An acoustic centrifuge

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***Abstract*—An acoustic centrifuge has been designed and experimentally validated to compact micron sized particle suspensions using containers with cylindrical and rectangular geometries. Centrifuge tubes with cylindrical and rectangular geometries were fabricated using computer aided design techniques and rapid prototyping. Acoustic standing wavers were generated using PZT-8 ceramic transducers operating at approximately 2 MHz to trap and sediment out micron sized particles. Impedance spectra were acquired between 2 MHz and 2.25 MHz to determine the optimal operating frequency. A 3% yeast solution was used to test the system on a live cell model. The results of this study show that rectangular geometries are more efficient in separating 10 µm sized cells from solution for this particular system.**

Keywords- Cell separation; acoustic; ultrasound; Acoustic radiation pressure

I. INTRODUCTION

Centrifugation is an important experimental technique for separating micron sized particles from solution based on size, density, shape, and viscosity. Traditional centrifugation methods, however, can be labor intensive and are difficult to scale. As a result, alternative, scalable, and efficient centrifugation methods need to be investigated.

Acoustic separation techniques offer an alternative to traditional centrifugation methods. Vessels don't have to withstand high gravity conditions. In addition, acoustic centrifugation has the potential to be incorporated into a closed system for cultivating and separating cells. Reduced labor and scalability make it an attractive alternative to traditional methods. Acoustic standing waves are set up in a chamber with fluid and particles. The acoustic radiation forces trap particles at nodes or anti-nodes based on their relative densities and sizes. The power consumption is potentially lower compared to traditional centrifuges.

This study investigates the use of acoustic standing waves to remove micron sized particles from suspension. Ceramic PZT-8 transducers operating in the 2MHz range examined and used to compact a 3% yeast cell suspension. Centrifuge tubes with cylindrical and rectangular geometries are examined.

II. METHODS AND MATERIALS

A. Acoustic Centrifuge Setup and Measurements

The experimental system is shown in Fig. 1. An aluminum frame was designed for three chambers having glass walls. Ceramic PZT-8 transducers (APC International) were cut to 1 inch square and attached to the chamber walls. The each filled with water and driven by a 1, 2, and 3 MHz ceramic transducers. An impedance analyzer (Sine Phase 1-16,777 kHz) made measurement of the PZT-8 ceramic between 2.5 and 3.5 MHz before and after attachment to the bioreactor. A computer data acquisition system (National Instruments LabVIEW) controlled a signal generator (Agilent 33210A) that produced a sinusoid signal that was amplified () and applied to each transducer. An oscilloscope () monitored the applied signal. A syringe pump (New Era Syringe Pump NE-1000) raised each centrifuge container through the acoustic field.

Centrifuge sample containers were designed using a rapid prototyping system. The wall thicknesses were chosen to produce the optimum transfer of acoustic energy into the sample. A 3% yeast (Fleischmann's ActiveDry) solution was used to test the acoustic centrifuge. The efficiency of the acoustic separation was quantified by measuring the packed cell mass weight left in the supernatant following acoustic centrifugation.

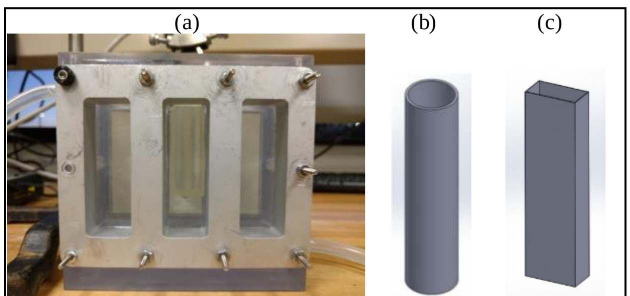

Fig. 1. Acoustic centrifuge and container tubes. (a) Cylindrical, (b) rectangular. Rapid prototyping produced centrifuge containers with the correct wall thicknesses to allow the most efficient transfer and reflection of acoustic energy. (c) Experimental setup.

III. RESULTS

Figure 2 shows the impedance spectra of the 2 MHz PZT-8 transducer used in this study. Multiple peaks were observed in the operating range of the transducer. Based on the acquired data an operating frequency of 2.25 MHz was chosen.

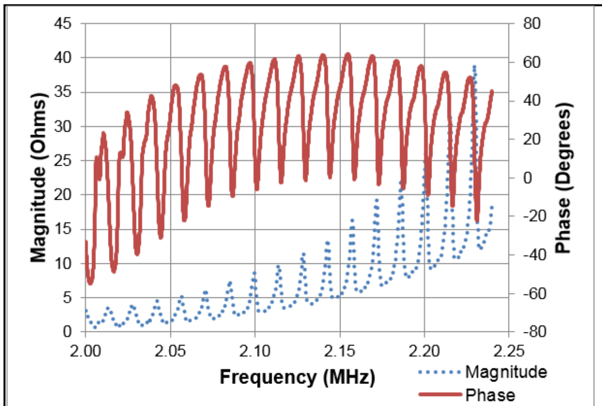

Fig. 2. Impedance spectra of a 2MHz PZT-8 transducer. The observed resonance peaks with the attached transducer were used to determine the driving frequency. During the measurement the chamber was filled with water.

A summary yeast cell acoustic centrifugation using both rectangular and cylindrical containers is shown in Fig. 3. The packed cell mass following acoustic separation is significantly higher for a rectangular geometry compared to a cylindrical geometry.

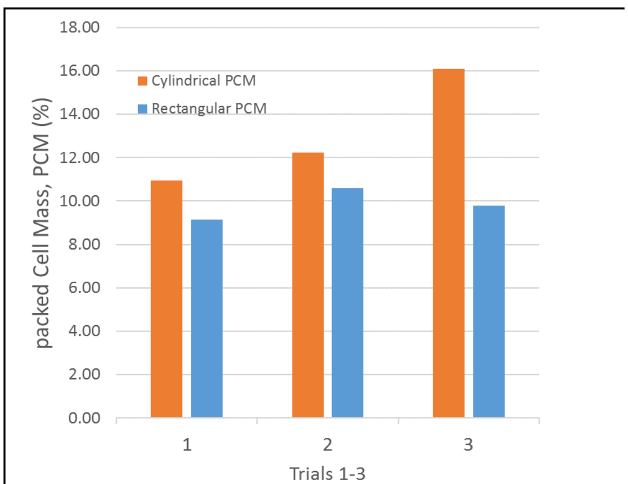

Fig. 3. The Percentage pack cell mass remaining in the supernatant following acoustic centrifugation using cylindrical and rectangular centrifuge containers. The t value or p value is

IV. DISCUSSION

An important aspect of the acoustic centrifuge container design lies in the wall thickness. The wall thickness was set to be equal to one quarter wavelength multiple of the acoustic wave. When the thickness is equal to one quarter wavelength a greater transmission of acoustic energy is produced. The material used to prototype acoustic centrifuge container design was FullCure 720. Improved results will likely results from using a material with less acoustic dissipation, such as glass or stainless steel.

A centrifuge system based on acoustic standing waves has a number of important application over traditional centrifugation methods. An acoustic centrifuge can be included as a closed concentrating system. Application include the cultivation of three dimensional tumor clusters. It can also be used as a way to concentrate blood samples to separate the red blood cells from the surrounding liquid. From a customer perspective the device will have be autonomous requiring little to no user input, it needs to be in line with a system of processes, it should be easy to clean and maintain, easy to switch out units if disposable or sterilize if the unit is good for multiple uses. Biologically, the device must be safe to use with human media such as blood or cells. The centrifuge must not harm cells through thermal exchange or acoustic forces.

V. CONCLUSION

An acoustic cancer cell bioreactor has been designed, implemented and tested using a 3% yeast cell concentration. The results of this study show that a rectangular geometry is more efficient than a cylindrical geometry.

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