leading to uneconomical production. Mukhopadhyay et al. [8] have used bone porcelain scraps in bone porcelain formulation and concluded that application of these scraps can result in increased strength and density, and decreased firing temperature. Marinoni et al. [9] has used the scraps of soda-lime glass in sanitary ware as ceramic flux. He has shown that this results in decreased firing temperature, diminished fuel consumption, and removal of scraps from the environment. Similar to this work has been carried out by Oulaseyi et al.

[10] to use soda-lime glass in hard porcelain. Moreover, Pagani has recommended application of hard porcelain scraps at high percentages in sanitaryware [11].

Gouvêa et al. [12] has employed bone ash as an additive in sintering of bodies and has shown it can be used as a flux in porcelain composition. Developing of anorthite-based porcelain [13] and improving the porcelain characteristics of body with bone ash encourage us to verify the effect of bone porcelain scraps (BPS) on the characteristics of hard porcelain. It can help us for environmental scope and improving the hard porcelain properties.

Hard porcelain with 0, 3, 6, 9, 12, 18 percent BPS was prepared and fired at temperature 1030, 1100, 1250, and 1340 °C and the main properties of hard porcelain was investigated.

Materials and methods

A mixture of 80 wt.% clay (65 wt.% Iranian Zenoz clay + 15 wt.% French Imerys clay), 7 wt.% Indian feldspar, and 13 wt.% silica has been considered as the base body. The chemical analysis of the all of the raw materials and the bone porcelain scraps consumed in the study is provided in Table 1. The BPS was milled in a disk mill (Retsch, PRDM01) to reach a particle size of lower than 1% on a 63-micrometers sieve. Different percentages of the BPS (0, 3, 6, 9, 12, 15, and 18 wt.%) were added to the composition of the base body. In each experiment, 2500 g of raw materials were grounded in a 5-L Jarmill for 390 min with 1250 ml water and 2.5 g Dispex N40 (Allied Colloids, UK), as deflocculant, until reaching a particle size of 58% under 15 μm . The slurry obtained from seven bodies (B_0 , B_3 , B_6 , B_9 , B_{12} , B_{15} , B_{18}) was transferred to storage tank, passed through a 105-micrometers sieve and permanent magnet. The density was adjusted at 1.8 g/cm^3 , and the viscosity was regulated at 180° with Torsion viscometer (Anderen Ltd, UK). The slurry was dewatering up to 20% on plaster tablets, and then converted to bars with a cross-section of 1 cm \times 2 cm and length of 10 cm using an experimental extruder (Netzsch, D-95100). Thereafter, it was dried in a dryer at a temperature of 100 ± 5 °C.

Table 1 – Chemical analysis of the raw materials used.

	Feldspar (India)	Silica (Iran)	Kaolin (France)	Kaolin (Iran)	BPS
SiO_2	65.21	99.3	46.37	62.01	45.82
Al_2O_3	18.71	0.21	37.12	25.71	12.12
CaO	0.27	–	0.29	1.02	22.24
K_2O	12.22	–	2.22	0.68	1.72
Na_2O	2.67	–	0.01	0.20	0.71
MgO	–	–	0.38	0.31	0.59
Fe_2O_3	0.09	0.21	0.76	0.52	0.27
TiO_2	–	–	–	–	0.07
P_2O_5	–	–	–	–	16.43
LOI ignition at 1100 °C	0.31	0.1	12.42	9.21	0.01

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