SPATIAL AND TEMPORAL RESOLUTION OF A FAST-RESPONSE AERODYNAMIC PRESSURE PROBE IN GRID-GENERATED TURBULENCE

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ABSTRACT

The spatial and temporal resolution of a fast-response aerodynamic pressure probe is investigated in a benchmark flow of grid-generated turbulence. Besides statistical quantities, velocity spectra of measurements downstream of a grid are quantified. Results of a conventional fast-response probe with piezo-resistive differential pressure sensors are compared to single-wire hot-wire anemometry data. In addition, newly developed fiber-optic pressure sensors are applied in a pressure probe. Estimates of temporal and spatial turbulent scales show good agreement to data in the literature but are affected by filtering effects.

INTRODUCTION

In addition to the spatial calibration of a multi-hole pressure probe, in the temporal calibration of a fast-response aerodynamic pressure probe (FRAP) the acoustic behavior of the line-cavity system inside the probe is specified (Heckmeier et al. (2019)). Due to resonance and damping effects in the acoustic system and due to the outer dimensions of the probe, both, spatial and temporal, filtering effects of the velocity fluctuations are expected. The measurement of turbulent flows with turbulence length and time scales (e.g. Kolmogorov length scale η) smaller than the corresponding probe sensing length and bandwidth is challenging. Ashok et al. (2012) and Bailey et al. (2012) examined various hot-wire constant temperature anemometry (CTA) probes with different wire lengths in grid-generated turbulence. Hence, a similar wind-tunnel set-up can be used to characterize and validate the FRAP measurement behavior. Measurements with different probe types downstream of the grid are compared to results in the literature (Ashok et al. (2012) and Bailey et al. (2010)). Furthermore, different types of differential pressure sensors, including a newly developed fiber-optic sensor, are examined in different probe set-ups.

RESULTS AND DISCUSSION

The experiments on the grid-generated turbulence are conducted in the *Wind Tunnel B* of the Chair of Aerodynamics and Fluid Mechanics of the Technical University of Munich (TUM-AER). The wind tunnel, which is of Göttingen type (closed-loop), has a cross section of $h \cdot b = 1.20\,m \cdot 1.55\,m$. Turbulence intensity without the grid lies below 1%. At the nozzle section, a weaved grid with a mesh size $M = 6.4\,mm$ is installed (see Fig. 1), which is similar to grids in the literature (see Ashok et al. (2012)). Various points in streamwise direction are measured downstream of the grid $x/M = 20 \dots 100$. The free-stream velocities are set to match the Reynolds numbers $Re_M = \{4300, 12800\}$.

Figure 1. Wind tunnel set-up with the FRAP being installed downstream of the grid in the nozzle section.

In Fig. 2 (a), it can be seen that the turbulent kinetic energy and, hence, the variance of the streamwise velocity fluctuations $\overline{u'^2}$ decay with an increasing distance from the grid, and can be estimated by

$$\frac{\frac{3}{2}\overline{u'^2}}{\overline{U}^2} = C_1\left(\frac{x - x_0}{M}\right)^{-C_2} \quad (1)$$

where C_1 and C_2 are constants to be determined.

By calculating the turbulent dissipation rate ε as the gradient of the variance in Fig. 2 (b)

$$\varepsilon = -\overline{U}\frac{d}{dx}\left(\frac{3}{2}\overline{u'^2}\right) \quad (2)$$

the Kolmogorov scale $\eta = (\nu^3/\varepsilon)^{1/4}$ can be calculated.

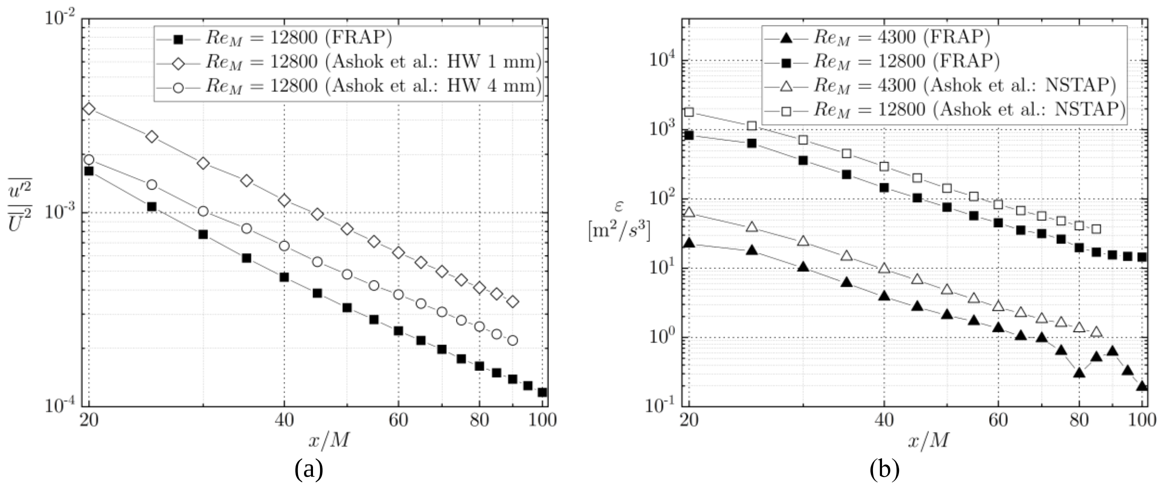

Figure 2. (a) The normalized variance of the velocity fluctuations in streamwise direction $\overline{u'^2}/\overline{U}^2$ and (b) the dissipation rate ε, as functions of the distance x/M from the grid; FRAP: fast-response aerodynamic probe, HW: hot-wire probe, NSTAP: nanoscale thermal anemometry probe (Ashok et al. (2012))

In the preliminary results, a spatial filtering effect in the pressure probe measurements can be observed, leading to a constant offset in both figures.
It can be concluded, that the FRAP shows similar filtering behavior as the hot-wire probes with same outer dimensions. Therefore, the majority of the temporal and spatial content of the turbulent flow can be detected by both measurement techniques. Improvements can be achieved by optimizing the bandwidth of the sensors and by a miniaturization of the pressure probe outer dimensions.

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