Systematic measurement error of pneumatic probes in periodically fluctuating flows

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In numerous applications, pneumatic probes are used to measure the thermodynamic values of a flow. Specifically in aircraft and turbomachinery research it is of great importance to achieve a high measurement accuracy while reducing the influence of the probe itself. Miniaturized single- or multi-hole probes are used to measure the total pressure of a flow. These probes are typically calibrated in free-stream channels with low turbulence even though their application can be under highly fluctuating conditions, e.g. downstream of a compressor or turbine.
Within the proposed paper, the results of a numerical and experimental study on pneumatic probes under periodically fluctuating flow conditions will be presented. A systematic variation of flow and probe parameters has been conducted to quantify the accuracy with a focus on performance measurements in turbomachinery. The specific influence of the unsteadiness will be discussed in the paper regarding the validity of calibrations performed under steady conditions.
In a sequential study, the capacity of different probe geometries to measure the total pressure has been analyzed in unsteady numerical simulations. These simulations are validated with an experimental setup of an oscillating probe in a free stream channel. The respective probe geometries are furthermore analyzed numerically in the vicinity of a compressor rotor whereupon the effect on the systematic performance measurement error is discussed.
The results show that the periodic wakes from the turbomachinery rotors significantly affect the accuracy of pneumatic probes since the measured total pressure does not necessarily represent the actual temporal average at a specific location. Particularly multi-hole probes are sensitive to respective fluctuations. It can be shown, that the angular insensitivity of typical probe geometries strongly depends on the flow characteristics that change with the channel height and has to be considered as a systematic error. Based on the presented results a recommendation for fixed and traversable measurement setups can be derived.

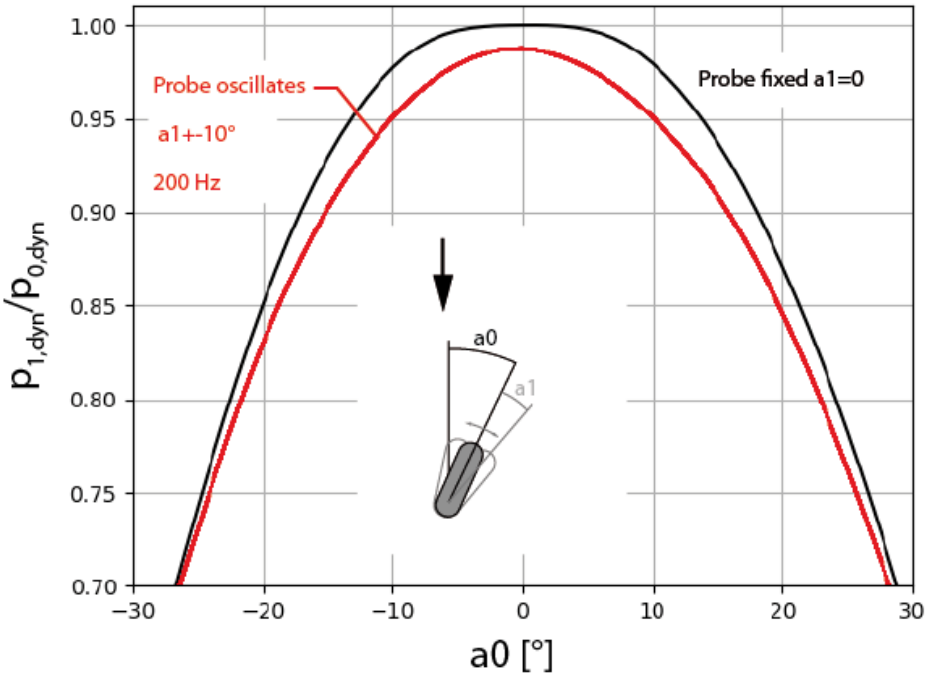

fig 1 dynamic pressure recovery as function of the static yaw angle; experiment of fixed and oscillating probe