Limitations of Gaussian Beam Property Based LDA-Velocity Profile Measurement

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For reliable turbulence property investigations in high Reynolds number turbulent flows, LDA-systems are required to possess a higher spatial resolution than that achievable with conventional LDA-optical systems. For this reason, the research and development work of the authors described in this paper was carried out. In order to test the applicability of such systems in turbulent wall bounded flows, the authors performed their own developments to finally carry out turbulent velocity measurements. The outcome of the development work and the velocity measurements is described in this paper.

The first part of the paper summarizes the work that needed to be done to select lasers with good Gaussian beam properties. An Argon-Ion laser and a Nd:YAG-laser were finally chosen and combinedly employed in a LDA-optics yielding two fringe systems of different wave lengths in the measuring volume. The fringe spacings were measured to prove relationships deduced from the theory for Gaussian beam properties. Gaussian laser beam theory was then supposed to yield one fringe pattern with linear by varying fringe spacing. Again verification experiments were performed to prove the measured fringe variations agree with the corresponding theoretically described relationships. The proven theory provided afterwards the basis for the final design of the optical system employed to carry out velocity profile measurements in laminar boundary layer flows. The schematic diagram of authors' proposed system is described in Fig. 1. The first fringe system was employed for conventional LDA-measurements and the second was used to deduce the position of the scattering particles passing the measuring control volume. Velocity measurements with high spatial resolution were supposed to become possible in this way. This is demonstrated for laminar boundary layer velocity profiles and its results are shown in Fig. 2. The resultant LDA signals were processed to yield velocity profile measurements without traversing the measuring LDA-probe volume. The final measurements provided good information for the mean velocity profile and through it for the local wall shear stress by deducing the slope of the velocity profile.

The last part of the paper analysis the measurement properties of the LDA-system with respect to turbulent measurements. The sensitivity of the system with respect to its possible spatial resolution is considered. Furthermore, spurious measuring data are analysed due to the simultaneous presence of two particles in the measuring volume and it is shown that additional signal processing is needed to eliminate signals of this kind. The application of a third photomultiplier is suggested for this purpose and its function is described. Furthermore, position errors due to particle motions parallel to the fringe systems are considered an unavoidable scatter of the data are reported due to the small sensitivity of LDA-optical systems of this kind to measure the fringe spacing to deduce from the particle location in the measuring volume. From author's own investigations, the author's conclusion is that the proposed LDA-system, which makes the velocity profile measurement possible, is not suitable to study turbulent flows with a high temporal resolution.

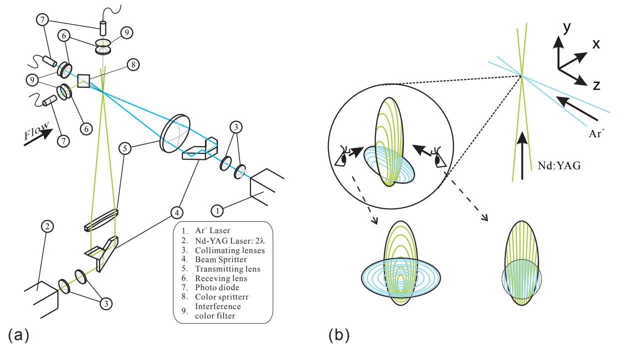

Figure 1: Schimatic diagram of extended LDA-system

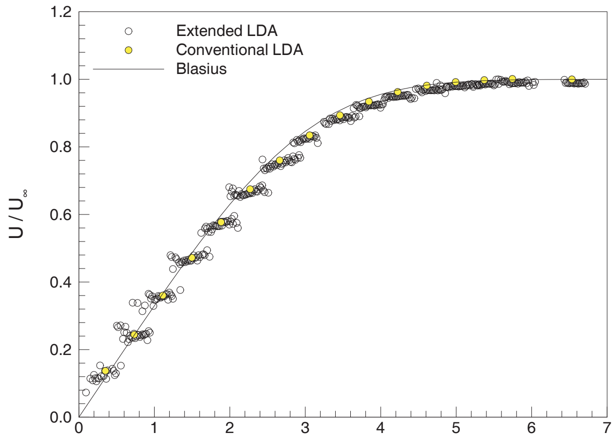

Figure 2: Averaged Velocity Profile of the Laminar Boundary Layer at x = 185 mm

References

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