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The Numerical Recalibration Procedure of Water Calibrated CFM for Cryogenic Fluids Application.

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Extended Abstract

Nowadays, cryogenic fluids are employed in many fields, including health care, aerospace, and maritime industries. As commonly known, these fluids are most often applied as refrigerants. For example, liquid nitrogen (LN) is used for the thermal insulation of high-temperature superconducting transformers [1]. Aside from cooling, the application of cryogenic fluids as fuels and oxidizers provides a unique economic advantage due to their high energy densities. Moreover, such cryogenic fuels as liquefied natural gas (LNG) offer a solution to the problem of growing emissions [2]. Therefore, accurate measurement of cryogenic fluids is a vital component for sustainable development today.

Coriolis flowmeter (CFM) is one of the most promising tools for measuring fluids of this type. This is explained by its high accuracy, non-obstructive nature and potential suitability for multiphase metering. Due to the features of cryogenic fluids, however, multiple challenges present themselves. First of all, the non-linearity of CFM material properties is observed for low temperatures. Secondly, the composition of cryogenic fluids may vary due to the origin or the different boiling rates of components. Finally, there are challenges that are inherent for all CFMs, including environment temperature, zero shift, and external vibration influence. The complex of these challenges leads to the lower CFM accuracy for cryogenic fluids than for water, which was reported in [3]. While new CFM configurations may be developed to address these challenges, the calibration of them is required. However, currently, the calibration process is restricted significantly by cost and size limitations of experimental facilities. Therefore, a numerical calibration procedure was developed as an alternative.

The presented numerical calibration includes modal and fluid-solid interaction (FSI) simulations. To ensure the reliability of simulations, space and time discretization independence studies were conducted. Additionally, modal analysis was validated by experimental data. It was demonstrated that the accuracy of calculations is acceptable and may be improved by avoiding the material properties assumption. The developed numerical calibration procedure was applied for LNG and LN metering by CFM, what may decrease the costs of experimental calibration and increase the meter application range.

Finally, the suitability of developed calibration was demonstrated for the CFM's challenges study. For instance, the measurement error, which is caused by the difference of natural frequencies of empty and filled tubes, was studied. It was concluded that this error is less significant for cryogenic fluids than for water, due to its higher density. Also, the zero shift of CFM, associated with low measurement accuracy [4], was investigated. Results of FSI analysis showed that it is caused by secondary circulation and is higher for cryogenic fluids than for water. This significant increase may be one of the main reasons for the low accuracy of LNG metering. However, the developed methodology should be used for the study of other cryogenic effects to identify which of them plays the main role in the high error. This will allow the improvement of cryogenic fluids metering, therefore benefiting industries relying on them.

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