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GAS DYNAMICS IN VACUUM TOTAL PRESSURE SENSORS

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ABSTRACT

Improving vacuum pressure sensors for lower measurement uncertainties requires a thorough understanding of the underlying physics. We have used experimental, analytical and computational methods to understand the sensor behavior. Here we briefly demonstrate the use of DSMC methods for improving capacitance diaphragm sensors and the numerical solution of the S-model kinetic equations for Pirani sensors.

Introduction

INFICON manufactures, among many other products, total pressure sensors for vacuum processes. Using several different measurement technologies, those sensors span the full range from 10^{-10} to 10^{5} Pa. In order to further improve the sensors, a detailed analytical understanding of the sensors is necessary. However, this is not easily achieved and computational models are used. The pressure range from 10^{-1} to 10^{2} Pa is difficult to model. In this transition range continuum models do not work satisfactorily anymore and the same is true for molecular models. Direct Simulation Monte Carlo (DSMC) calculations are computationally expensive and are not so well suited for quick engineering optimizations. We have used different methods to further our understanding of our sensors in the framework of the European GASMEMS program. Here, we will give a brief sample of our previous activities.

Capacitance Diaphragm Gauges

Capacitance Diaphragm Gauges (CDG) are variable capacitance sensors, where one electrode moves under pressure load. These sensors are mainly used in the semiconductor industry. They have comparatively low measurement uncertainties of the order of 0.15 % of reading and span a pressure range from 10^{-4} to 10^{5} Pa. Many CDGs used in process industries are operated at higher temperatures than room temperature in order to prevent condensation of process gas on the interior surface of the sensor cell that could affect the measurement uncertainty. However, by heating the gas we introduce another error caused by thermal transpiration that needs to be compensated. There are several approximations for thermal transpiration, e.g. [1,2]. In addition, we introduced a baffling system in the gas path to thermalize the incoming gas and protect the sensitive membrane. The baffle has also an effect on the measured pressure as shown in Fig. 1. These effects were studied with experimental and modeling efforts during the European GASMEMS project.

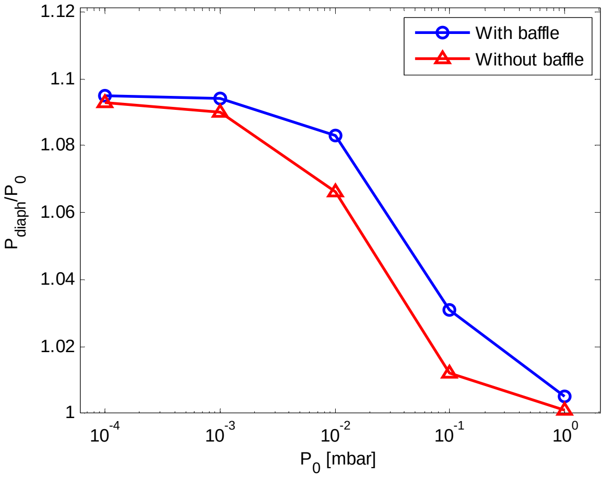

Figure 1: Variation of the ratio between the pressure at the diaphragm and at the vacuum chamber as a function of the reference pressure obtained with DSMC for a helicoidal baffle system (blue circles) and a system without baffle (red triangles) for T_{diaph} = 82ºC, T_0 = 23ºC [3].

Pirani Heat Transfer Gauges

Pirani sensors consist of a heated wire and the measured heat loss to the surrounding wall is a function of pressure. These sensors are used in the pressure range from 10^{-3} to 10^{5} Pa and have a typical measurement uncertainty of 10-15 % of reading. These sensors require some time in pressure transients to reach a stable pressure signal again. In order to improve on this behavior, unsteady S-model kinetic equations are solved numerically over a broad range of rarefactions [4].

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