SUMMARY

Discussed herein are systems and methods for acoustophoresis for generating optimized particle/fluid clusters to improve gravity/buoyancy separation and collection efficiency. Improved, continuous, acoustophoresis devices using improved fluid dynamics are also discussed, as well as drivers and control devices for operating/implementing the systems and methods..

In a first aspect, the present disclosure provides an acoustophoresis system comprising a chamber for receiving a fluid mixture that includes cells or particles in a fluid; an ultrasonic transducer coupled to the chamber and configured to be excited to generate an acoustic wave in the chamber; a driver electrically connected to the ultrasonic transducer and configured to provide an excitation to the ultrasonic transducer to generate the acoustic wave in the chamber; and a controller electrically connected to the driver and the ultrasonic transducer and configured to receive feedback signals from the ultrasonic transducer and to control the driver based on reactance determined from the feedback signals.

In a second aspect, the present disclosure provides a method for controlling an acoustic transducer, the method comprising: receiving feedback signals from the acoustic transducer; determining an anti-resonance frequency of the acoustic transducer based on the feedback signals; determining a reactance minimum or maximum adjacent to the anti-resonance frequency based on the feedback signals; and providing a power signal to the acoustic transducer with the frequency substantially of the reactance minimum or maximum.

In a third aspect, the present disclosure provides a device for controlling an acoustic transducer, the device comprising a modular controller for implementing a control scheme; a power section connected to the controller for supplying power to the acoustic transducer; and a feedback section interposed between the acoustic transducer and the controller to provide feedback to the controller for the operating parameters of the acoustic transducer; wherein the controller is configured to determine reactance of the acoustic transducer to implement the control scheme.

Control of the acoustic transducer can be implemented on the basis of power setpoints. For example, a user can set a desired power level for power delivered to the transducer. Performance of acoustophoresis in an acoustic chamber using the acoustic

transducer can be modulated on the basis of modulated input power to the acoustic transducer. In some instances, a power setpoint is desired for operation, while other parameters, such as frequency, for example, are modified. The power setpoint determines the power output of an RF power supply or power amplifier. A power control is provided to maintain the power setpoint, while other parameters associated with operation of the acoustophoresis device are varied. The power control senses signals provided to the acoustic transducer, such as, for example, voltage and current. These feedback signals are used to determine frequency and phase angle for the power delivered to the transducer. In some examples, a buck converter is used as the power supply. The buck converter has a response bandwidth, which may influence the responsiveness of the power control. For example, if the buck converter bandwidth is relatively narrow, the system response for the power control may be relatively slow for the desired operational performance environment for the acoustophoresis device.

A number of different materials may be processed through the acoustophoresis device, each of which may provide different load characteristics on the acoustic transducer and acoustic chamber. The power supply thus may be subjected to a wide range of loads, which may place demands on the power supply that are challenging to meet. For example, heavy loading of the acoustic transducer and/or acoustic chamber experienced with certain types of materials being processed may cause power supply components to be overloaded, and/or overheated, or may cause trip point thresholds to be met or exceeded. The heavy loading or trip point thresholds crossings may cause faults to be identified in the power control, causing the power supply to be shut down. In addition, the power demands on the

CLAIMS

What is claimed is:

1. An acoustophoresis system, comprising:

a chamber for receiving a fluid mixture that includes cells or particles in a fluid;

an ultrasonic transducer coupled to the chamber and configured to be excited to generate an acoustic wave in the chamber;

a driver electrically connected to the ultrasonic transducer and configured to provide an excitation to the ultrasonic transducer to generate the acoustic wave in the chamber; and

a controller electrically connected to the driver and the ultrasonic transducer and configured to receive feedback signals from the ultrasonic transducer and to control the driver based on reactance determined from the feedback signals.

2. The system of claim 1, wherein the ultrasonic transducer comprises a plurality of transducers, each of the plurality of transducers being electrically connected to a distinct driver.

3. The system of claim 1, wherein the driver further comprises a DC converter and an RF inverter.

4. The system of claim 1, further comprising a capacitor electrically connected between the driver and the ultrasonic transducer.

5. The system of claim 1, further comprising a power resistor electrically connected between the driver and the ultrasonic transducer.

6. The system of claim 1, further comprising the controller being configured to determine frequencies where anti-resonance, and reactance minima and maxima occur based on the feedback signals.

7. The system of claim 1, further comprising the controller being configured to select a frequency associated with a reactance minimum or maximum based on the feedback signals.

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8. A method for controlling an acoustic transducer, comprising:

receiving feedback signals from the acoustic transducer;

determining an anti-resonance frequency of the acoustic transducer based on the feedback signals;

determining a reactance minimum or maximum adjacent to the anti-resonance frequency based on the feedback signals; and

providing a power signal to the acoustic transducer with the frequency substantially of the reactance minimum or maximum.

9. The method according to claim 8, further comprising:

scanning a frequency range for a new reactance minimum or maximum; and

adjusting the frequency of the power signal to a new frequency associated with the new reactance minimum or maximum.

10. The method of claim 8, further comprising determining an electrical power consumed by the acoustic transducer based on the feedback signals.

11. The method of claim 10, further comprising controlling one or more of a voltage, a current or a frequency of the power signal provided to the acoustic transducer to control electrical power consumed by the acoustic transducer.

12. The method of claim 8, further comprising:

decomposing the feedback signals into in-phase and quadrature-phase components.

13. The method of claim 12, further comprising determining phase angle and reactance based on the in-phase and quadrature-phase components.

14. The method of claim 8, further comprising sampling voltage and current of the acoustic transducer with pipelined analog-to-digital converters.

15. The method of claim 8, further comprising initiating a frequency scan based on one or more of a timed interval or an event.

16. The method of claim 15, further comprising receiving parameters of the frequency scan that include one or more of a frequency range, a frequency step size or a frequency step time interval.

17. The method of claim 8, further comprising determining the phase angle of the impedance of the ultrasonic transducer.

18. A device for controlling an acoustic transducer, comprising:

a modular controller for implementing a control scheme;

a power section connected to the controller for supplying power to the acoustic transducer; and

a feedback section interposed between the acoustic transducer and the controller to provide feedback to the controller for the operating parameters of the acoustic transducer;

wherein the controller is configured to determine reactance of the acoustic transducer to implement the control scheme.

19. The device of claim 18, wherein the power section further comprises a power converter and an RF inverter.

20. The device of claim 18, wherein the controller further comprises a processing engine configured to receive feedback signals, determine a minimum or maximum reactance from the feedback signals, and provide control signals to the power section to control one or more of voltage, current, or frequency of an output of the power section.