Additive manufacturing of flow measurement probes

Innovation **Engineering** **Business** **End-to-End Integration**

Vectoflow GmbH makes customized measurement solutions to determine the state of a flow. Additive manufacturing is applied to fabricate flow measurement probes in different sizes, shapes and materials for various applications.

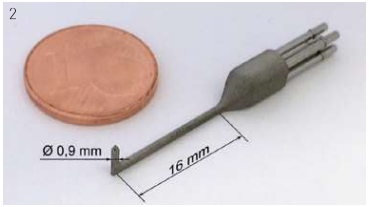
Customer **Various customers**
Manufacturer **Vectoflow GmbH**
Technology **Laser melting, laser sintering**
Material **Stainless steel, titanium, inconel, ceramics, plastics**
Machine **Machines from different suppliers**
Produced quantity **–**

Whether it's airplanes, drones, racing cars, gas turbines or submarines: in many areas it is essential and crucial to measure the characteristics of a fluid flow. So-called flow measurement probes are used to determine pressure, velocity and angle of an incoming flow. The example of an aircraft shows how important it is to measure the speed of the air stream correctly. If the aircraft speed is too low, the flow can stop abruptly, whereas too high a speed puts too much stress on the components.

Flow measurement probes have to meet a variety of requirements depending on the application and the flow field to be measured. For example, the size of a measuring probe must not be too large, as this would interfere with the flow field and distort the measurement results. With a reduced size, however, probes are particularly fragile and must nevertheless withstand forces during operation. Depending on the application, probes are also exposed to elevated temperatures. In case of damage, a quick replacement or repair is advantageous. Therefore, flow measurement probes have to be built robust and deliver exact results.

1

2



The company Vectoflow GmbH is active in the field of fluid dynamic measurement technology and develops custom-made flow measurement probes. To meet the aforementioned requirements, the company relies on the potential of additive manufacturing. Vectoflow GmbH offers a wide range of different probes in its product portfolio.

Depending on the field of application, probes can be adjusted regarding the type of probe, the shape of the probe and the probe head, the number of measuring holes, the selected material and the examined system.

For this specific application the use of additive manufacturing processes such as laser melting and laser sintering offers a variety of advantages. The design freedom can be employed to produce various configurations of flow probes. Flow probes are manufactured as stand-alone components or can be directly integrated into another part. Besides geometric freedom, additive manufacturing also offers a high degree of flexibility in the choice of materials. Depending on the field of application, a high-strength alloy such as Inconel is selected for a gas turbine or turbomachinery operating at elevated temperatures of up to 150 °C, or a material such as titanium is chosen for lightweight applications.

Additive manufacturing also has the advantage of building flow measurement probes in a very small size. One of the smallest flow measurement probes manufactured by Vectoflow GmbH has an outside diameter of 0.9 mm and integrates five channels with a diameter of about 0.1 mm. Powder removal is a challenge for such small dimensions, but can be accomplished. Decisive for the quality and correct functioning of the measurement probes is the orientation in the build space of the printer and the process parameters.

3

A post-processing of the additively manufactured probes depends on the selected process and application. For most probes, the tip of the probe is post-processed. No rework is usually carried out for the integrated channels. Since no fluid flows through the channels and only a pressure builds up, it is simply important that the channels are open and separate from each other. Depending on the shape of the probe and the application, the surface of the component can be optionally reworked using various post-processing techniques.

After the fabrication of a flow measurement probe, its calibration is carried out in a wind tunnel. The measuring technology and probe are aligned accordingly to the intended application. The first step is to define the flow conditions that occur during operation and then simulate them using the wind tunnel. In addition to the flow velocity, this

1 Kiel probes for measurement of total pressure and temperature

2 Small-sized flow measurement probe with five integrated channels

3 Measurement probes in different shapes

4

may also include the angle of attack of inflow. The probe is then exposed to the wind tunnel flow field. The probe takes measurements and assigns them according to the simulated flow conditions. In this way, the probe "learns" which signals occur in a given flow field. Later in operation, the probe uses this acquired knowledge to determine the flow characteristics. Depending on the intended application and the flow area to be monitored, a suitable and customized flow measurement probe can be manufactured. Pitot or Prandtl probes, for example, are available in any shape: e.g., straight, L-shaped, cobra-shaped, and drilled elbow-shaped or completely customized. So-called kiel pressure and kiel temperature probes have been specially developed for measuring

5

6

4 and 5 Rakes integrating multiple probes

6 Calibration of measurement probe in wind tunnel

the total pressure or total temperature of a flow at angles of incidence other than 0°, whereby the total pressure can be measured within an angular range of ±60°. Unsteady probes combine the robustness of a pressure probe (e.g., five-hole probe) with pressure sensors, which allow a high temporal resolution of the pressure signal. Depending on the probe geometry, frequencies of several kHz can be measured.

In order to carry out a measurement for a flow area directly at several points, e.g., during a complex test of a gas turbine in a wind tunnel, so-called rakes are frequently used. A rake combines several flow probes into one component and leads to a higher spatial resolution of the flow field. Again, additive manufacturing offers a high level of geometric freedom, allowing a rake to be adapted exactly to the application requirements and to be integrated into other components. The example of a rake also highlights how different configurations can be created with parametric CAD models. For instance, in addition to the number of probes, the type of each probe, the positioning of the probes relative to each other and other parameters, the geometry of the corresponding rake is automatically derived. For the individualization of measurement probes, the results of a flow simulation may also be used to define a suitable arrangement and selection of probes.

In summary, the application case of Vectoflow GmbH impressively shows how tailor-made flow measurement technology can be fabricated for many different areas. The advantages of additive manufacturing regarding design, size and material are leveraged in a targeted manner and combined with expertise in measurement technology. In this way, it is possible to offer customized flow measurement probes, which are robust, flexible, integral, and measure with high precision.