

Modeling of the Flow Comparator Prototype as New Primary Standard for High Pressure Natural Gas Flow Metering

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Introduction

For the trade with natural gas the uncertainty of high pressure natural gas flow meters is of major importance. The calibration of the flow meters is done with transfer standards which are calibrated by the German national primary standard for high pressure natural gas flow. The current primary standard is a High Pressure Piston Prover (HPPP) (Schmitz and Aschenbrenner; PTB, 1991, 2009). It is owned and operated by the National Metrology Institute of Germany Physikalisch-Technische Bundesanstalt (PTB) and installed on the calibration facility for gas meters pigsarTM in Dorsten, Germany. The HPPP can be operated with inlet pressures up to 90 bar and flow rates up to 480 m³/h (PTB, 1991).

The PTB is developing a new concept for volumetric primary standard to calibrate high pressure gas flow meters. The TUHH is supporting these R&D activities with its competence to elaborate computational models for detailed analysis of complex mechanical systems including fluid flow aspects. The new primary standard is based on a actively driven piston prover to measure the gas flow rate using the time the piston needs to displace a defined enclosed volume of gas in a cylinder.

Experimental Setup

The key element of the Flow Comparator is a piston in a cylinder. Together they act as an asynchronous linear motor. For this, the cylinder has two layers, one with magnetic properties and the other one acts as an electrical conductor. The stator core with its windings is integrated into the piston. For the electrical power of the stator core a supply cable is connected to the piston. The velocity of the piston is controlled by using a frequency inverter to set the control voltage and frequency for the stator core. The differential pressure over the piston is measured with a sensor in the piston. A specified leakage in the piston with a flow sensor measures the fluid flowing through it. With the two sensors, it is possible to compare the piston movement relative to the fluid flow. The piston has an integrated check valve to limit the pressure drop across of the piston. The position of the piston is measured using a distance measuring equipment (DME). The ambient temperature and pressure as well as the temperature and pressure downstream of the cylinder are measured.

Computational Model

A computational model written in Modelica[®] is developed to investigate the Flow Comparator's dynamic behavior. The measuring cylinder is divided into one volume upstream and one volume downstream of the piston. As a first approach to model the force of the linear motor, a function depending on control voltage input and velocity of the piston is derived. Verification of the model shows correct physical implementation and accurate solution of the equation system. Validation of the model shows good compliance of the piston velocity and differential pressure at the piston in the model with measured data.

Conclusion and Outlook

With the model the frequency inverter control voltage trajectory is optimized to maximize the available measuring time. With this simple optimization, the measuring time could be increased by 80 % in the model. This result of optimization will allow to extend the upper limits of flow rate usable for calibrations. Furthermore, the possibility to gather detailed information about pressure and temperature development at arbitrary chosen locations in the system with high time resolution enables much better and more reliable statements about the accuracy of flow rate measurement with this system.

In the future, the linear motor should be modeled using physically based equations. Additionally, it will be essential to extend the model by heat transfer from the motor components to the gas.

Keywords: modeling of multi-domain physical systems, flow comparator, high pressure natural gas flow metering, linear motor, optimization

References

- Physikalisch-Technische Bundesanstalt PTB. Prüfschein der Rohrprüfstrecke. 1991.
- Physikalisch-Technische Bundesanstalt PTB. PTB Mitteilungen. *Special Issue Volume 119 no.1*, 2009.
- G. Schmitz and A. Aschenbrenner. Experience with a Piston Prover as the New Primary Standard of the Federal Republic of Germany in High-Pressure Gas Metering. In *Proceedings of the 18th World Gas Conference, Berlin, 8.-12.7. 1991*.