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Ultrasound assisted cleaning of ceramic capillary filter

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ABSTRACT

Research in the fields of filtration and dewatering connected with the use of ultrasound (US) has been carried out mainly with small laboratory-scale batch or continuously operating devices. So far the only large scale industrial cake filtration applications have been developed and manufactured by Larox Oyj for mining industry. These applications apply ultrasound for cleaning of ceramic capillary action elements having at maximum total filtration area of approximately 150 m^2. Several hundreds of filter units have been delivered worldwide during the past two decades.

1. Introduction

A wide range of studies has been carried out to enhance membrane and particle filtration by utilising ultrasound technology. Studies have been performed mainly in lab or pilot scale, but only very few applications have been proceed to large commercial use. The efforts have been focused on changing suspensions properties to more favourable for filtration and or preventing fouling substance to stick the filter surface or cleaning the filter element itself. Combinations of ultrasound, electric field and washing chemicals have been used [1]. Only four applications which are worth mentioning are electro-acoustic dewatering press (EAD), CERTUS-polishing filter, Scamsonic screening filter and CERAMEC–ceramic capillary MF-filter [1–3]. The two cases mentioned the latest have found industrial use.

In this paper, the development of ultrasound cleaning of CERAMEC-filter will be presented as a case story. General issues dealing with the applying of ultrasound will also be viewed.

2. Ceramic capillary filtration

Ceramec filter discs (Fig. 1a) are patented sintered alumina membranes with micropores that create strong capillary action in contact with water. This microporous filter medium allows only liquid to flow through (Fig. 1b). Filtrate is drawn through the ceramic discs as they are immersed into the slurry bath, and a cake forms on the surface of the discs. Despite an almost absolute vacuum, no air penetrates the filter media (Eq. (1)). Consequently, Ceramec filters require only a small (2.2 kW-CC-45 and 7.5 kW-CC-144) vacuum pump to transfer filtrate from the discs to the filtrate receiver. This is in strong contrast to conventional vacuum filters that have high air flow through the filter cake, and need a large vacuum pump. Filter cake is removed from the ceramic discs by scrapers, eliminating the need for compressed air snap blow off [2].

The pore diameter for the air flow through the plate can be calculated by the Young–Laplace Law:

$$D = 4\tau\cos(\theta)/\Delta P \tag{1}$$

where τ – surface tension for water (N/m), ΔP – bubble point pressure (N/m^2), θ – wetting angle, D – pore diameter (m).

The pressure difference needed to draw water out of capillary is presented in Table 1. As an example 1.4 bar (=140 kPa) pressure difference is needed to get water through a capillary having 2 μm pore diameter [2].

3. Ultrasound assisted cleaning of ceramic filter element

The physical effects of acoustic cavitation derive from the formation, growth and implosive collapse of bubbles in liquids irradiated with high-intensity ultrasound that produce intense local heating and high pressures with very short lifetimes. Cavity collapse near a solid surface becomes non-spherical, drives high-speed jets of liquid into the surface, and creates shockwave damage to the surface. Cavitation and shockwaves produced during

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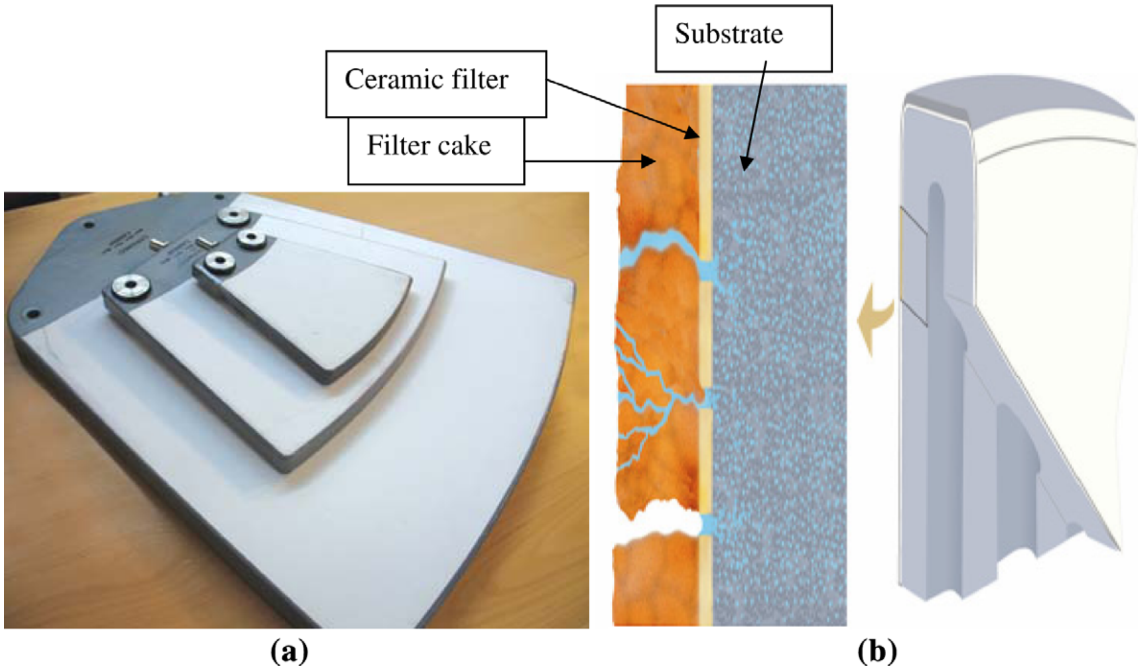

Fig. 1. (a) Examples of Ceramec filter plates, and (b) basic idea of Ceramec filtration [2].

Table 1
The pressure difference needed to empty pores of different diameters. Surface tension of 0.070 N/m and cos (θ) = 1 have been used [2].

D (μm)	8	4	2.5	2.3	2	1.5	1	0.5	0.3
ΔP (kPa)	35	70	112	122	140	187	280	56	933

ultrasonic irradiation of liquid–powder slurries can accelerate solid particles to high velocities [4]. Microscopic contaminants are best removed by lower frequency ultrasound, while submicroscopic contaminants are often best removed by ultrasound at higher frequencies [5].

Ultrasound has been used for cleaning a variety of materials from dental instruments to steel strip. Ultrasonic cleaning generally uses a frequency in the range of 16–70 kHz (Fig. 2) [6]. Higher frequencies, on the order of 400–1000 kHz, have been used very successfully in the silicon wafer industry to clean microscopic particles from wafer surfaces. With higher frequency cleaning, acoustic streaming (a large scale movement of fluid), plays a significant role in particle removal. For frequencies in the ultrasonic range, cavitation events and associated shock waves, microstreamers,

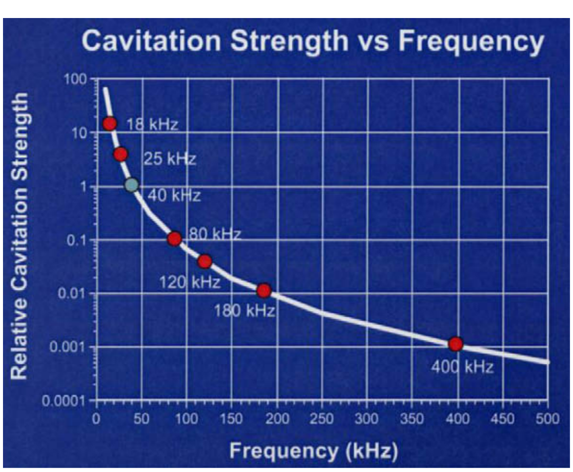

Fig. 2. Cavitation strength vs. ultrasound frequency [6].

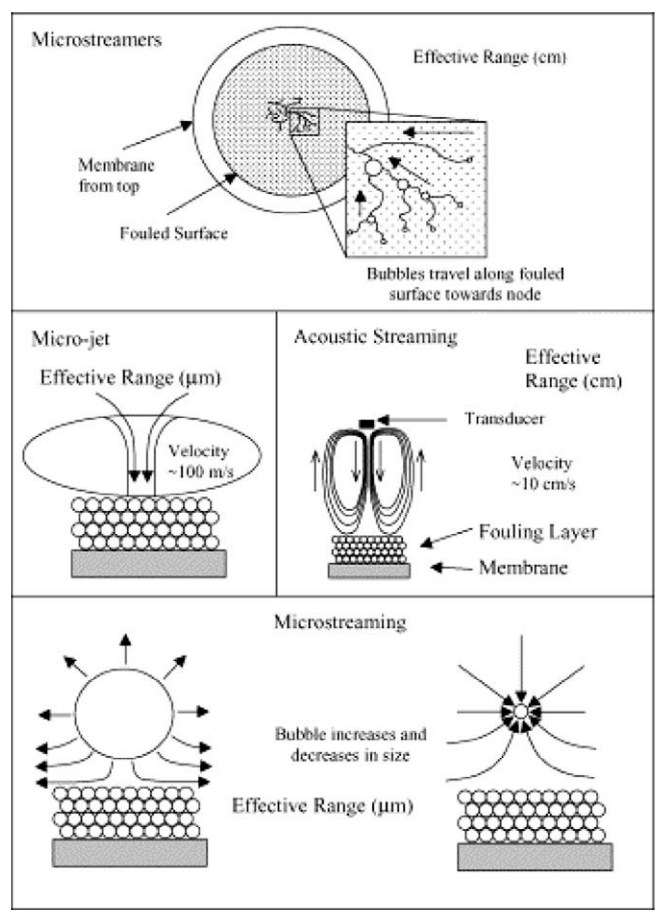

Fig. 3. Possible mechanisms for particle removal/detachment observed with ultrasonic cleaning [7].