DEVELOPMENT OF AN ADDITIVE MANUFACTURED MINIATURIZED WEDGE PROBE OPTIMIZED FOR 2D TRANSONIC WAKE FLOW MEASUREMENTS

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EXTENDED ABSTRACT

Reliable flow measurement results on turbine and compressor cascades are essential for the validation of numerical design processes for new engine profiles. Especially transonic turbine profiles are in focus of many research projects closely linked to the benefit of increasing the spool speed in turbomachine applications. A major challenge arises when measuring with pneumatic multi-hole-probes in transonic wake flows, because of the existing constraint close to Ma=1 resulting in an insensitivity of determining the flow Mach number (respectively the static pressure) [2]. The affection of this insensitivity can be reduced by using sharp probe head geometries instead of blunt shapes. Another promising improvement can be achieved by using a base pressure tap in wake of the probe which it is not affected by the mentioned constraint [3]. Besides the above mentioned design aspects, the probe head ought to be as small as possible facing the challenge of measuring in high pressure gradients wake flows. Therefore, advanced manufacturing techniques are required.

After a detailed analysis of the requirements, the development of the in flow direction orientated shaft probe for cascade measurements resulted in a two-parted probe concept consisting of a miniaturized probe head (grey part in Fig.1) and a connecting shaft manufactured conventionally with standard steel tubes and hypodermic pressure tubes. The outer geometry of the probe head was designed for two-dimensional transonic wake flow conditions. The pressure taps diameter was chosen to be 0.3mm from a trade-off between settling time and miniaturizing and the head thickness was forced to be less than 1.5mm. Two possible manufacturing methods – drilling Electrical Discharge Machining (EDM) and Additive Manufacturing (AM) – were considered and optimized internal duct designs were developed. Finally, the AM techniques was chosen because of its advantages concerning financial, time, and resource aspects as well as the higher degree of freedom in the internal duct design. With AM machines of different precision, two prototypes were produced. The finer and more expensive manufacturing process was finally chosen after a detailed analysis of the prototype. From the experiences of the design process different suggestions for the development of similar miniaturized probes are given.

The final Miniaturized Wedge Probe (MWP) was calibrated for Mach numbers between 0.5 and 1.6 and pitch angles of ±16° at the Wind Tunnel for Probe Calibration (SEG) from the Institute of Propulsion Technology at the German Aerospace Center (DLR) in Göttingen [1]. For the application of the probe at low ambient pressure in the High-Speed Cascade Wind Tunnel at the Bundeswehr University Muenchen the calibration was carried out at a constant ambient pressure of 12kPa resulting in a Reynolds number between $1.8 \cdot 10^3$ and $9.3 \cdot 10^3$ based on the probe head thickness of 1.3mm. The calibration characteristic shows, that the MWP featured almost no constraints close to Mach unity utilizing the base pressure taps for the calibration coefficient k_{Ma}. Furthermore, this reveals the improvement of the sensitivity determining the Mach number in the transonic flow regime compared to conventional multi-hole-probes.

This potential is to be proven in further investigation by transonic wake flow measurements with the MWP downstream of a transonic turbine cascade. Preliminary tests already revealed promising results.

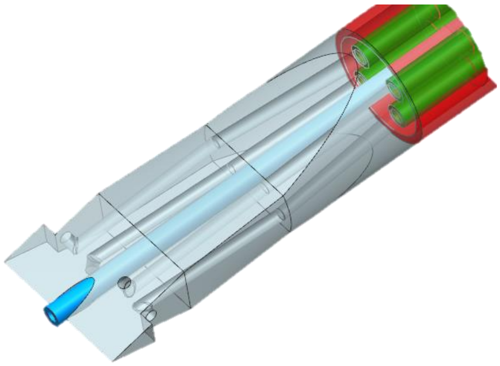

Figure 1. Additive manufactured Miniature Wedge Probe head design (0.3mm diameter pressure taps and 1.3mm wedge thickness)

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