On the use of various oscillatory air flow fields for characterization of biomimetic hair flow sensors

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To determine the characteristics of flow sensors, a suitable source for flow generation is required. We discuss three different sources for oscillating air flow, by considering their acoustic impedance, frequency range, velocity and ability to distinguish between flow and pressure. We discuss the impact of these sources on characterization of our biomimetic hair flow sensors (Fig. 1), which operate at flow velocities from 1–100 mm/s within a frequency range from 10–1000 Hz [1, 2].

First, a loudspeaker was used as source. Its frequency range is in the order of 10–1000 Hz, capable of generating high flow velocities (up to 1 m/s) The distance of the loudspeaker to the sensor is of importance, since the typically small acoustic impedance (the ratio of flow to pressure) decreases with distance to the loudspeaker [3]. Using this well modeled and characterized source (Fig. 2), we determined the sensor's mechanical transfer (both magnitude and phase), all using laser doppler vibrometry (LDV). Also, a clear directivity profile was observed, indicating that the sensor is mainly responsive towards flow.

Another used source is a vibrating sphere, which behaves more like a monopole than a dipole source in the near field compared to a loudspeaker. The vibrating sphere is typically used for frequencies in the range of 10–100 Hz. A property of the sphere's near field is that for measuring right below it (Fig. 3) the acoustical impedance is theoretically zero, meaning no pressure fluctuations and thus only flow [4]. We used this source for realizing a nearly incompressible flow field for lateral line experiments. Measurements with a reference flow sensor and our flow sensors showed both a flow profile in close resemblance with the theoretical predictions for dipole source flows (Fig. 4).

The third type of source used is a standing wave tube (Fig. 5). Inside, well-defined patterns of standing waves occur at frequencies depending on the tube geometry [5]. Advantages are the range of frequencies (10–4000 Hz) together with high flow velocities (up to 1 m/s). An advantage is the ability to distinguish between pressure and particle velocity (i.e. flow), since for standing waves there is a 90 degrees phase difference between pressure and particle velocity. Exploiting this property, we learned that our flow sensor has finite pressure sensitivity. However, directivity measurements using a loudspeaker showed almost exclusively sensitivity to flow (Fig. 6). This is explained by the acoustic impedance at the sensor's position, which was much smaller in case of the loudspeaker. Therefore, the acoustic impedance matters for measurement quality on our flow sensors.

In conclusion, depending on the design and application of flow sensors, a suitable source is required to determine the sensor properties. For our sensors, the combination of three different flow sources gave good insights in the behavior of our flow sensory system.

Word count: 439

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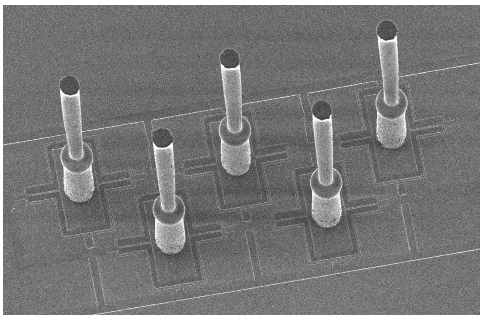

Fig. 1. MEMS hair flow sensors.

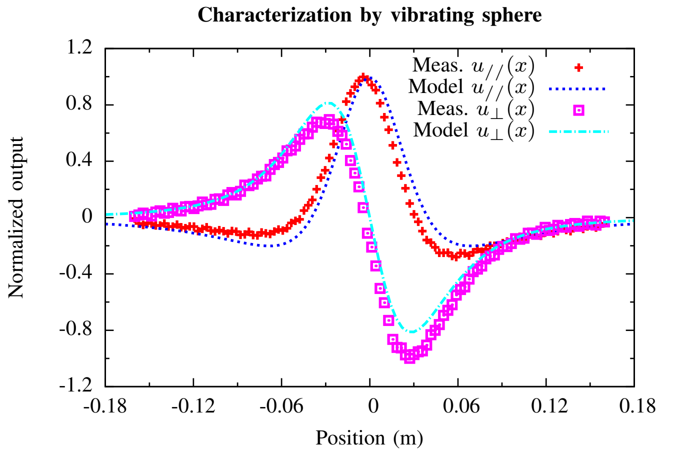

Fig. 4. Comparing model and measurements of the vibrating sphere.

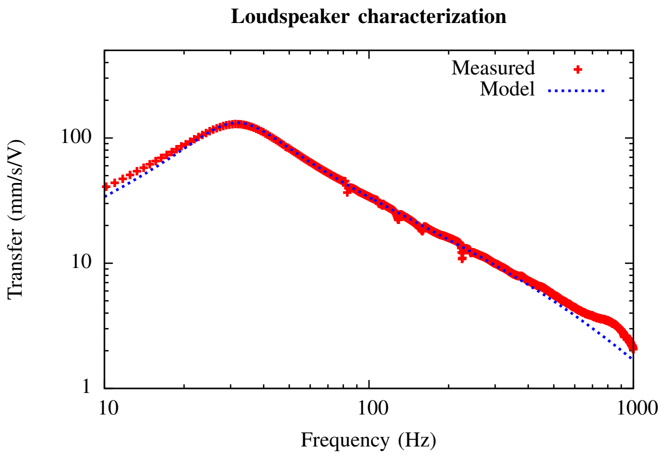

Fig. 2. Comparing model and LDV measurements of the loudspeaker.

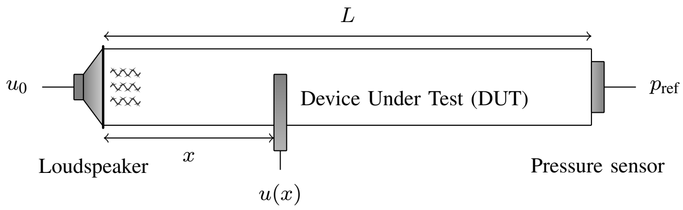

Fig. 5. Schematic of a standing wave tube.

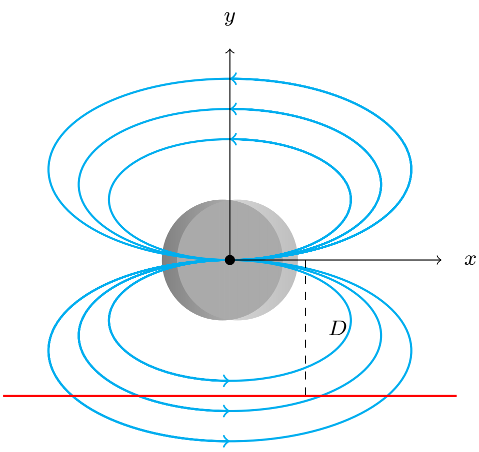

Fig. 3. Schematic of a vibrating sphere.

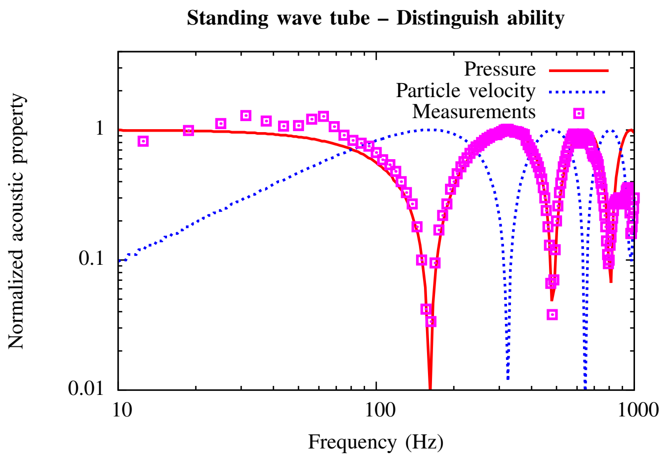

Fig. 6. Determining flow and pressure sensitivity using the standing wave tube.