SYSTEM AND TECHNIQUE FOR CHARACTERIZING FLUIDS USING ULTRASONIC DIFFRACTION GRATING SPECTROSCOPY

RELATED APPLICATION DATA

[0001] The present application is a continuation-in-part of U.S. application Ser. No. 10/430,474, now U.S. Pat. No.______, which claims the benefit of commonly owned U.S. Provisional Application Ser. No. 60/378,530 filed May 6, 2002 and commonly owned U.S. Provisional Application Ser. No 60/467,878 filed May 5, 2003 and titled Characterization of Fluids and Slurries Using Ultrasonic Diffraction Grating Spectroscopy. The present application claims the benefit of U.S. Provisional Application Ser. No.______ filed Jan. 17, 2005. The present application is related to commonly owned U.S. application Ser. No. 10/099,412 filed Mar. 15, 2002 and titled Self Calibrating System and Technique for Ultrasonic Determination of Fluid Properties. The disclosures of the above referenced applications are all hereby incorporated by reference.

GOVERNMENT RIGHTS

[0002] This invention was made with Government support under Contract Number DE-AC0576RLO1830 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

BACKGROUND

[0003] The present invention relates to fluid analysis and more particularly, but not exclusively, relates to the determination of fluid properties by detecting ultrasound reflected from a diffraction grating.

[0004] Fluids are encountered in a wide variety of industrial applications, and there is a continual need to determine properties of those fluids. Ultrasound based sensors have been developed for a variety of industrial applications, but there continues to be a need to develop improved sensors and sensor techniques for determining fluid properties. In particular there is a need for sensing systems and techniques that are accurate, reliable, cost effective and can be implemented in a wide variety of industrial applications. The present invention is addressed to these needs and provides novel systems and techniques for determining fluid properties utilizing ultrasonic diffraction grating spectroscopy. In particular embodiments, the present invention may be used in characterizing multiphase fluids, for example solid liquid mixtures, such as slurries, suspensions and the like.

BRIEF DESCRIPTION OF THE VIEWS OF THE DRAWING

[0005] **FIG. 1** is a diagrammatic view of a system for determining fluid properties via multiple reflections from a fluid-solid interface.

[0006] **FIG. 2** is a schematic view of a device for performing an ultrasonic time-of-flight measurement on a fluid.

[0007] **FIG. 3** is a schematic view of another device for performing an ultrasonic time-of-flight measurement on a fluid.

[0008] **FIG. 4** is a diagrammatic view of a variation of the **FIG. 1** system for determining fluid properties.

[0009] **FIG. 5** is a side view of a clamp on sensor attached to a pipeline.

[0010] **FIG. 6** is a sectional view of the **FIG. 5** sensor.

[0011] **FIG. 7** is an exemplary plot of echo magnitude versus time illustrating echoes **1-5** of a representative diminishing series of echo amplitudes.

[0012] **FIG. 8** is an exemplary plot of log echo amplitude versus echo number with a straight line fit to the exemplary data where m indicates the slope of the line.

[0013] **FIG. 9** is a perspective view of an acoustic system for determining fluid properties implemented as a spool piece that can be coupled to a process line. The acoustic system of **FIG. 9** is a combination sensor that includes a pair of transducers for performing sensing based on multiple reflections from a fluid-solid interface and a pair of transducers for performing ultrasonic diffraction grating spectroscopy.

[0014] **FIG. 10** is a schematic illustration of a system for detecting the reflection spectrum including the zero order diffraction.

[0015] **FIG. 11** is an exemplary schematic illustration of the relative location of reflected and transmitted zero order waves for a stainless steel water interface with a diffraction period of 300 μm and illustrating the frequency dependence of the relative orientation of the diffracted first order waves.

[0016] **FIG. 12** is a schematic illustration of an ultrasonic beam incident on a diffraction grating.

[0017] **FIG. 13** is a schematic illustration of a system for performing ultrasonic diffraction grating spectroscopy.

[0018] **FIG. 14** is a plot of reflection coefficient as a function of frequency for the zero order diffraction collected with an exemplary embodiment as described where the fluid is water.

[0019] **FIG. 15** is a plot of reflection coefficient as a function of frequency for the zero order diffraction collected with an exemplary embodiment as described where the fluid is 10% sugar water.

[0020] **FIG. 16** is a plot of reflection coefficient as a function of frequency for the zero order diffraction collected with an exemplary embodiment as described where the fluid is 15% sugar water.

[0021] **FIGS. 17 and 18** are plots of normalized transducer response versus frequency for various concentrations of water and 215 micron polystyrene spheres.

[0022] **FIGS. 19 and 20** are plots of normalized transducer response versus frequency for various concentrations of water and 275 micron polystyrene spheres.

[0023] **FIG. 21** are plots of normalized transducer response versus frequency for various concentrations of water and 363 micron polystyrene spheres.

[0024] **FIG. 22** are plots of normalized transducer response versus frequency for various concentrations of water and 463 micron polystyrene spheres.

[0025] **FIG. 23** is a plot of normalized transducer response versus frequency for 1 wt % mixtures of polystyrene spheres at different average particle sizes.