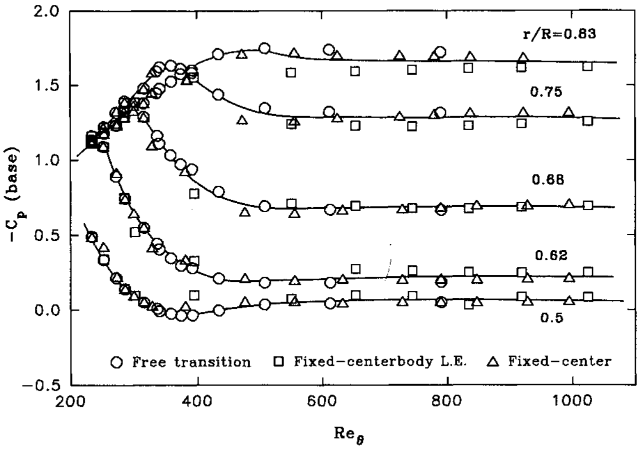

Fig. 3 Base pressure coefficients, 50-deg base.

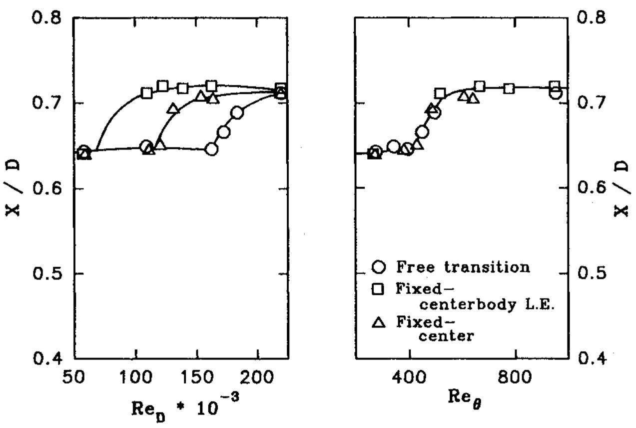

Fig. 4 Wake stagnation point locations, 40-deg base.

for low slant angles were found to vary slightly with Reynolds number, although pressure distributions remained reasonably consistent. Variations in base pressure coefficient for the 50-deg base (vortical wake) at two locations on the upstream side of the model centerline and along the symmetry plane are shown in Fig. 2. The strong variations are caused by changes in the location and strength of the longitudinal vortices. The results from Fig. 2, together with others from different stations, are shown in Fig. 3 using an appropriate nondimensional independent variable, that is the Reynolds number based on the incoming boundary-layer momentum thickness Re_θ. It is seen that free- and fixed-transition results now collapse onto single curves.

Wake Stagnation Point

The location of the wake stagnation point (the point of zero mean velocity) for low slant-angle bases (closed wake) was found to move closer to the base surface as the slant angle is increased, but away from the base at the onset of transition. Results again fall onto single curves when plotted against Re_θ, as shown in Fig. 4.

Conclusions

The wake of a family of slanted-base bluff bodies has been studied. Base pressure and wake stagnation point locations are influenced by the incoming boundary-layer momentum thickness. Similarity exists if the Reynolds number based on the Re_θ is chosen as the independent variable.

Acknowledgments

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In-Flight Velocity Measurements Using Laser Doppler Anemometry

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Introduction

LASER Doppler anemometry is a well established technique for nonintrusive measurement of flow velocities, and offers both high spatial resolution and high accuracy.[1] Although these advantages are very attractive for a wide range of aerodynamic investigations, the use of the laser Doppler anemometer (LDA) outside the controlled conditions of the laboratory has been inhibited by the size of the equipment, its power requirements, and the need to have small particles in the flow which act as scattering centers for the laser light. This is especially true for mobile applications such as in-flight or on-road velocity measurements. The recent availability of high-powered laser diodes has, however, led to newly designed LDA optical systems which are much smaller and require much less power while still offering good detection characteristics of small particles. In this study such a measurement system has been used to measure boundary-layer profiles on a twin engine Fairchild Swearingen Metro II aircraft in flight. Potentials of the technique for in-flight applications are demonstrated in this Note, and operational aspects of the present equipment are described.

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Description of the Measurement Equipment

The optical system used for these measurements has been developed jointly by the Lehrstuhl für Strömungsmechanik (LSTM) at the University of Erlangen-Nürnberg and INVENT GmbH. It is known as a laser diode fiber optic LDA (DFLDA) and is shown schematically in Fig. 1. A 100-mW single-stripe, index-guided laser diode acts as a light source and is operated with temperature regulation. The wavelength of emitted light is 830 nm. After collimation, the laser beam is split equally, and one of the outgoing beams is frequency shifted by 65 MHz using an acousto-optic modulator (AOM). The frequency shifting is used to provide directional sensitivity to the velocity measurement.[1] The 65-MHz frequency is chosen to match the expected high flow velocities and small particle residence times in the measurement control volume (mcv). The laser light is then coupled into two single-mode, polarization preserving fibers which lead to a backscatter probe.

Fiber optic probes have been used for some time in laser anemometry, offering flexibility and compactness. In the present case a very specific design compared with conventional probes has been chosen. In particular, a high beam expansion has been used after outcoupling. This leads to much smaller focused control volumes, and therefore, higher light intensities. This is one method of increasing the detection sensitivity of the system to small particles. As in conventional probes, the light scattered from the particles is collected onto a graded-index fiber leading to a photodetector. Here, an avalanche photodiode (APD) is used, since its quantum efficiency at infrared wavelengths reaches 85%. This high detection efficiency also leads to a high signal-to-noise ratio of the received signal. Several probe sizes and working distances are available. For the present measurement, a probe 30 mm in diameter and with a focal length of 120 mm was chosen. The mcv was 46 μm in diameter and 700 μm long. Thirty mW of light power was available in the mcv. Further details of the optical system can be found in Ref. 2.

The aircraft used for this study is a test aircraft of the National Aerospace Laboratory (NLR). The measurement point chosen was 3.6 m from the nose on the underside of the fuselage, just downstream and offset from the pitot tube. The fiber optic probe was mounted in an inner cylinder which could be traversed inside of an outer cylinder in steps of 3 mm. The outer cylinder was fixed in the floor of the aircraft. The endwall of the outer cylinder was positioned flush with the aircraft's skin and has a glass insert. The outer surface of the insert was recessed 4 mm from the aircraft's skin. A scan of the measuring volume between 0–94 mm from the glass surface was possible. The scan direction was 29 deg from the normal of the aircraft's skin. The position coordinate used below refers to the position of the mcv along the traversing axis relative to the outer surface of the glass insert.

In laser anemometry a signal processor is required to determine the signal frequency for each detected particle. This frequency is passed to a computer, where flow statistics can be performed. A frequency counter from TSI Inc. (model 1990C) was installed to determine the expected high frequencies (75–100 MHz). Data was transferred to and processed on a laptop computer (Toshiba T 5200), using the LDA acquisition interface and software from Dostek (model 1400A). Both on-line processing for data validation and data recording to disc were used in flight.

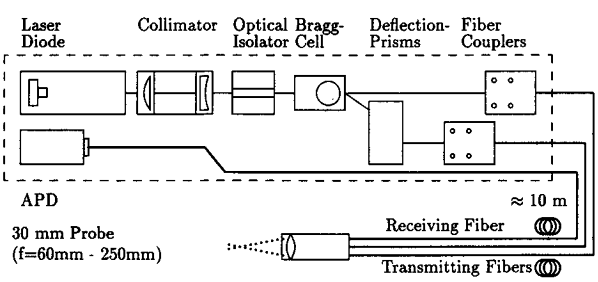

Fig. 1 Schematic representation of the DFLDA optical system.

Measurement Results in Clouds

During the measurement flight, which was performed over the North Sea, clouds were encountered at low altitude above the sea. Several runs were made to measure at different speeds and with different positions of the mcv in the boundary layer. It was not possible to change the position of the mcv during stable flight in clouds because of the limited extent of the clouds that day. The true airspeed (TAS) fluctuated slightly in between and during runs (typically 1 m/s). True airspeed was measured with the air-data-computer (ADC) on board the aircraft.

Velocity data obtained in the boundary-layer measurements are shown in Fig. 2 at two different airspeeds, 127 ± 2 kt (≈65 m/s) and 175 ± 5 kt (≈90 m/s). The distribution of mean velocities in the boundary layer is the distribution of velocities in a turbulent layer. It is peculiar that the boundary layer at 175 kt TAS is thicker than the layer at 127 kt. This may be caused by the flow changes due to a smaller angle of attack of the aircraft, or by influences of disturbing objects upstream (e.g., the pitot probe).

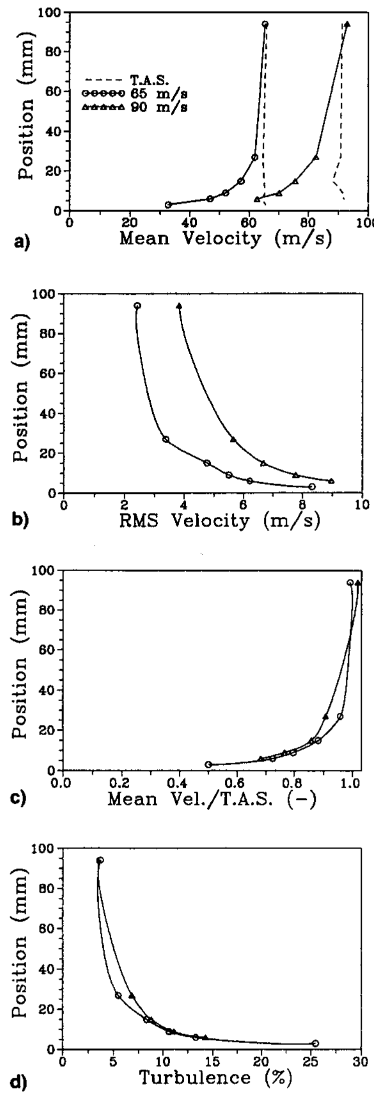

Fig. 2 Two different aircraft speeds are shown: a) mean DFLDA velocity and b) rms velocity profiles; also c) velocity data normalized on the TAS measured with the ADC; and d) rms velocity data normalized on the measured DFLDA velocity are shown.

Turbulence intensity levels were calculated by dividing the root-mean-square (rms) of the velocities measured with DFLDA by the mean DFLDA-velocity at each run. These values are biased by the fluctuations of the true airspeed during a run. TAS fluctuation levels did not differ significantly during the measurements as was checked with the ADC. Taking account of the bias due to fluctuations of TAS of the aircraft, the turbulence levels measured in the boundary layer seem reasonable.

The difference between the TAS measured with the ADC of the aircraft and the velocities determined with DFLDA at the maximum distance from the glass plate (position = 94 mm) was calculated at 128, 177, and 240 kt true airspeed. The maximum deviation was 2.6% at 240 kt. Such small differences may be expected, because the flow in the mcv is influenced by the presence of the aircraft.

Data rates were typically 20–250 Hz, and the data points shown in Fig. 2 were typically averaged over 2000–8000 individual velocity measurements.

Measurements Outside of Clouds

In general, it is considered preferable to measure outside of clouds for two reasons. First, clouds are not always available. Second, the scattering centers are water droplets which have a wide size distribution, much of which lies above the 0.5–1 μm limit, under which the particles truly follow the flow around the aircraft at cruising speeds.

Outside of clouds the data rate decreased considerably, typically less than 1 Hz. However, observation of the signals from the detector on an on-board oscilloscope indicated that a significantly higher number of particles was present, but signals were apparently not of sufficient quality to be validated by the counter processor. Future measurements should therefore employ frequency domain processors, which offer better detection schemes no longer based on amplitude discrimination, as well as more robust frequency estimators less sensitive to signal noise. A shorter focal length, e.g., 60 mm instead of 120 mm, can also be used to increase the particle detection probability. The traversing range is more limited with the shorter focal length lens.

Conclusions

The results of this study indicate that in-flight LDA measurements are now feasible. Velocity measurements in the boundary layer were obtained. The results indicate the boundary-layer thickness and would certainly also indicate separation and/or recirculating flow features if present. Therefore, the LDA technique may find increasing application for inflight aerodynamic studies.

Flexibility in operation, robustness of laser and probe, and especially the low power consumption, make the DFLDA attractive for in-flight applications compared with other laser Doppler anemometers. Further improvements of both the optical system and the signal processing system can be expected. For instance, Nd:Yag lasers, which will be available in the near future with output powers of up to 1 W are an attractive alternative to the laser diodes. The size of these lasers does not exceed the size of the diode laser used in the present study. Also, with some frequency mixing, it may be possible to employ more efficient signal processors to improve the signal validation rate.

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Aircraft Landing Gear Positioning Concerning Abnormal Landing Cases

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Introduction

AIRCRAFT landing gear mechanisms serve several design purposes such as supporting the weight of aircraft, providing rolling chassis/taxiing, and shock absorption function, especially during takeoff and landing.[1,2] Out of many thousands of landings during the lifecyle of a typical aircraft, there might be some abnormal landings due to various causes such as adverse weather. For a typical normal landing of an airplane, once the main landing gears (MLG) touch down first, the pilot will operate the pitch controls to provide proper aerodynamic righting moment in order to avoid heavy nose landing gear (NLG) impact on the runway which may cause probable damage or serious accidents. However, this kind of aerodynamic righting moment may not work in time, especially under adverse weather conditions such as wind shear, therefore, it cannot be counted on in many cases of abnormal landings.

The NLG and MLG together share the ground sinking impact energy for an airplane at landing. The landing approach is subject to pilot skill, airplane damage conditions (after combat), runway situations, and weather conditions. Sometimes the NLG may touch down first abnormally, or free-fall to the ground without correct pitch control for tail down landing. In these cases, the NLG will absorb more sinking energy than the usual amount. For normal landing, the sinking speed generally falls in the category of 0.3 m/s ($\approx$1 fps) to 0.915 m/s ($\approx$3 fps). Any landings with sinking speed above 2.44 m/s ($\approx$8 fps) are commonly considered a very hard landing,[3] a landing that hard might occur only once in 300 landings for military service. Due to probable various abnormal landing conditions, the landing gear design is required to allow for a wide range of sinking speed. Hence, as stated in military specification MIL-A-8862A,[4] usually landing gear structural requirements for limit load are 3.048 m/s (10 fps) for land-based fighter airplane and 3.96 m/s ($\approx$13 fps) for trainer or other special types such as carrier-based naval fighter airplanes.

The layout and design of aircraft landing gears is a rather complicated iterative process for engineering judgements and compromises.[5] The proper positioning of aircraft landing gears is particularly important to pursue an optimal c.g. location and weight distribution between NLG and MLG, statically speaking. Usually, the NLG is designed to carry 6–20% of the total weight of an aircraft. Despite all the traditional prudent design consideration for aircraft landing gears, the search for dynamically superior positioning of aircraft landing gears has not been well addressed in terms of percussion theory as reflected by current literature.[1,6–8] In this study, the concept of center of percussion (Cp), center of oscillation (Co), and

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