Aerodynamic Design and Analysis of 45 Hole Flow Analyzer for Various Mach Number Range

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1. INTRODUCTION & OBJECTIVE

Fluid mechanics has many applications, and one of them is the measurement of fluid flow rate. Various instruments have been developed over time to do this. There are many different types of flow-measuring devices, each with a different level of sophistication, size, price, accuracy, versatility, capacity, pressure drop, and operating principle. It is essential to determine fluid behaviour to solve real-life problems in the field of aerodynamics. In aerodynamics, experimental studies are performed and executed in wind tunnels. Like every other instrument, the wind tunnel also needs to be calibrated before proceeding with experimentation and research activities. In most cases, a pitot tube or pitot static tube is being used if the wind tunnel is subsonic and pressure probes with multiple holes are being deployed in the case of a supersonic tunnel. The main objective of this work is to develop an instrument with forty-five pressure tapings that is suitable for wind tunnel calibration. The instrument is designed using CATIA V5 and the developed instrument is tested in varying flow regions. The instrument investigates the truth flow and flow angularities in the wind tunnel test facilities. Also, pressure charts at different locations of the wind tunnel can be plotted to provide an easy understanding of the truthiness of the wind tunnel test facility.

2. METHODS OF ANALYSIS

In supersonic flow regimes, conical probes are commonly employed to determine three-dimensional flow vectors, making them suitable for use in wind tunnels and turbomachinery analysis. The unique design of the probe head ensures that the calculation slots remain isolated from the supporting stem, preventing any flow interference that could affect measurement accuracy. While the standard stem diameter is typically 7 mm, other diameters can be adapted based on specific application needs. Conical-type probes are primarily utilized to measure Mach number, total pressure, and flow direction in high-speed flows. A critical design consideration for such probes is the selection of an appropriate probe angle to accommodate both subsonic and supersonic conditions effectively. To determine the optimal angle, the θ-β-M relationship is used, which correlates the shock wave angle (β), flow deflection angle (θ), and Mach number (M).[1-6]

3. RESULTS AND/OR HIGHLIGHTS OF IMPORTANT POINTS

Among the range of semi-cone angles from 5° to 30°, the 20° angle was found to be the most optimal, as it enables effective performance in both subsonic and supersonic flow regimes. Choosing larger angles increases the overall size of the instrument, potentially introducing complexities related to tunnel blockage factor.[7,8] At Mach 3.0, a 20° semi-cone angle generates a shock wave approximately 29.3°, which aligns closely with the outer edge of the probe, indicating the suitability of the selected configuration for operation up to Mach 3. To accomplish this, an axisymmetric computational analysis was carried out using a single conical probe under realistic environmental conditions, including constant ambient pressure and temperature, across a range of inlet velocities. The resulting outputs were analyzed and presented as CFD plots**.**The ANSYS FLUENT™ (v18.2) software suite was employed to manage all stages of the simulation process, including geometry creation, mesh generation, setup configuration, solver execution, and post-processing. FLUENT served as an integrated platform for managing the grid structures, case files, and simulation data. Numerical simulations were conducted using the ANSYS

Fluent **c**ommercial solver, incorporating air properties—density and dynamic viscosity—derived from the atmospheric pressure, temperature, and humidity conditions specific to the wind tunnel.

4. CONCLUSIONS

In summary, this study shows that the 45-hole pressure measurement instrument provides a reliable and accurate alternative to the pitot tube for air pressure measurement in low-speed wind tunnel experiments. Future work could investigate its applicability in broader contexts or focus on advancing more sophisticated pressure measurement systems built on the same principles.

5. REFERENCES

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