Viscosity Monitoring with a quartz crystal thickness shear resonator

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The paper describes a novel quartz crystal sensor for the measurement of the density-viscosity product of Newtonian liquids. The sensor element consists of two circular quartz crystal plates with an air-gap in between and the liquid sample in contact with the outer plate surfaces. Plano-convex AT-cut quartz crystals arranged in mirror symmetric crystallographic orientation and vibrating in an even-symmetric thickness-shear fundamental mode at 2.77 MHz are utilized. The two outer plane sides of the crystals are fully covered by gold electrodes, which are both connected to ground potential. This special mirror symmetric set-up allows the compensation of spurious displacements in the circular clamping zones of the two crystals. The measurement values of the sensor are the fundamental resonance frequency *f* and the associated resonance *Q*-value, which are analytically dependent on the density-viscosity product of the liquid in contact with the sensing surfaces. The quartz crystals, together with a miniature platinum resistance temperature sensor, are mounted in a stainless steel housing. In contrast to an earlier report [1] about a sandwich resonator sensor, which entrapped the liquid sample in between two quartz plates, the immersible sensor presented here is not restricted to low viscosity samples. For Newtonian liquids, the double-quartz sensor features high absolute accuracy and reproducibility without the need of calibration and without any fitting parameter.

The sensor covers a viscosity range from almost zero (air!) up to 2000 Pa.s, and is not restricted to electrically insulating liquids. Non-Newtonian behaviour can be identified and the complex mechanical impedance of non-Newtonian fluids can be determined at high shear rates (10^7 s^{-1}). The flange mounted immersible sensor was employed successfully in rough industrial environment for on-line monitoring viscosity and temperature of waffles dough flowing through the dough supply pipe of a waffles production plant (Manner®-Schnitten, Wien, Austria). The high viscosity resolution could be demonstrated by adding small amounts of water (1 vol.% or 0.5 vol.%, respectively) for which corresponding decreases in dough viscosity could be observed. Dough viscosity is an essential parameter for quality control in waffles production.

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[1] R. Thalhammer, S. Braun, B. Devcic-Kuhar, M. Gröschl, F. Trampler, E. Benes, H. Nowotny, and M. Kostal, *Viscosity sensor utilizing a piezoelectric thickness shear sandwich resonator*, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 45, pp. 1331-1340, 1998.