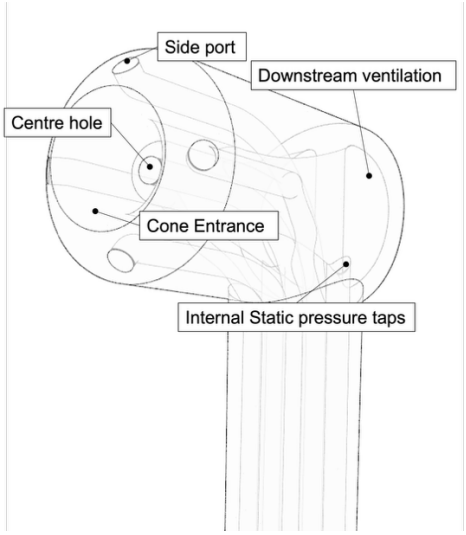

Figure 1Schematic Illustration of one version of the Kiel-MHP variant

Title: Novel approach to MHP uncertainty in turbomachinery

Author: Isak Jonsson
Affiliation and Contact:
Isak Jonsson PhD
isak.jonsson@chalmers.se
Chalmers University of Technology
Fluid Dynamics Department
SE-412 96 Gothenburg Sweden

Introduction and Motivation

Multi-hole pneumatic probe (MHPs) remains an essential tool for characterizing complex fluid dynamics, particularly when evaluating velocity, angles and pressure variations in turbomachinery applications as the single device can measured them all. For decades, studies have been proposing increasingly complex numerical data reduction schemes aimed at minimizing the interpolation or calibration time. These numerical schemes are frequently evaluated under ideal, uniform flow conditions. This inherently masks common uncertainties introduced during real-world measurement such as unsteady flows, turbulence and high-pressure gradients. This research supports some relative studies that these physical vulnerabilities entirely dominate the error profile, dwarfing numerical interpolation errors, and proposes a novel hardware modification to fundamentally resolve the issue.

Conceptual Approach

Initially, a comprehensive evaluation was conducted comparing common numerical data reduction methods, from standard sector interpolation to more recent methods like the robust method and Gaussian process regression. The analysis confirmed that while these algorithms show exceptional precision in ideal flow conditions, this precision rapidly degrades when exposed to non-linear averaging during unsteady flow events. Recognizing that algorithmic tweaks evaluated in uniform flow cannot cure physical measurement corruption in fluctuating flow, a novel MHP configuration and data reduction method was developed. The design features a modified center port after a Kiel probe and wake port, capturing stagnation pressure directly and bypassing the severe penalties of numerical extraction.

Experimental Validation

The modified physical probe and its adapted calibration framework were validated in an open jet calibrator and a large-scale wind tunnel cylinder wake study at a Reynolds number of 55,000. The total pressure was measured directly at the center port, and the new data reduction was used to compensate for unsteady flow conditions. This intervention mitigated the massive uncertainty typically observed when conventional MHPs—and their associated numerical reduction schemes—are subjected to highly fluctuating, quasi-unsteady environments. Consequently, the novel design yielded up to a two-order-of-magnitude improvement in total pressure accuracy compared to standard MHP setups.

Impact and Applications

This methodology offers the turbomachinery community a robust, high-precision drop-in replacement for standard probes in demanding, real-world flow characterization.