

Alternative Porous Media and Designs for Automotive Oil Filters

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ABSTRACT

Alternative automotive engine oil filtration devices are described herein, aiming at alleviating the environmental issues caused by conventional one-piece, spin-on, throwaway filters. The spin-on feature has been retained in these novel filters, to facilitate retrofitting, however provisions to dismantle the filter have been incorporated to allow for periodic replacement of the filter element (cartridge). The filter element is made of ceramic powder and, upon replacement, it may be treated and reused as such, or it may be crushed, treated and remanufactured from the recycled powder. In the process, the entirety of the used motor oil may be retrieved, treated and reused, thus conserving energy and resources, minimizing waste streams and, most importantly, preventing environmental ground-water contamination. The ceramic filter element (made of silicon carbide, cordierite or mullite) is extruded in the typical configuration of a honeycomb-shaped monolith, with adjacent channels plugged at alternate ends. The element is housed in an easy-to-dismantle casing. The filter element may be replaced at every vehicle oil change, but not the casing which is intended to last the lifetime of the engine. The ceramic elements can be manufactured to possess high-filtration efficiency characteristics and have large contaminant accumulation capacity. Herein an overview of the design of these filters is presented, and results of selected tests attesting to their performance are included.

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INTRODUCTION

Upon its introduction to the market in the mid-1950's, the *spin-on* oil filter (a self-contained housing and element assembly which can be unscrewed from its mount, discarded, and replaced with a new one, see Fig. 1) grew in popularity as it facilitated filter changes [1]. It quickly became the dominant type of oil filter installed by the world's automakers. More than 1 billion used spin-on oil filters are discarded globally every year (approximately 500,000,000 in the United States alone). They constitute a pressing solid waste problem and, even more importantly, they contain residual motor-oil, which leaches out and contaminates ground-waters, see Fig. 2. Commercial spin-on oil filters have been designed for durability, making their disassembly difficult and impeding their recycling for scrap metal and residual oil. Currently 90% of used oil filters are not recycled. This also constitutes a waste of resources, since "recycling one ton of used oil filters recovers 1,700 pounds of steel and up to 60 gallons of used motor oil" [2]. Draining oil filters is helpful in recovering some of the used motor oil therein, however, a filter that is drained overnight may still retain up to 50% of its oil capacity, whereas, an oil filter that has been

drained and crushed, see Fig. 3, may still retain about 12% of its oil [2,3]. However, most filters are disposed in landfills, often without crushing or draining, thus residual oil therein is never recovered. Current, state-mandated disposal regulations of commercial oil filters are neither sufficient, nor enforced, leading to landfill space shortage, wasted resources, and contamination of the soils and water beds by used motor-oil, which US-EPA classifies as a hazardous waste. It has been reported that a gallon of used motor oil, which can be readily found in just 100 crushed and drained oil filters, may be sufficient to contaminate 1,000,000 gallons of fresh water [2].



Figure 1. A conventional spin-on, throw-way automotive oil filter and its engine application.

The automotive oil filter described herein consists of a dismantable casing, which incorporates a replaceable ceramic honeycomb filter element (cartridge) [4,5,6,7,8,9,10]. When the cartridge needs to be changed (typically at the manufacturers recommended oil change intervals), the casing is detached from the engine, opened, the ceramic filter removed, drained and sent for treatment. A new filter element is inserted in the casing and the casing is then re-mounted on the engine. Treatment of the used filter element may take place thermally or by using a solvent. Upon completion of such treatments, the element may be re-used. Alternatively, the ceramic filter may be crushed to powder, and all oil can be thus removed. The powder may then be treated and re-cycled to manufacture new filter elements.

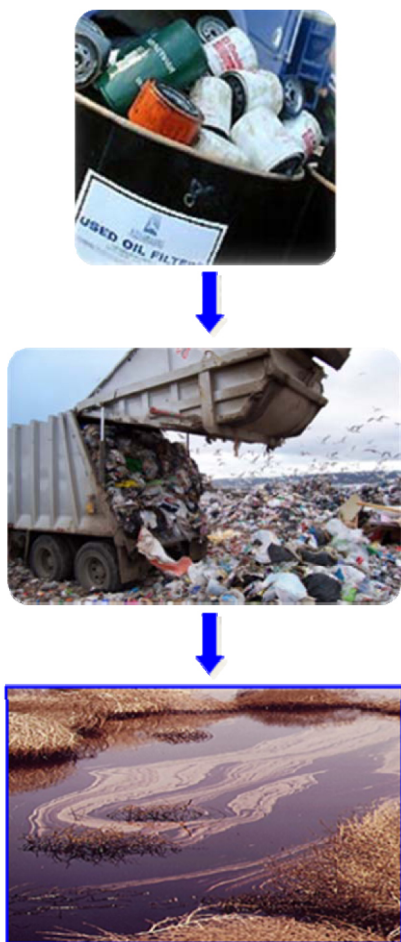


Figure 2. *Used conventional spin-on oil filters are typically discarded in municipal waste streams and leak oil, which ends up contaminating ground waters.*



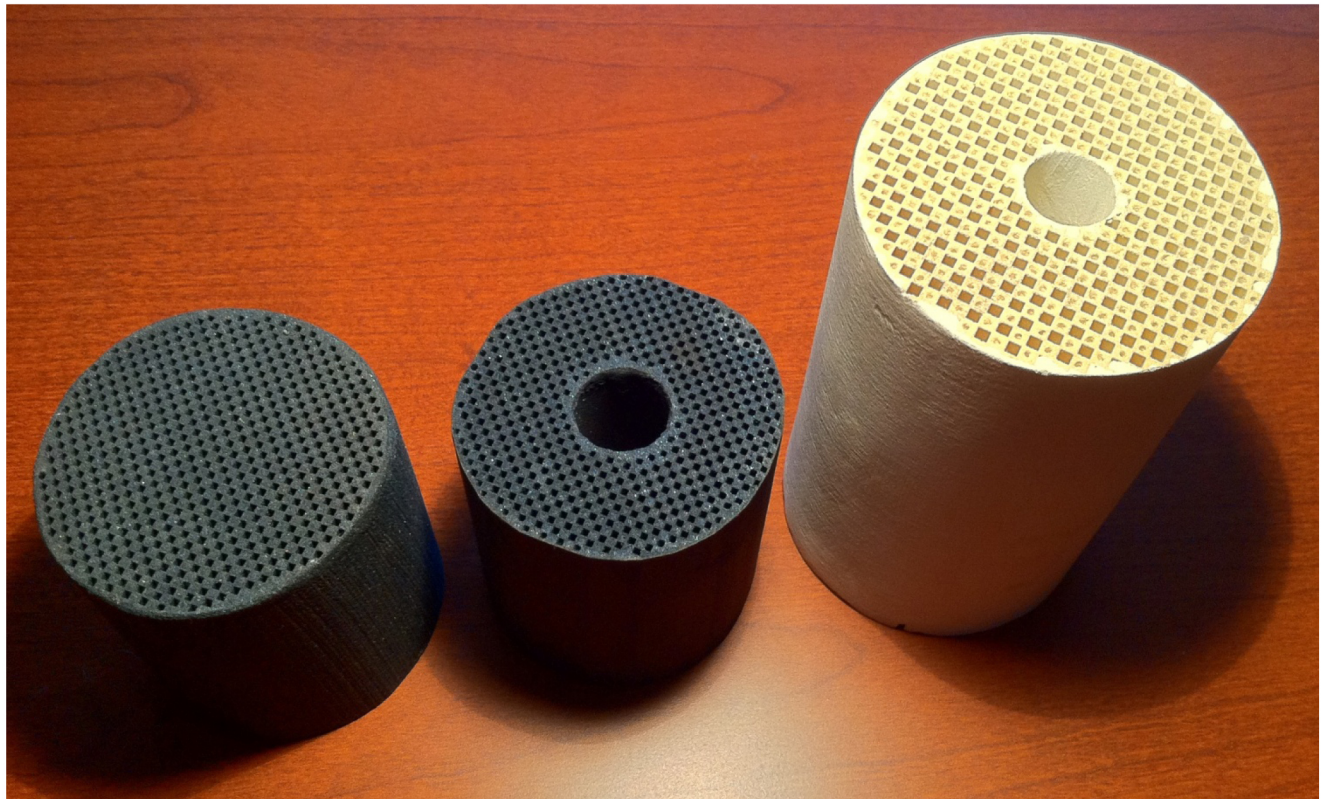
Figure 3. *Used oil filters are rarely crushed, but even then they still retain significant amounts of contaminated motor oil.*

DESCRIPTION OF THE OIL FILTER WITH THE CERAMIC CARTRIDGE

An example of the automotive oil filter housing developed in this work is depicted in Fig. 4. This particular housing (casing) consists of a metallic base plate (flange) permanently-attached to a stamped metallic cup [10]. Aluminum and/or galvanized steel may be used. The base plate is dismantable. The housing allows for retrofit to conventional spin-on filter mounting on an engine, as shown in Fig. 1. In conventional filters, contaminated motor oil enters through the perimeter inlet holes of the base plate (flange) of the casing. The oil is cleaned from debris as it flows radially through a pleated cellulosic (paper) filtering



Figure 4. *Latest evolution of the Environmentally-Benign Automotive Oil Filter [10].*



Filter elements: A

B

C

Figure 5. Ceramic honeycomb filter cartridges: A and B are silicon carbide (SiC) monoliths manufactured by Notox, element B has a central hole. C is a cordierite monolith manufactured by Corning.

element. It then exits the filter through its center hole, of the base plate, and enters the engine block [3].

In the designs described herein, oil flows through honeycomb ceramic filter elements, therefore its overall flow direction is axial. Different honeycomb filters are shown in Fig. 5. Elements A and B, on the left are constructed out of silicon carbide (SiC) and are manufactured by Notox. Element B has a central hole. Element C, on the right is made out of cordierite and is manufactured by Corning. The existence of the central hole allows for operation of the filter without provisions for a relief valve [5]. This will be illustrated later in the manuscript. The dimensions of the cylindrical elements (A and B), depicted in Fig. 5, were 7.5 cm in length and 6.7 cm in diameter, whereas element C was twice as long. The center hole of element B was 2 cm in diameter. The hole was sealed with a membrane and, thus, all adjacent channels were intact. These honeycomb monoliths incorporated a multitude of square cross section channels, which were plugged on alternate ends. Upon entering each open channel at one end, the oil was forced to flow through the channel walls to adjacent channels [3]; the porous ceramic walls retained the oil contaminants. The ceramic filter elements are extruded wall-flow monoliths. The flow pattern of the oil through the honeycomb ceramic element is

depicted in Fig. 6. The prototypes used herein were based on production-type Diesel Particulate Filters (DPFs). The Notox filter monoliths are manufactured from commercially available SiC powder, mixed with a submicron SiC powder and different binders and processing additives to make it into a ceramic paste formed by extrusion. The pore size of the final body of the SiC elements is to a very large extent governed by the particle size and shape of the coarse SiC fraction in the ceramic paste. The coarse particles are typically in the size range from 20-75 μm to attain the desired pore sizes of a particulate filter, see scanning electron micrographs (SEM) in Figs. 6b and c. Pore sizes of commercially-available SiC filters are in the range of 9-28 μm .

For this specific application a standard pore size of 12 μm was used. After extrusion and drying the unfired filter segments were cut into the desired length, and every second channel was plugged with a Silicon Carbide plugging paste, to form a chess board like pattern paste, shown in Fig. 6a. The porosity of the walls was 42%. Further details on the physical properties and on the manufacturing process of the SiC filters are given in Ref. [5].

The filter material resulting in a pore size of 12 micron has not been optimized for this application, it is just the