Paper 4.2

Range and accuracy of a Laser-Doppler Anemometer for in-flight measurements

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ABSTRACT

We have extended the range of in-flight LDA instrumentation, realizing working distances of up to 1 m with a compact 1-Watt semiconductor LDA operating in backscattering mode. The instrument design was based on a model describing the achievable data rate as a function of particle size distribution and system parameters.

The main difficulty of in-flight LDA measurements in backscattering mode is the sparse natural "seeding": natural aerosols typically follow a Junge distribution with the concentration $n(r)$ falling off with the radius r as $n(r) \sim r^{-3}$. One may deduce that to achieve sufficient data rates, small particles should be detected. In contrast to this, our recent work indicates that best results are obtained when particles comparable in size to the wavelength used are *just* detected. For the in-flight LDA, this was achieved by choosing a suitable beam expansion to tailor measuring volume size and power density. As the scattered power is inversely proportional to the fourth power of the wavelength for very small particles, better results have been predicted using lasers emitting at shorter wavelengths. However, our Mie-scattering calculations suggest that particles in the 1µm size range scatter near-infrared light as well as green light. Thus our LDA uses a powerful semiconductor laser emitting at 980 nm.

Single particle detection mainly depends on the power density in the measuring volume and on the angular aperture of the receiving lens. The *SNR* therefore decreases rapidly with working distance d, $SNR \sim d^{-4}$. This may lead to the expectation that only short working distances are feasible. However, we need to consider not just the *SNR*, but the *signal rate* G of signals exceeding a given *SNR*. This will depend not only on the concentration of detectable particles but also on the rate at which particles enter the measuring volume, i.e. on the size of the measuring volume. Our approximate model shows that for optimal optical lay-out the *signal rate* G is just inversely proportional to the working distance d, $G \sim 1/d$. Hence larger working distances become feasible for in-flight experiments. We have adapted our in-flight LDA accordingly and during several test flights under visual flight rules on-line measurements of the air speed were obtained below the fuselage of a small research aircraft, with working distances up to 1.0 m. The LDA was calibrated to be accurate within 0.5%. Excellent agreement of the LDA in-flight data with corresponding Pitot probe measurements was obtained.

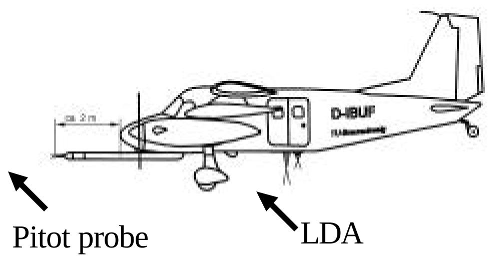

Fig. A: Side view of DO-128 research aircraft, indicating measuring locations.

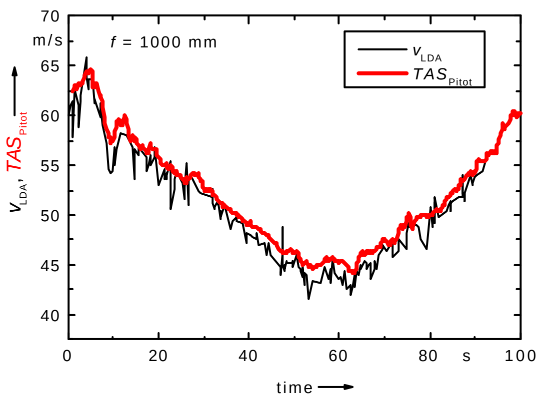

Fig. B: LDA measurements, measuring distance 1.0 m, and comparison with TAS_{Pitot}.

Our model is also applicable for monodisperse particle distributions often found in the laboratory. Again, the signal rate is inversely proportional to the working distance if suitable optical parameters are chosen.