vectoflow measurements in fluids

Fast Response Measurement System

- Additive manufacturing allows almost any geometry
- Titanium, Inconel, stainless steel, plastics
- Robust design
- Adjustable reference surfaces, connection and software
- Measurement frequencies up to 25 kHz

Fast response multi-hole probe

Geometry	Straight, L-shaped, Cobra, Drilled elbow
Number of holes	Custom (5-Standard)
Max. length	Custom
Min. tip diameter	Standard 4-3 mm (down to 1 mm with micro-printing techniques)
Shaft diameter	15 mm (standard)
Tip geometry	Conical, spherical or custom
Material	Stainless steel, titanium, inconel, plastics
Fixture	Square, hexagonal, one-sided flattened cylinder or custom
Reference	Reference surface normal to Z axis
Pressure sensors	Custom (>1PSIG)
Acquisition Hardware	2x NI 9237 1x cDAQ 9181(Chassis) or custom
Acquisition & postprocessing software	Included (Labview based)
Temperature range	100°C (higher with water cooling)
Angle range	±60° (depending on number of holes)
Angle accuracy	< ±1°
Velocity range	3 m/s to Mach 1
Velocity accuracy	< ±1 m/s

The unsteady probes from Vectoflow make it possible to detect high-frequency flow phenomena in the kHz range and not just in terms of only one measured quantity, but related to all quantities, that are also available from a conventional multi-hole probe: velocities, flow angles, total and static pressure, Mach number and density. In order to achieve this high temporal resolution, the pressure sensors must be as close as possible to the probe head. This is to minimize the modulation of the pressure fluctuations in amplitude and phase. Furthermore, this modulation must be determined experimentally, which is being done at Vectoflow with a specially developed frequency calibration rig. Of course, all the advantages of the the Vectoflow steady probes are also available to the customers for the unsteady probes, due to the optimized additive manufacturing process, like the geometric flexibility and increased robustness of the probes.

Vectoflow offers the following solutions for the measurement of unsteady flow phenomena:

- probes with embedded pressure sensors (higher frequency response) or conventional probes with seperated pressure sensors
- frequency calibration of each pressure channel

System solutions

Vectoflow provides complete system solutions for velocity measurements for different flow conditions.

The Fast Response measuring system includes:

- FRAP probe
- cabling and connection
- cDAQ System
- acquisition and post-processing software

Frequency calibration

Calibration System	Acoustic calibration
Frequency range	<25kHz (depends on probe geometry)
Transfer function frequency step size	Custom

Sensors

Dependent on the required velocity range. Kulite & Endevco models.

Measurement error

The measurement error of a multi-hole probe depends on the pressure scanner used for the calibration and data acquisition.
We recommend the use of pressure sensors whose pressure range just covers the expected dynamic pressure, and which accuracy is 0.1 % full scale or better.
The lower the velocity, the higher becomes the impact of the pressure measurement error onto the determination of the flow velocity, as shown in figure 1 (for a scanner accuracy of ± 0.05 % FS).

Generally, an error of 1 m/s or 1% of the measured velocity —whichever is higher— is expected at higher speeds. For lower speeds, the error depends on the pressure scanner and increases the lower the speed.

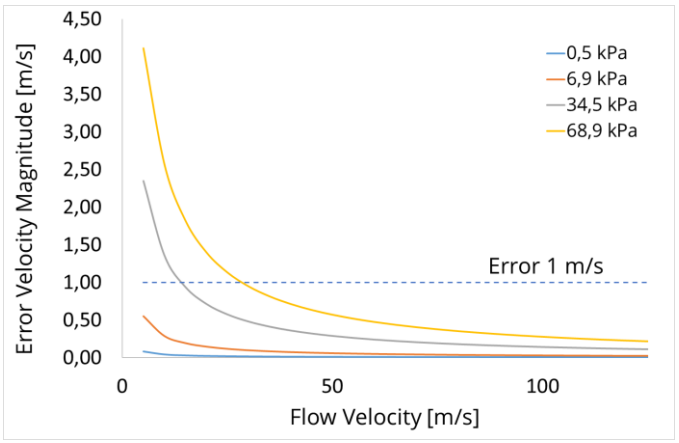


Figure 1: Dependence of velocity measurement error on pressure scanner range (0.05% FS accuracy)

Angle calibration process

The calibration of the process is always necessary for each manufactured multi-hole probe. Vectoflow has its own calibration wind tunnel, delivering flow speeds from 1 m/s up to Mach 1.4. Vectoflow has a very rigid quality assurance, which ultimately leads to the highest possible measurement accuracy of the flow probes.

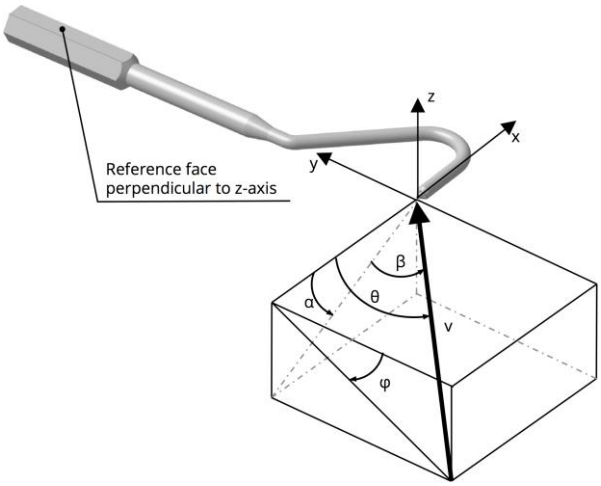
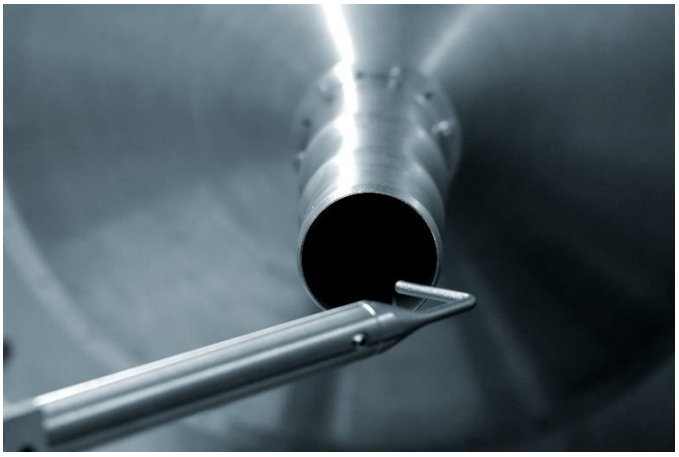


Figure 2: Flow angle definitions

During the calibration process, the probe is exposed to a steady flow with known conditions, while pitch and yaw angles change through thousands of positions. The definition of the flow angles is shown in figure 2.

The following table shows the main characteristics of the Vectoflow calibration wind tunnel:

Calibration wind tunnel	
Angular range	±165° (yaw axis), 180° (roll axis)
Max. Power	90 kW
Velocity range	From 1 m/s to Mach 1.4
Control parameters	Mach number, velocity (m/s)
Long-term velocity stability	±0.25 % (at M 0.1)



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