Dielectrophoretic Separation Systems

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Background:
In the field of tribology (the science of lubrication), it has been found that much of the wear on an engine occurs even when particles that are greater than 10 microns are filtered. Typical oil filters used in the automotive industry can only filter particles greater than 10~40 µm. In this work, we present a novel dielectrophoretic filter system in which clumps of nano-sized particles are separated from a fairly large amount of fluid in a short amount of time. The method we are using is called dielectrophoresis, where we use electric fields to induce dipoles within particles and then attract them to the high electric field regions.

Simulations and Operating Principle: In dielectrophoresis, particles are attracted to high or low field regions. In the case of carbon particles within an oil medium, the particles are attracted to high field regions. Figure 1 shows the electric field distribution between semicircular electrodes. Every other electrode is connected together and connected to an power supply. The particles will be collected in the red regions.

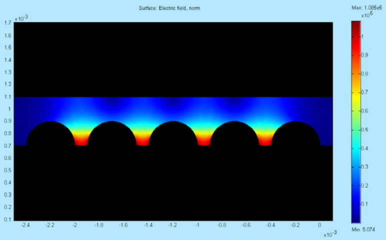

Figure 1. Simulation of the electric field distribution between semicircular electrodes.

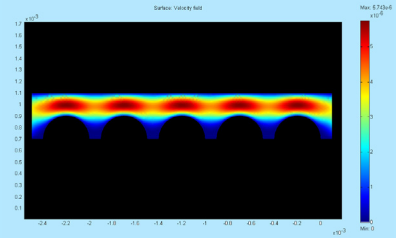

Figure 2. Simulation of the velocity field distribution for semicircular electrodes within a fluidic channel.

Figure 2 shows the velocity profile of the same electrode array (flow is from left to right). These simulations can be expanded to wire designs. You can think of each semicircular electrode as a wire split down the middle.

Initial Design: The first design (Fig. 3) was fabricated using single wires spaced apart with ~100 µm spacers and by connecting the end of every other wire together. After connecting the wires to an alternating current source, dirty oil (canola oil with nanofibrous carbon) was pumped over the wires. The carbon fibers were trapped between the wires while the clean oil flowed past. Although trapping of particles was observed, it was not possible to remove enough particles from the dirty oil flow to see an obvious visual difference when compared to the control. Several different designs with different numbers of electrodes and electrode diameters were tested, and designs with more electrodes were found to be more efficient.

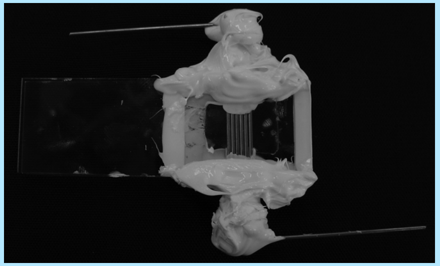

Figure 3. Photo of one of the first prototypes. (6 steel electrodes sandwiched between two microslides sealed with PDMS and Silicone II.)

Improved Design: The improved design (Fig. 4) consisted of two long wires wrapped the around a wooden centerpiece. The electrodes were spaced apart by threading a narrow tube between the wires. This design has the following advantages: 1) Sealing of the system was facilitated of the tubular design. 2) The problem of creating electrical interconnects to every other electrode was avoided through the use of a spiral design consisting of only two wires. 3) It is much easier to create devices with more electrodes (if we consider each full rotation as an electrode.) Figure 5 shows the experimental setup. A high voltage amplifier capable of $2kV_{pp}$, a function generator, a syringe pump, as well as our custom setup were used to test the devices.

Figure 4. A photo of one of the devices based on the improved design.

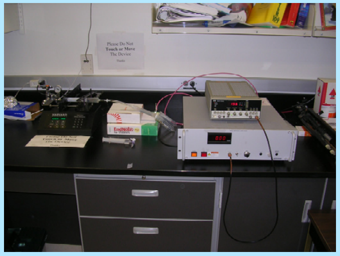

Figure 5. A photo of the equipment used in the experiments.

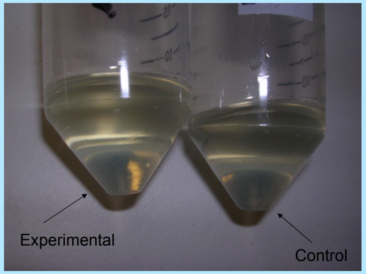

Figure 6. A photo showing visual contrast between oil passed through control and experimental setups.

Experimental Results: There was a marked visual difference between the experimental and the control set up (Fig. 6.) Dirty oil was passed through the device shown in figure 4 at a rate of 1 mL/min. An AC voltage of 250 Vpp at 5 kHz was applied for the experimental setup. There was some voltage drop during the experiments due to carbon accumulation between the wires. No voltage was applied for the control.

We were able to quantify the contaminant levels of the oil by looking at a sample of the oil under a microscope. We were able to count the number of particles in a given area to see that indeed the control samples were dirtier then the experimental (Fig. 7.) Note that particle size was not taken into consideration, and for the most part, the particles observed in the control were much larger than the particles in the experimental setup. We believe that if the weight of the carbon nanofibers are compared, there will be a larger difference

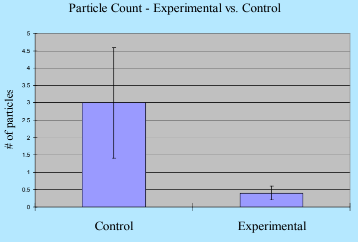

Figure 7. Experimental data from 3 different control and experimental setups.

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