SELF CALIBRATING SYSTEM AND TECHNIQUE FOR ULTRASONIC DETERMINATION OF FLUID PROPERTIES

BACKGROUND

The present invention relates to fluid analysis and more particularly, but not exclusively, relates to the determination of fluid properties by detecting ultrasonic reflections from a solid-fluid interface.

Fluids are encountered in a wide variety of industrial applications, and there is a continual need to determine properties of those fluids. One approach to the determination of fluid properties is based on measuring the reflection of ultrasound from a solid-fluid interface. The relative amount of ultrasound that reflects from a solid-fluid interface, expressed as a reflection coefficient, is a function of properties of the solid and fluid material. Therefore, at least in theory, if the reflection coefficient can be measured and the relevant properties of the solid are known, properties of the fluid can be determined. However, existing techniques for determining fluid properties based on reflections from a solid-fluid interface fail to satisfactorily address all industrial requirements.

For example, operating conditions of ultrasonic transducers and sensors assemblies can change over time. These changes can compromise the accuracy and precision of a measurement, and the adverse effects become particularly problematic when it is desirable to make comparisons between measurements taken at substantially different times. As changes in operating conditions become more significant and unpredictable, it becomes increasingly difficult to accurately compensate for such changes, and comparisons between data taken at different times becomes unreliable.

In addition, metals such as stainless steel and aluminum are common materials for fluid conduits and containers, but their usefulness in an accurate reflection based acoustic sensor is limited. One reason is that metals have a large acoustic impedance relative to the acoustic impedance of typical fluids. This large relative difference reduces the sensitivity of the reflection coefficient to changes in fluid properties. For example, at a stainless steel-water interface, where the acoustic impedance ratio of stainless steel to water is about 30.0, approximately 93.5% of ultrasound is reflected back into the steel from the interface in a normal incidence pulse-echo arrangement. An increase in the density of the fluid by about 6%, results in about 93.1% of the ultrasound being reflected, a difference of only about 0.4%.

Additionally, the speed of sound in metals is relatively high. Accordingly, for a given sound frequency, the wavelength of ultrasound in metals is relatively long. For example, at 2.5 MHz the wavelength of ultrasound is about 0.08 inches in stainless steel, which places significant limits on the cycle length of a 2.5 MHz sound pulse that would avoid echo overlap in a zero degree echo configuration in a thin member.

Accordingly, there is a need further contributions in this area of technology, including but not limited to better systems and techniques for determining fluid properties based on measuring acoustic reflections from an interface.

SUMMARY

One embodiment of the present invention includes a unique technique for fluid analysis. Other embodiments include unique methods, systems, devices, and apparatus for determining fluid properties.

In one embodiment a unique ultrasonic fluid interrogation system is provided including a transducer associated with a first surface of a wall with the fluid in contact with an opposed second surface of the wall. The transducer is operable to deliver an ultrasound pulse into the wall, with the ultrasound pulse reflecting in the wall between the first and second surfaces to provide an ultrasound pulse echo series at the transducer. The system includes means to detect a number of echoes from the echo series and to process the detected echoes to determine the decay rate of the echoes in the series. The decay rate is then compared to a calibrated decay rate to determine an acoustic property of the fluid. In one form, the transducer is clamped on to a pipe or container wall to provide a retrofit sensor device. In other forms, the wall is a metal, such as stainless steel. In still other forms a physical property of the fluid, such as the fluid density, viscosity, shear modulus, and/or shear speed is also determined. In still further forms the wall is thin relative to the size of the transducer face associated with the wall. In still further forms, the ultrasound pulse is a broadband pulse.

In a further embodiment, fluid properties are determined by delivering an ultrasonic pulse through a solid member with a transducer, reflecting the ultrasonic pulse between a solid-fluid interface and the transducer-solid interface a number of times producing a number of ultrasonic pulse echoes at the transducer, detecting the echoes, and determining the decay rate of the echo amplitude as a function of echo number. The decay rate is then compared to a calibrated decay rate to determine an acoustic property of the fluid, such as the acoustic impedance. In further refinements, the speed of ultrasound in the fluid is also determined and the fluid viscosity and/or fluid density is determined as a function of the acoustic property and the speed of ultrasound. In these or still further refinements, the transducer face is selected to be larger than the thickness of the solid member. In still further refinements, the size of the transducer face relative to the thickness of the solid member is selected such that the pathlength for the majority of the detected pulse echoes is less than the near field length of the ultrasonic transducer.

One object of the present invention is to provide a unique technique for fluid characterization.

Another object of the present invention is to provide a unique method, system, device, or apparatus for determining fluid properties capable of utilizing ultrasonic reflections from the metal-fluid interface in a pipe wall.

Another object of the present invention is to provide a unique ultrasonic method, system, device, or apparatus for determining fluid properties that is substantially independent of variations in inputs to the ultrasonic transducer and/or is substantially independent of the amplitude of measured signals.

Another object of the present invention is to provide a unique ultrasonic method, system, device, or apparatus for determining fluid properties capable of including a transducer clamped on to a preexisting pipe or container wall to provide a retrofit sensor.

Further embodiments, forms, features, aspects, benefits, objects, and advantages shall become apparent from the detailed description and figures provided herewith.

BRIEF DESCRIPTION OF THE VIEWS OF THE DRAWING

FIG. **1** is a diagrammatic view of system for determining fluid properties.

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

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

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