

Ultrasound flow meter errors related to transducer cavities

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1 Introduction

The development of the ultrasound flow meter technology is currently very rapid. This is especially seen in the small meter market. In both the district heating and natural gas industry the ultrasound flow meters are rapidly taking market shares.

In this context the error assessment of ultrasound flow meter becomes of interest. This have been made by several authors, se for example [1][2]. A special condition are errors associated with the flow situation within the meter, se for example [3], [6], [?]. For large diameter meters the effect of cavities in from of the meter have been investigated by Loland et.al.[5]. Based on CFD simulations this paper will discuss transducer cavities in small diameter ultrasound meters.

2 Theory

The work is based on 3D computer simulation of the flow pattern within the flow meter. The used CFD tool is CFDX. For the simulations an unstructured grid was used. To this we have applied an plane wave sound propagation model. Using this we have been able to simulate the calibration curve for a small diameter (13mm) ultrasound flow meter featuring an inclined sound path as shown in figure ???. The calibration curve have been simulated for flow velocities from 0.01 - 10 m/s corresponding to Reynodlsnumber from 130 til 130.000 cf. figure 2. To investigate the influence of the cavities in front of the transducers the sound propagation path was considered to be a cylinder. The receiving transducer will integrate the sound pressure field over this cylinder. The received sound field is modulated by the flow field. We here neglect the influence of a nonuniform temperature filed over the cylindric sound path. When looking at the flow meter body geometry, cf figure ?? it is obvious that the flow pattern in the cavities are not identical. A typical flow pattern situation is shown in figure 3. We can here se two differences. The recirculation pattern within the cavities are not identical and the cavity influence on the "free stream" flow is different for the up and down stream cavity.

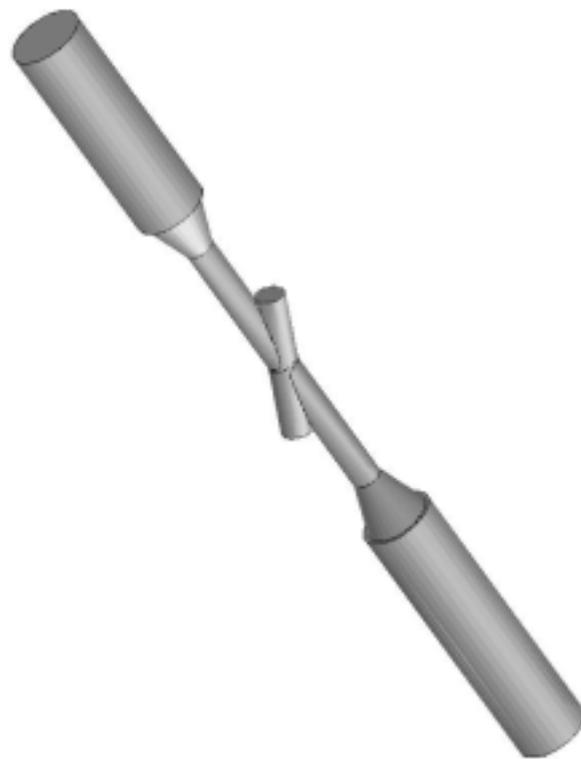


Figure 1: model used for 3D simulations of a flow meter body

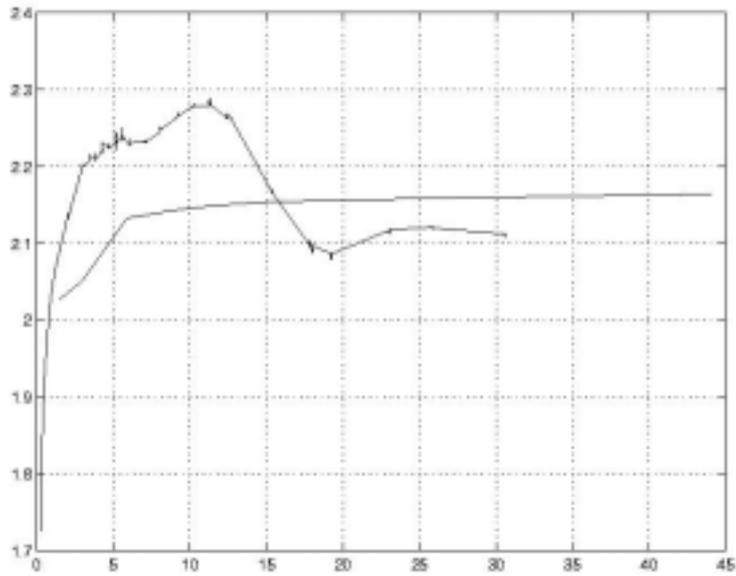


Figure 2: Two typical calibration curve for a two different geometries of small diameter ultrasound flow meter. The y axis gives k-value and the x axis gives l/min

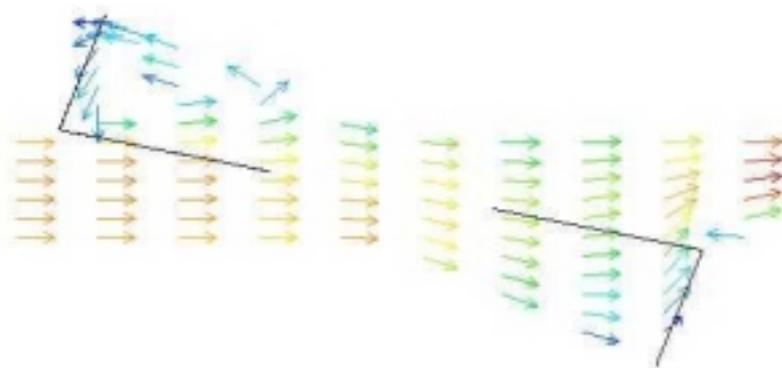


Figure 3: The flow pattern in the meter body around the upstream and the down stream cavity.

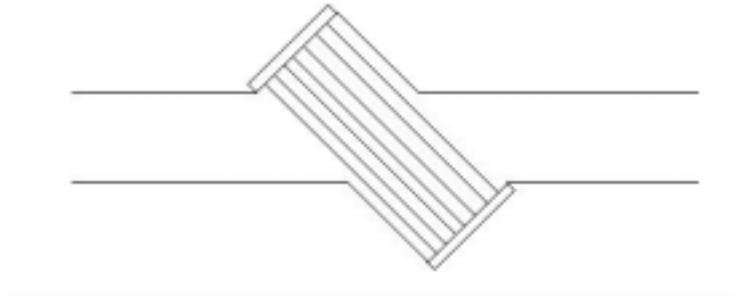


Figure 4: Illustration of the slicing of the cylindrical sound path. Slices are enumerated from left to right.

Assuming that the transmitted sound field is perfectly uniform (from intensity or amplitude point of view) over a cross-section of the cylindrical sound path and that the receiving transducers makes a perfect integration of the received sound we will get a flow measurement that representation a integration over the sonified fluid volume. In most cases this is not true. In general the sound field can not be considered to be of cylindrical shape and not uniform over a propagation cross-section se for example [4]. In this scenario we must start to considered the situation of asymmetries in the flow pattern within the assumed cylindrical sound path. In this paper this have been accomplished by slicing the cylinder in the length direction as shown in figure 4. Using this approach we can find flow meter calibration deviations that are related to the cavities provided that the sound field in the studied sound path slice is dominant compared to the other part of the sound path cylinder. This will be an extreme situation thus the simulated data will give us the extremes due to sound field shapes and flow pattern caused by the transducer cavities.

3 Results

A reference calibration curve was obtained using the ideal cylindrical sound path model. Simulations was med for Reynolds number from 130 - 130.000. In figure 5 the calibration curves for a the slices shown i figure 4. The deviation between the different slices are obvious. This gives us an impression of the magnitudes of errors associated with transducer cavity's and non ideal transducers.

4 Conclusion

The obtained simulations makes it clear that deviations from ideal transducers will introduce errors in and ultrasound flow meter. The simulation indicates that these errors can be large if only portions of the transducer is working. To minimize these errors flow meter body design that causes minimal differences in the sonified flow field are advantageous. Further the transducer design and its manufacturing is critical.

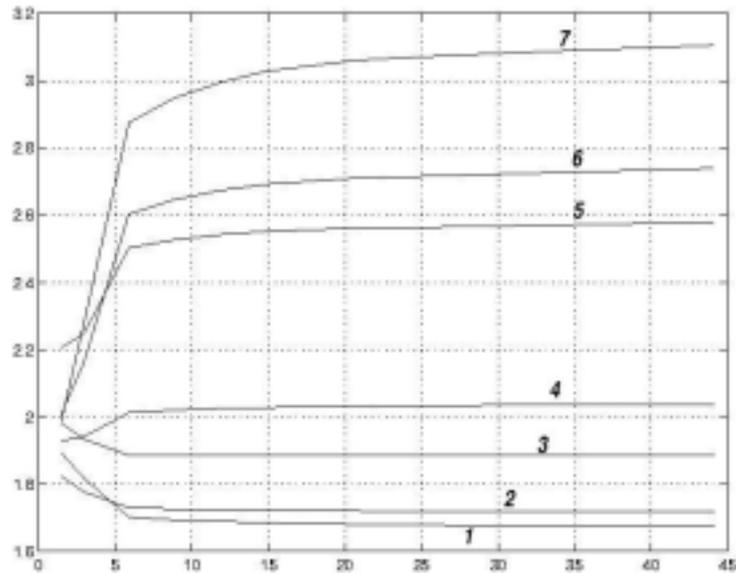


Figure 5: Calibration curves obtained from each of the slices shown in figure 4. Slice numbering from left to right, cf figure 4. The y axis gives the k-factor and the x-axis gives flow in l/min

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