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Slip cast forming of multilayer ceramic filter by fine particles migration

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Abstract

Multilayer ceramic filter was fabricated by fine particle migration occurring during the slip cast compaction of a particulate mix composed of a fine powder and coarse granules. The materials were prepared from the mixture of quartz, natural zeolite and lead borosilicate glass frit. The casting procedure involves the introduction of the powder slurry into a cylindrical shaped mold, allowing it to form a thin filtering layer onto the mold walls. The granules are then added into the mold without settlement of the previously filled slurry. The new casting method leads to a specific interlayer between the granular material and the filtering layer by a fine particle migration phenomenon. Casting, drying and sintering processes of the filters were discussed with respect to two different particle sizes of the powder slurry (δ_{50} = 0.98 μm and δ_{50} = 1.82 μm) and with variable solid concentration (5–40% solids by weight). Dilute slurry with relatively coarse size has appropriate condition for the filter fabrication.

Keywords: A. Slip casting; A. Suspensions; B. Microstructure-final; B. Porosity; D. SiO_2; E. Substrate

1. Introduction

Recently, the author has produced capillary ceramic filters using high silica ceramic powder (high SiO_2-containing glaze) by two fabrication process. The first study was similar to the conventional two layers filters; the substrate was shaped and sintered and later the filtering layer was coated by filtration [1]. The second study was a special technique in which thin filtering layers were shaped from fine particles by uniaxial pressing and later sintered at a temperature to reach for enough strength. The substrate materials were inserted between these layers and further sintering [2]. We are looking a simple fabrication process with providing high performance capillary ceramic filter with a high silica material.

It is shown that the fabrication of multilayer capillary ceramic filter is possible by fine particle migration onto granular substrate using a special casting route. The fine particle migration process was discussed in details in the filtration studies [3–9] and some approaches presented for the ceramic compaction [10–15]. The fine particles migrate through the cake pores and fill the voids at the vicinity of the bottom of the cake leading to non-uniform variations in the density across the thickness of the cake. The other consequence is the formation of a skin-layer at cake-mold interface. The high resistance layer decreased the rate of compaction and the longer casting time favours the segregation phenomena, resulting in a compaction gradient. Additionally, the deposited particles on the mold surface may be oriented and/or rearranged, and variation of local densification occurs. The non-uniform ceramic compaction also results in cracks and deformations during the drying and sintering processes.

Besides the above problems, this study is aimed to fabricate a multilayer ceramic compaction with migrating condition. If the process is successes, high performance ceramic filter has been obtained by a simple casting process and with requirement of minimum capital investment. This makes the filter wider uses in liquid/solid separation. The high silica ceramic material has low shrinkage, thus this type of materials have great potential for succession of drying and sintering without the cracking/deformation. On the other hand, it is easy to produce migrating phenomena with the silica materials.

2. Experimental

The composition for ceramic filter was designed as 86.86% SiO_2, 3.47% Al_2O_3, 5.28% PbO, 1.54% B_2O_3, 0.28% Na_2O, 0.71% MgO, 1.11% CaO and 0.11% K_2O, and prepared by

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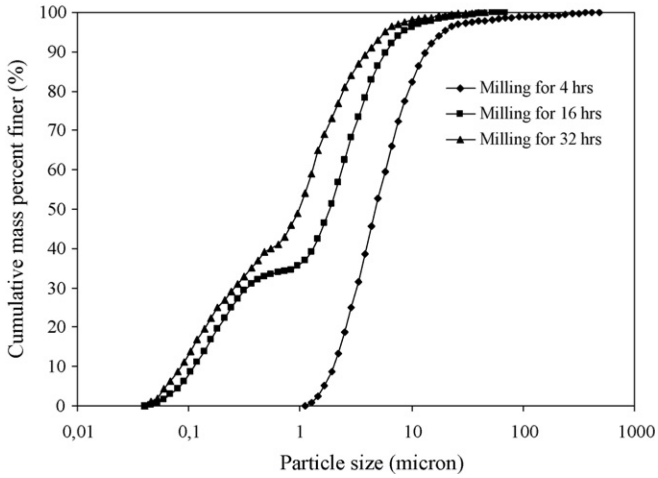

Fig. 1. Size distributions of the ceramic powders for granular core and the filtering layer.

using powder mixtures of quartz, lead borosilicate frit glass and natural zeolite (clinoptilolite). The powder mixture was ground for three different times as 4, 16 and 30 h using alumina balls in water. The particle size of the ground powders (see Fig. 1) was measured by using laser particle size analyzer (Malvern 2000). The glassy material (frit glass and zeolite) has low temperature sinterable material: the fusion point was determined by hot stage microscopy (Misura ODHT-HSM 1600/80) at about 940 °C.

The shorten time milled sample ($\delta_{50} = 6$ μm) was used for the granule production. The ground material was dried at 105 °C for 24 h, and wetted with water (5 wt.%) for agglomeration and sintered at 900 °C for 20 min with a heating rate of 5 °C/min. The agglomerates were furnace cooled. The sizes of granules are between 0.5 and 1 mm. Different solid concentrations of suspension (5, 10, 20 and 40% solids by weight) were prepared from the two fine sizes of powders ($\delta_{50} = 0.98$ μm and $\delta_{50} = 1.82$ μm). The slurries were mechanically agitated for 30 min and then casting was performed.

The important aspect in preparing the ceramic filter by means of the casting route is the multilayer compaction process. The casting unit consists of a hollow cylindrical mold, a cylindrical glass tube and a cover plate. The mold used was made of plaster of paris (produced with a plaster:water ratio of 3:2) and shaped as hallow cylinder (Ø20 mm × 100 mm). The glass tube with 20 mm internal diameter and 100 mm height tightly placed into the mold cavity. The prepared 200 ml of powder slurry was introduced into the mold with some part of slurry remained in the glass tube which is a reservoir for casting. The water of the cast slurry is absorbed into the mold walls whereupon a thin filtering layer forms on the inner surfaces. After then the granular particles were filled into the same mold in which the interior space of filter has been so filled with the granular material. The non-stop casting was achieved by the excess slurry remained in the glass tube: feeding the excess slurry into the granular medium produced a secondary compaction by the fine particle migration. By this way, an interlayer has been obtained (see Fig. 2).

The filter in the mold was allowed to dry by waiting an appropriate time such as about 30 min. Later, it was first air dried overnight in a room at 60% humidity, then, kept in ambient conditions for a day, and finally oven dried at 105 °C

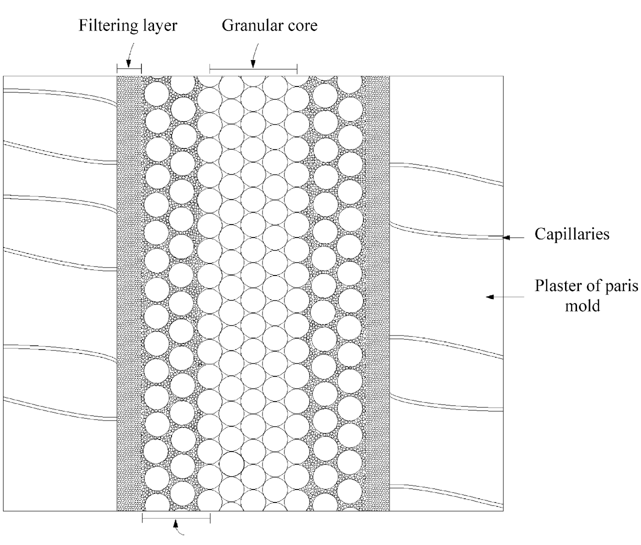

Fig. 2. Schematic representation of the casting process of a cylindrical multi-layer ceramic filter.

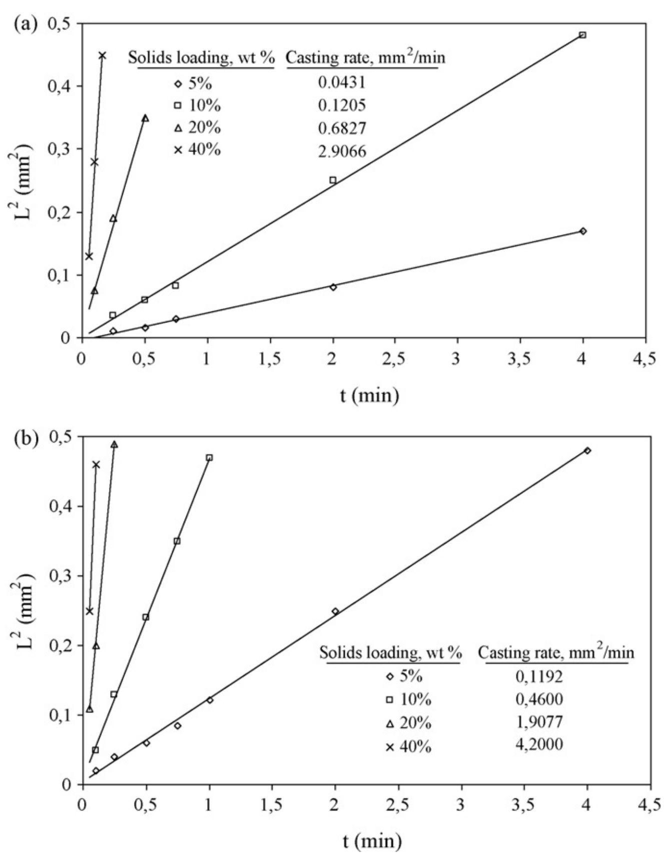

Fig. 3. (a) Parabolic dependence of the casting rates for the suspensions having relatively fine particle size ($\delta_{50} = 0.98$ μm). (b) Parabolic dependence of the casting rates for the suspensions having relatively coarse particle size ($\delta_{50} = 1.82$ μm).