Characterization of engine inlet flows by optical measurements of velocity profiles with high measurement rate

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1. Motivation

For characterizing inlets for aircraft engines, the inlet flow has to be measured at the aerodynamic interface plane (AIP), which is the interface plane between inlet and engine. Currently, grids of 40 pressure probes are applied [1], which have several limitations: intrusiveness of the probes, low number of measurement points, time-consuming (regarding the usage of the five-hole-probes), low flexibility and, thus, high costs, because one probe mesh cannot be used for different inlet models with different diameters. Hence, an optical technique is required overcoming these limitations. The key challenges are to measure in the inlet and to achieve high measurement rates ≥ 4 kHz for unsteady flow analysis.

2. Approach

The novel approach is to apply Doppler global velocimetry (DGV) measuring the flow velocity field, because DGV allows easy imaging through fiber bundles [2]. Using a fiber bundle is a flexible and simple solution for light detection from inside the inlet. However, conventional DGV systems have typical measurement rates of a few Hertz maximum, which is not sufficient. For this reason, the recently developed frequency modulated DGV (FM-DGV) system [3] was applied for the first time in combination with an imaging fiber bundle. The FM-DGV system is capable in principle of 100 kHz measurement rate, which is practically limited by the achievable signal to noise ratio. Hence, the FM-DGV measurement capability for inlet flow characterization was tested by an experiment at the test rig depicted in Fig. 1a.

3. Measurement results

In the experiment, sufficient measurement rates up to 8 kHz were achieved. This proves the principle applicability of FM-DGV for inlet flow characterization. The single component setup consisted of 16 measurement points linearly aligned at a radial line (compared to 10 points state-of-the-art). The measured mean velocity profiles were validated by checking the air mass rate. Measurements at 0.5 kg/s and 1 kg/s were performed. The resolved velocity spectra indicate significant flow oscillations up to about 1 kHz. As expected, the resolved velocity spectra show stronger oscillations when inserting a distortion plate, which is presented in Fig. 1b.

4. Conclusion

FM-DGV was proven to be a promising measurement technique for the non-intrusive characterization of inlet flows, which provides unsteady flow information due to high achievable measurement rates beyond 4 kHz.


Fig. 1 a) Experimental setup at the inlet test rig (inlet diameter 107.4 mm) and b) measurement results showing the power spectral density of the velocity of one channel of the linear array as an example in case of an unobstructed inlet and with a mounted distortion plate.