Determination of gas quality combining ultrasonic and thermal measurement principles

A novel approach to the measurement of physical gas properties and their use in a correlative measuring device

Graduate

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Introduction: Renewable energy production is only part of the transition to a carbon-neutral economy. To ensure that the energy is available all year round, it must also be stored. To span the seasons, the existing gas grid can be used as reservoir. However, because of all the different sources, end consumers do not know what the actual quality of the gas delivered to them is.

The company Mems AG manufactures measuring devices to determine necessary gas parameters. The technology is based on the correlative measurement principle, where the output values are not measured directly but derived from physical properties of gas.

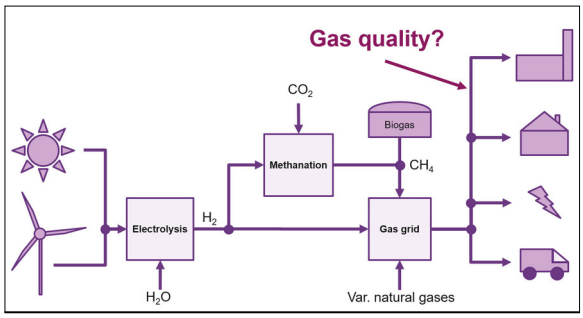
Objective: The measuring principle with a microthermal sensor as the basic element for correlation requires a predefined gas flow. To control the flow via the sensor, a critical nozzle is currently used. However, other flow sensor principles are also applicable. In this thesis, ultrasound is considered in more detail, as this technology is already widely used on the market and thus a wide range of products exists. Furthermore, the density can be correlated with the speed of sound and thus represents an additional measurement variable for determining the gas properties.

The thesis was divided into three phases; acquisition of the basic knowledge, sound propagation in tubes and finally the combination of ultrasound and calorimeter. To verify the measurement principle, a proof of concept was created from which findings and recommendations were derived. Critical elements and components of the system were identified and focal points and solution approaches for further development proposed.

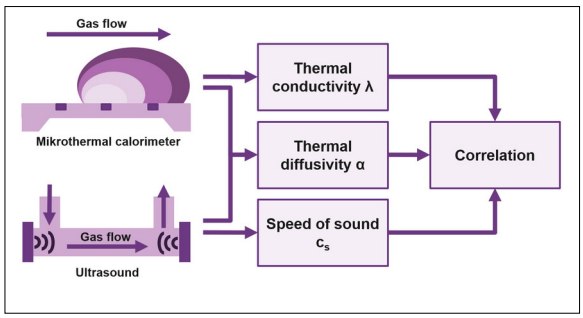
Conclusion: The results show that the technology of ultrasonic measurement is very well suited as an extension for the already existing microthermal measurement system (1% in density, 5% in calorific value). However, the mechanical design is fundamentally different from that of a flow meter, as the latter has different requirements for the flow regime (flow rate, low pressure drop). For this reason, several important points must be taken into account:

- For accurate measurement of thermal diffusivity, the ultrasonic flowmeter and the microthermal calorimetric sensor must be calibrated together.
- Since the same gas flow must be measured with both methods, the cross-section of the flow channels must be adapted to each other. The resulting small inner diameters of a few millimetres cause strong reflections in the ultrasonic measurement.
- The gas-dependent properties, such as resonance frequency and quality factor, of the transducers must be taken into account and compensated in the measurement algorithms.
- The required setup with a trans-axial radiation reacts sensitively to dead volumes and turbulence. The mechanical construction of the measuring unit must be designed accordingly.
- The kinematic viscosity can also be determined with ultrasound using boundary layer effects. However, a resonator with continuous-wave signals is more suitable for this measuring principle, as the signal output is relatively small due to reflections.

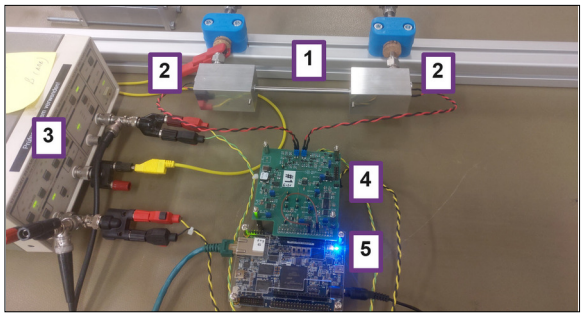
Unknown gas quality in the gas network
Own presentment



Measurement principles and their measured physical properties
Own presentment



Laboratory setup ultrasound (1 Measurement tube, 2 Transducers, 3 Amplifier, 4 Analog front end, 5 Data acquisition)
Own presentment



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