FLOW VISUALIZATION EFFORTS AND PILOT MEASUREMENTS WITH A LASER-DOPPLER ANEMOMETER IN BACKSCATTER MODE

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1. Introduction

At DFVLR flow visualization in wind tunnels has been a field of interest for many years and different techniques have been developed to high standards.

Currently DFVLR has the following techniques in routine use:

1. Schlieren and shadowgraph [1]
2. Smoke flow visualization at low and high speeds [2]
3. Surface flow visualization as oil flow, oil spots, and liquid crystals [3], [4]
4. Hydrogen bubble method [5]
5. Electron-beam-induced afterglow in rarefied gas flow [6]

Digital image processing techniques have been applied to colour-schlieren as well as to liquid-crystal pictures. Density and temperature profiles are the possible objectives. Further, an ultrasonic vortex detection method is presently being developed for low-speed application [7].

Regarding laser techniques, DFVLR started its work in the early 70's. A 1-component laser has been built by Petersen and Maurer [8]. A group in DFVLR-Berlin [9] has successfully used a very simple system for jet and turbulence investigations, and Schodl [10] has developed his dual-focus system for measurements in turbomachinery. The new efforts in Göttingen are concentrated on the installation of an LDA system operated in the backscatter mode in the 3 × 3 m^2 Low Speed and the 1 × 1 m^2 Transonic Wind Tunnels. Up to now the optical system allowed 2-D measurements with focal lengths of 250, 750, and 2200 mm, but to become familiar with measurements at large distances, mostly 1-component measurements have been performed. In a final stage, 3-D nonstationary-flow-field measurements in the backscatter mode will be achieved. The arrangement for this 3-D LDA will possibly be the same as that used in the Naval Surface Weapons Center (Yanta and Ausherman) [11].

2. Calibration measurements on a rotating disc

To avoid any difficulties with beam angles and their changes when going through curved windows, the well-known velocity of a rotating disc was used for the calibration of the system. Thereby it was found that it was very important to get a real parallel fringe system. In figure 1 the measured relative-velocity change as a function of the position of the disc surface within the measuring volume is shown. Curve A represents the result when the fringes are not parallel. The measured velocity changes more than ±10%, whereby the statistical weight varies about 3 orders of magnitude. Curve B has been achieved when the adjustment has been done very carefully.

3. Turbulent pipe flow measurements

Figure 2 shows the arrangement for measurements in a fully developed turbulent pipe flow at the exit of a pipe with a length of more than 60 diameters. To avoid the influence of curved windows the measurements have been undertaken at the exit of the pipe. The focal length was 750 mm at a total laser power of about 2 watts. The measurements were made along a horizontal pipe diameter under an angle of about 42° to make possible also measurements in the inner part of the pipe. This seemed to be very important in order to achieve some information about a possible velocity change in the axial direction. Figure 3 shows a measured profile in comparison with an experimental result of Musker et al. [12]. The agreement at this Reynolds number of 3.5×10^5 is rather good. Some values near the axis deviate due to a change in the operating conditions of the pipe facility.

Near the wall the measuring volume was too large so that the local resolution is rather poor. On the other hand the measured values near the axis could be reproduced with a high accuracy. As a consequence we could find a small asymmetry (fig. 4) within the velocity profile, although the pipe had a smoothed length of 60 diameters and a total length of 100 diameters. This asymmetry was confirmed by pitot-probe measurements, as the operation of the pipe facility was controlled very carefully.

4. Local velocity determination in the 3 × 3 m^2 wind tunnel

As a first step in measuring at low speeds but large distances local velocity measurements in the 3 × 3 m^2 wind tunnel NWG have been performed. The focal length was 2200 mm. Small olive oil particles produced by a LASKIN nozzle have been introduced alternatively into the settling chamber, the test section, and the diffuser inlet to study different possibilities for later applications.

In the undisturbed flow the agreement of the measured values with the predicted is within an accuracy of ±0.5% (fig. 5). The next step was to measure two components within the flow field of a 6:1 prolate spheroid with a length of 2400 mm at different velocities and angles of incidence. Figure 6 shows a preliminary result of these velocity measurements within the boundary layer of the model. Although the focal length was again 2200 mm the local resolution in the z-direction was quite good.

5. References

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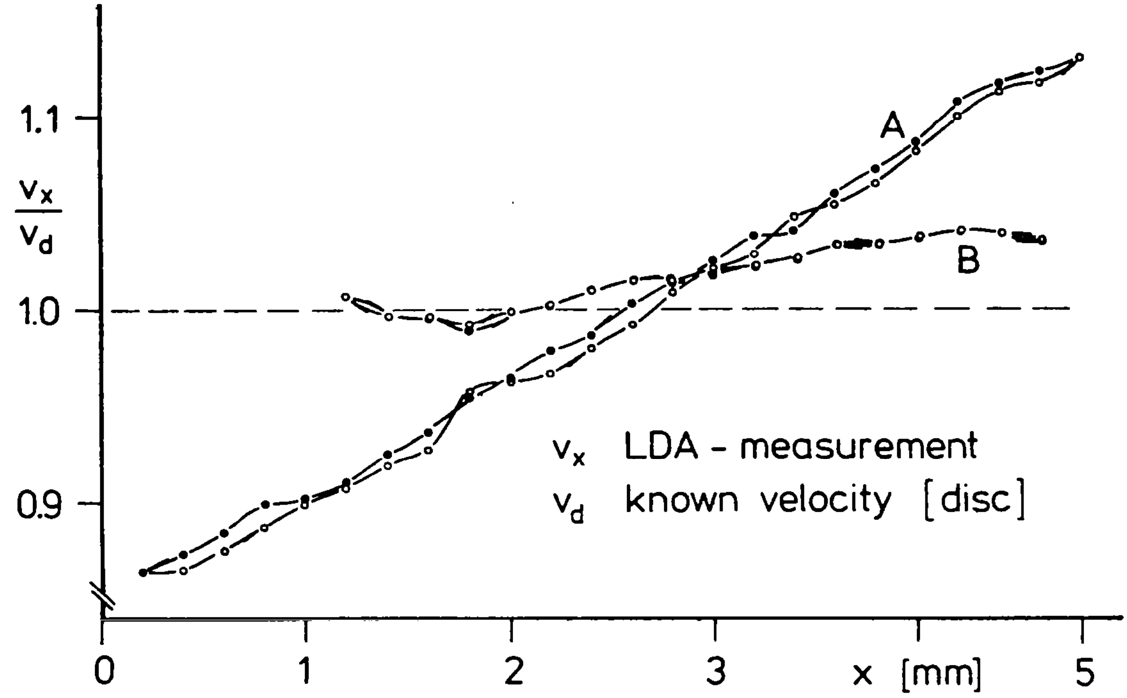

Figure 1.- Relative measured velocities on a rotating disc.
A - Fringe system nonparallel; B - fringe system well adjusted.

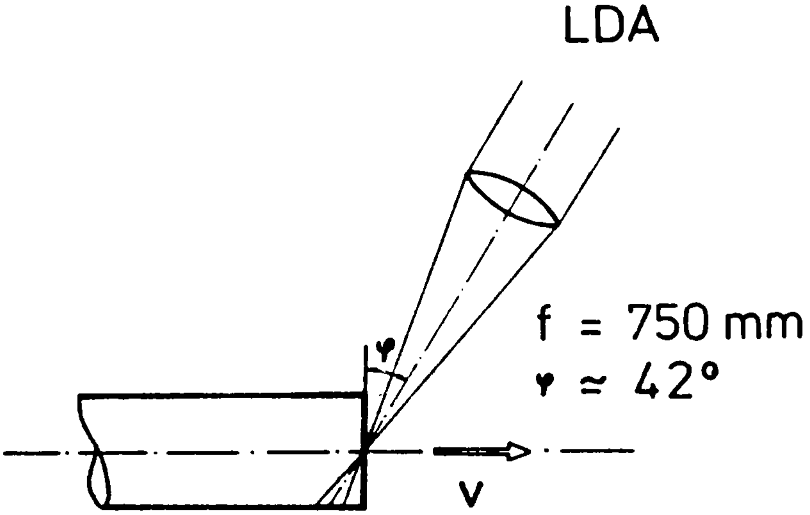

Figure 2.- Arrangement for pipe flow measurements.

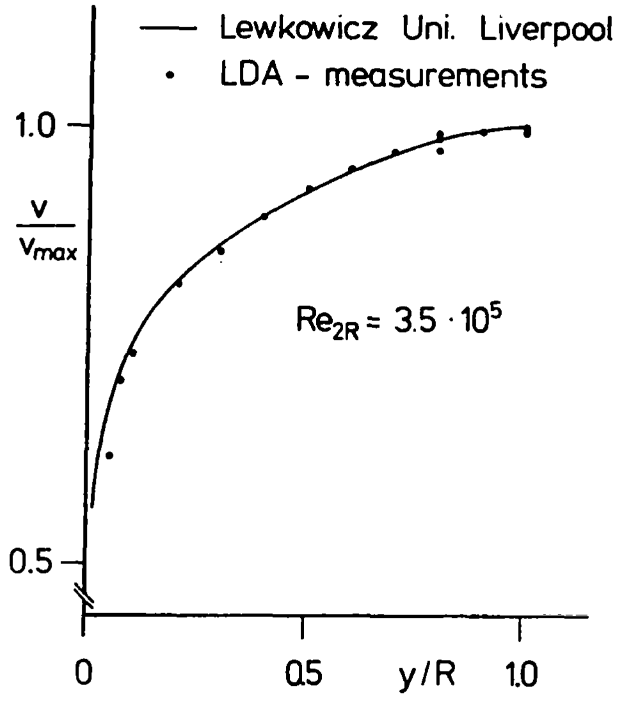

Figure 3.- Velocity profile in turbulent pipe flow.

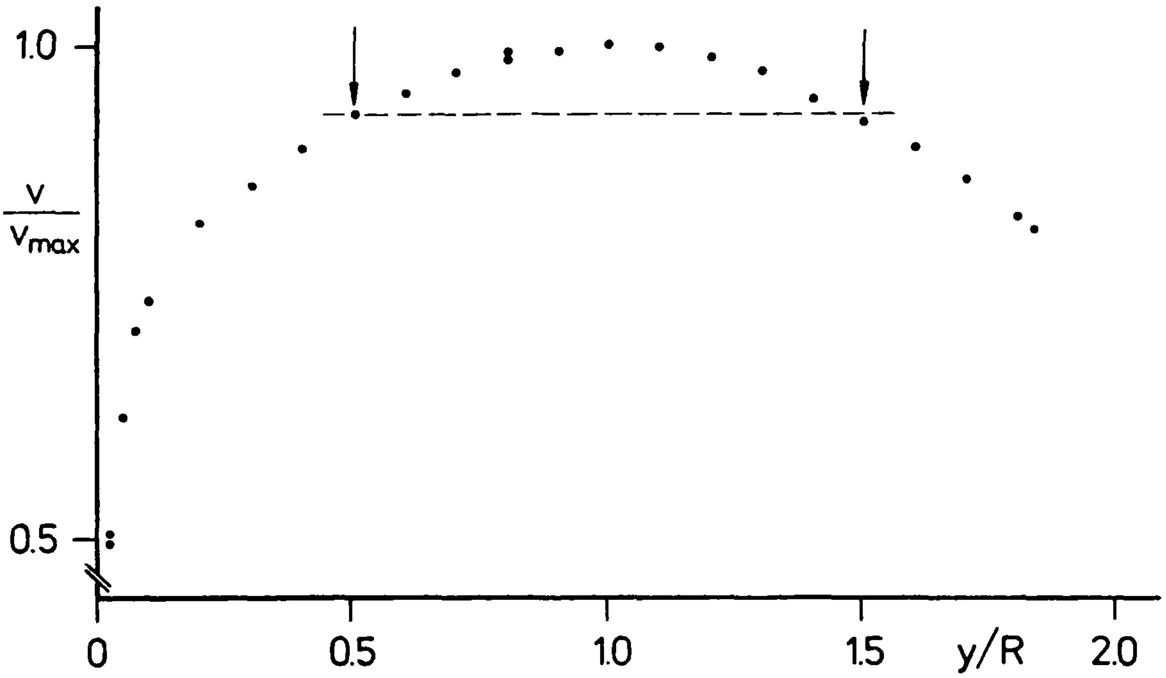

Figure 4.- Asymmetry in turbulent pipe flow.

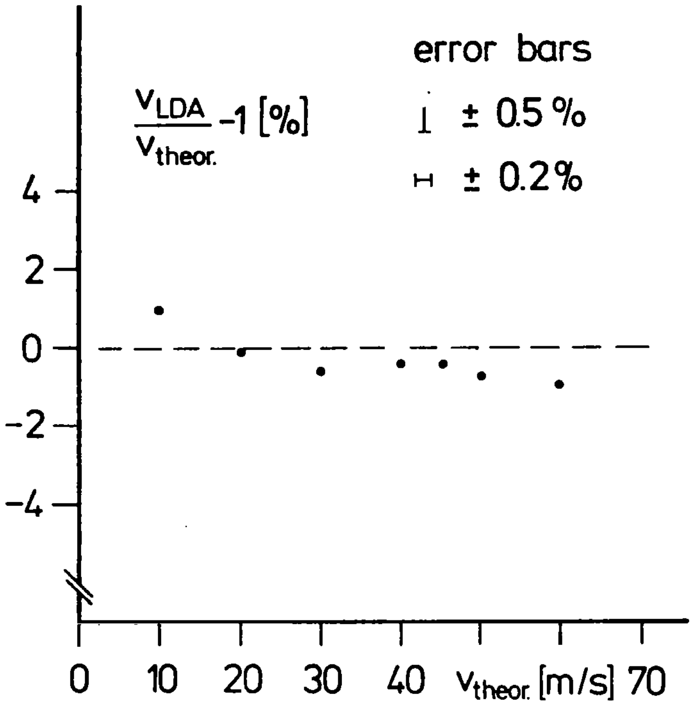

Figure 5.- Local velocity measurements in the 3 × 3 m^2 Low-Speed Wind Tunnel.

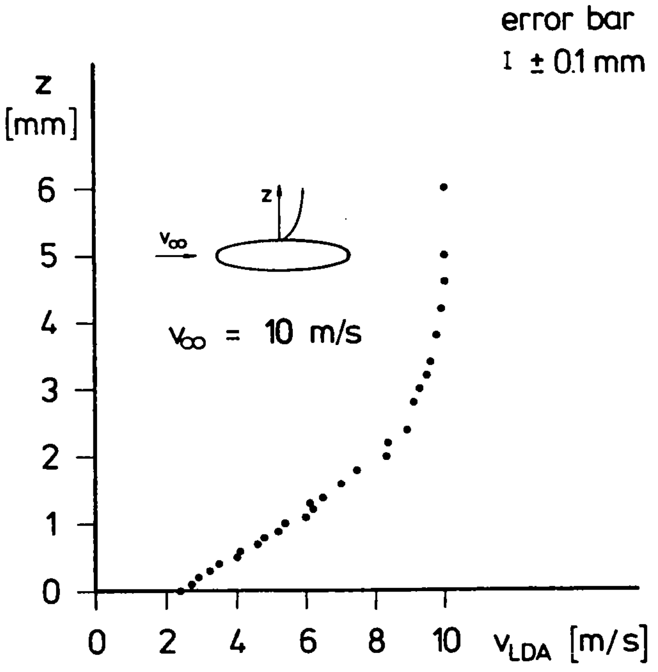

Figure 6.- Profile of the horizontal velocity component in the plane of symmetry for an angle of incidence $\alpha = 0$ within the flow field of a prolate spheroid.