MesoScale® Technology

The innovative sensor techology for measuring density & viscosity with unmached compactness and application flexibility

WIKA

AVENI SENSE™

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Density, a fundamental property of matter

The density of a substance is defined as mass per unit volume and can be reported in a variety of units such as kg/m3 or lb/ft3. It is a unique physical characteristic of any gas, liquid or solid. If the composition or temperature of the substance changes, its density will change. If measured to enough precision, each substance has a unique density. This value can be viewed like a fingerprint and is routinely used to identify the fluid. Thus, the density can be seen as a fundamental parameter in determining the quality of a fluid.

Furthermore, the density also can be used as an analytical technique to make the most basic measurement of the composition of a two-component liquid or gas. The sensitivity of this measurement is affected by the density differences between the two substances. Any substance will expand or contract with changes in temperature. This complicates the measurement of density, which has to be reported at the measured temperature of the fluid.

Measurement of liquid density can be as simple of weighing the mass of the fluid in a known volume. The accuracy is a function of the accuracy of the known volume of the container and the accuracy of the weigh scale. The device for making this measurement is called a Pycnometer and normally includes a precision thermometer. When measuring gas density, which is a compressible fluid, the absolute pressure of the gas along with the absolute temperature must also be reported.

Methods for measuring density

For a periodic manual measurement of liquid density, the principle of buoyancy is used to in the form of a hydrometer. A hydrometer, typically a hollow glass float that has been calibrated with a scale that indicates liquid density calibrated using fluids of known density. For continuous measurement of density in a flowing pipe the principle of a spring-mass harmonic system has been exploited. Such a system can be a tube with a fixed volume fabricated using a rigid material formed in the shape of a U to become a resonating structure. Actuators and sensors vibrate the tube at its resonant frequency, which is a function of the weight of the tube and the mass of the fluid in the tube. Highest resolution of density measurement occurs when the mass of the tube is substantially less than the mass of the fluid in the tube. Tubes have been fabricated from various metals, glass and crystalline silicon depending on the pressure, temperature and installation of the sensor.

An alternative to flowing liquid through the tube is to immerse a cantilever-vibrating element in the liquid. This vibrating element is typically some type of paddle shape and the paddle is vibrated at its resonant frequency in the fluid. The density of the fluid will change the resonant frequency of the paddle. The benefit of this technology is the sensor can measure density of a static fluid in a tank and or in a flowing fluid. The material used for the vibrating cantilever element has been made from crystalline silicon, zirconium, stainless steel or a steel alloy. The selection is based on the fluid to be measured along with the temperature and pressure of the fluid. A precision temperature sensor is typically included in the sensing assembly to measure the fluid temperature surrounding the sensor.

Gas density measurement is a challenge due to the low density of a gas compared to a liquid. The ratio of the mass of the sensing element to the mass of the displaced gas determines the sensitivity of the measurement. Cantilevered sensors used for liquid density have been be used for gas density measurement, but the success of the technology has been limited. The challenge is displacing enough gas volume using a very light structure. The most common structure duplicates a resonating tube similar to a tubular bell. The resonance of the tubular bell is a function of the density of the gas. The resulting structure has to be very large to achieve sensitivity.

Miniaturization of a sensing element typically leads to improved performance because environmental changes play a smaller effect on the measured property. This has led silicon micro-machined technology (MEMS) to dominate many sensing technologies dealing with the measurement of force such as pressure. The problem in applying silicon sensor technology to fluid property measurement is the silicon to metal interface. This has limited this technology to niche applications with limited pressure and temperature.

Viscosity, a fluids resistance to flow

The viscosity of a fluid is a measure of its resistance to flow by shear stress. It can be seen as the resistance of flow, due to internal cohesion forces (van der Waals forces) on molecular level. To overcome this internal cohesion, an external force must be applied. This force equals the viscosity value.

Shear viscosity characteristics of a fluid can be characterized as being Newtonian where the resistance to shear is a linear relationship with shear rate, the higher the shear the greater the resistance. Fluids that do not follow this model are called non-Newtonian. Shear thickening fluids increase resistance to flow with increased shear. Shear thinning fluids decrease resistance to flow with increased shear.

Density and viscosity as a quality Indicator

In fuel measurement, density is an indicator of the “quality or type” of fuel, since every fuel category has an acceptable density range. A fuel that has been contaminated would have a density and viscosity measurement outside industry norms. Viscosity is one of the most important parameters to characterize the type and quality of lubricating oil.

In the food and beverage industry, the density of a liquid is a widely accepted quality parameter. It can be used as an indication of the alcohol concentration or sugar content of a beverage.

With the increasing trend to process analytical concepts (PAT) in various industries, density and viscosity are gaining attention as an analytical parameter to be measured in-line and at-line. The challenge for further use of density and viscosity measurements has been the size and cost of the available sensing technology.

MesoScale® Technology

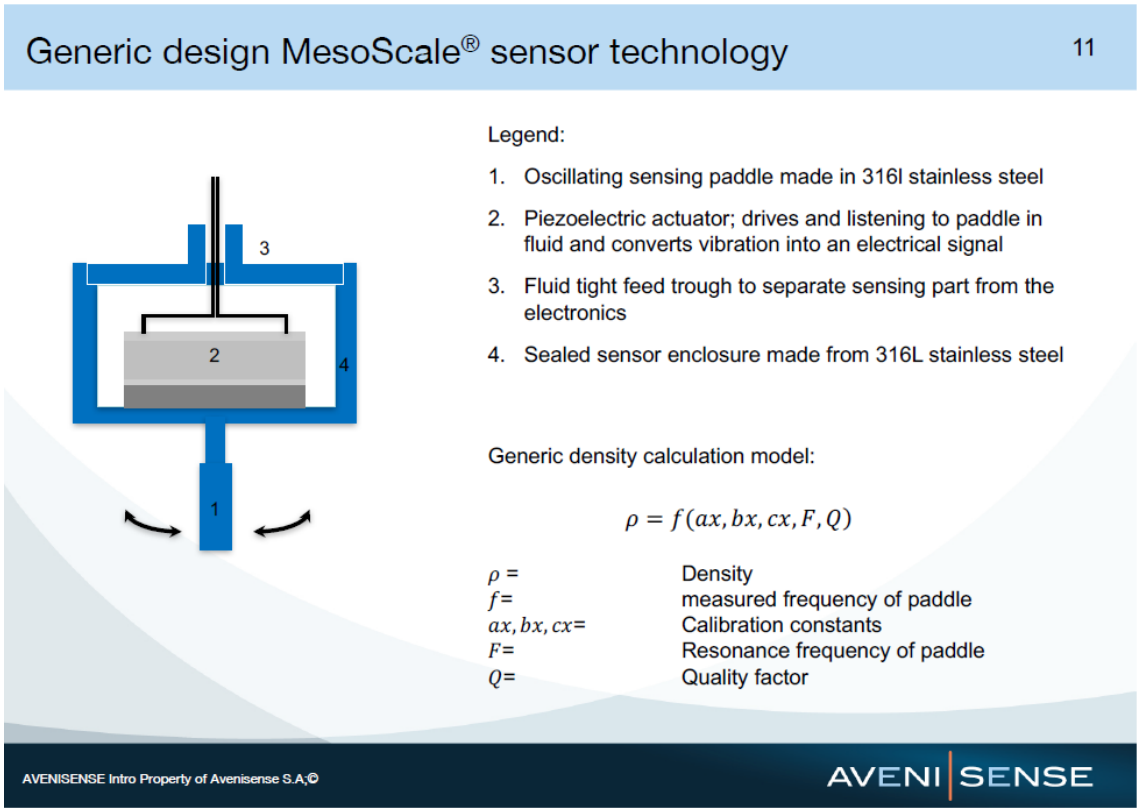
The MesoScale® technology is a patented combination of sensor design, sensor actuation and software (European patent demand EP12305433.0 (April 2012), followed by PCT PCT/EP2013/05774 in 2013, European patent demand EP15306476 (2015) followed by PCT (2016)). These components are the sensor's backbone to measure density and viscosity of a liquid or density of a gas. The philosophy of MesoScale® Technology is to capture the benefits of sensor miniaturization with traditional metal construction technology to produce a product suitable for use in process applications. The heart of the sensor is a fluid wetted single piece, precision micro-machined metallic resonating element.

The MESOSCALE® ultrathin disk of NORTHDOME®, the Gas Density Sensor

The MESOSCALE® oscillating paddle of DEVIL®, the Liquid Density and Viscosity Sensor

This resonating element is coupled on the back side (outside of the process) to an actuating and detecting subsystem that excites the element at an innovative dual resonance frequency that allows the removal of internal sources of noise that usually interfere with standard measurement methods. This subsystem alternates between exciting the resonating element and then detecting the response of the element to the effects the fluid on the element. Dual excitation at two different frequencies, allows one sensor element to measure liquid density and viscosity. For gas applications sensor system operates in a single vibration mode.

Generic design



Embedded low-power, fast digital electronics drives the sensor and processes the signals to determine density and viscosity based on a factory calibration using fluids of known density and viscosity. WIKA TECH developed proprietary equations that utilize measured temperature, resonance frequency and sensor material characteristics to determine fluid density and viscosity. The sensing element and control electronic form an inseparable measurement system.

For process integrity, the resonating element is machined from a single piece of metal along with the thin flexible metal diaphragm that attaches the piezo electric actuator to the element. This single piece is welded to the sensor body with no potential leak paths from the process to the electronics behind the diaphragm. The precision diaphragm is an active and critical part of the sensor system. The result is a sensor with a high-pressure rating and ability to operate at elevated temperature.

Application Flexibility

MesoScale® provides the user mounting flexibility when measuring density and viscosity. The small size of the sensor means it can be installed in a flow-through block using small tubing. The setup can be used for continuous measurement in a bypass flow loop or in low-flow processes like pilot plants. The sensor can also be used as an immersion sensor in a tank or mounted on a T on a process line. The single-piece all metal construction results in a robust design suitable for high pressure and higher temperatures found in process installations. The sealed stainless steel electronic enclosure means the sensor is suitable for use in harsh environments such as desert or artic regions.

The MesoScale® sensing element high resonant frequency results in a density measurement technology that is not affected by common process vibrations that routinely affect larger vibrating tube density meters. All sensors are available for use in explosive hazardous electrical areas, zone 1 and zone 0 being certified according to ATEX directive 2014 and also corresponding to IECEx standards. A variety of analog and digital communication options are available for communicating measured and calculated values to outside electronics.

Products Using MesoScale® Technology

WIKA TECH use MesoScale® Technology in three different product families each focused on different applications:

> DEVIL® : A small and compact liquid density and viscosity sensor suitable for measuring density and viscosity of a variety of fuels, oils and aqueous solutions.

> NORTHDOME® : The smallest gas density and temperature sensor on the market.

Registered trademarks and patents

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MesoScale® patent numbers are European patent demand EP12305433.0 (April 2012), followed by PCT PCT/EP2013/05774 in 2013.

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