Active flow control investigations on a flat plate using PIV, Stereo-PIV and Astigmatism-PTV

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This paper presents results from active flow control investigations at the Institute of Fluid Mechanics and Aerodynamics at the Universität der Bundeswehr München. The investigations focus on the flow conditions of a single jet. Additionally, the applicability of Standard-PIV in multiple planes, Stereo-PIV in multiple planes and Astigmatism-PTV on high velocities and velocity gradients within turbulent flow of an under-expended jet is compared. Different possibilities of three dimensional flow field investigations were analyzed in regard to resolution, accuracy, applicability and robustness under the conditions of limited optical access and dominating main flow velocity. Commercial software was used for the analysis of the Standard-PIV and Stereo-PIV measurement data, whereas the algorithm for the Astigmatism-PTV evaluation was developed at the Institute.

The flat plate model was also investigated in the Trisonic Windtunnel Munich (TWM). The measurement results regarding jet blowing height are presented. These investigations were performed by using a Standard-PIV setup.

Model

The measurements were performed on the fully equipped wind tunnel model (see Figure 1) with a one slotted actuator plate and a subsonic leading edge. The slot with dimensions of 10 × 0.3 mm² (length × width) is supplied by an underlying chamber which ensures a homogeneous jet. There are connections for air supply, a pressure transducer and a temperature sensor on both sides of the model. A pressure regulator system is able to provide a maximum chamber total pressure of $p_{c,\text{max}} = 6$ bar with an accuracy of $\Delta p_{c,\text{ch}} = \pm 5$ mbar.

Results

Standard-PIV shows good resolvability of high velocity gradients even on shock waves which closely follow one another. The calculated velocity values match, to a reasonable extent, with the theoretical values at different $p_{c,\text{ch}}$. It is even possible to visualize a three dimensional flow field by measuring several planes.

Stereo-PIV velocity fields also display good agreement with Standard-PIV results. Supersonic velocities perpendicular to the light sheet can also be resolved with the disadvantage of increasing RMS. The small jet dimensions in lower planes cause difficulties in resolving the velocity gradients as shown in Figure 2.

APTVP is a technique which enables the measurement of a three dimensional flow field with only one optical access in contrast to Standard- and Stereo-PIV. Also, at high velocities up to 480 m/s the particle tracking is possible, as illustrated in Figure 2.

This measurement technique enables future flow control investigations to get three dimensional flow field information.

The measurement analysis of the TWM investigation provided information concerning the blowing height relations. As expected, it was shown that the height significantly depends on the velocity ratio $\frac{w_{\text{jet}}}{u_{\infty}}$ (see Figure 3). The effects of the Reynolds and Mach numbers are negligible.

![Fig. 1 Sketch of wind tunnel model](image1)

![Fig. 2 Comparison of average jet velocity at $p_{ch} = 4500$ mbar](image2)

![Fig. 3 Blowing height as function of $p_{ch}$ at $M_c = 0.3$ and $p_l = 2000$ mbar](image3)