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LDV measurements on wing/engine interferences

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Abstract
ZARM successfully conducted LDV measurements at the Low Speed Wind Tunnel (LSWT) in cooperation with DASA Airbus. Subject of investigations was the engine-airfoil section of an A3XX model. Within this paper we compare the results from Pitot-probe and laser Doppler velocimetry measurements.

Introduction

Most of interest of aircraft manufacturers is focused on reduction of aircraft drag and thus to realize a lower fuel consumption. Further aspects are the optimization of high-lift devices for a steep take-off and a low speed landing as well as reducing vortices during take-off for higher frequencies of aircraft traffic. In order to reach these objectives, industries and research institutes investigate extensively the laminarization of the aircraft's boundary layers. More drag-reduction potential is formed by aircraft sections, where different components are joined together such as wing-engine configurations. An overview on aerodynamic aspects of engine-aircraft integration is given with [1].

Experimental set-up and measuring techniques

The experiments were carried out in the Low Speed Wind Tunnel (LSWT), equipped with a test section of 2.1 x 2.1 m^2 and a length of 4.3 m (fig. 1). The LSWT's maximal flow speed of about 70m/s is achieved at a mean level of turbu-lence of about 2%. The characteristical data of the LSWT are listed in table 1.

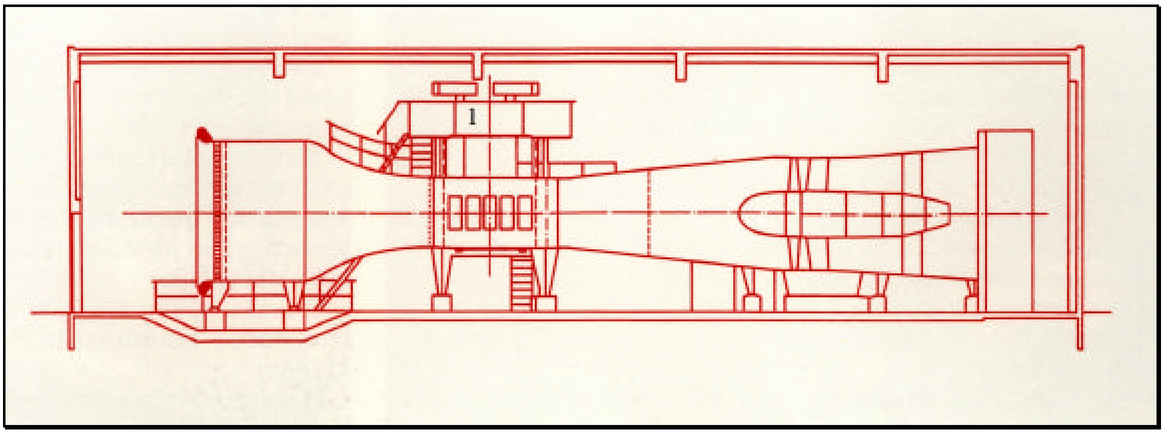

Fig. 1: Schematic view of Low Speed Wind Tunnel Bremen (LSWT)

Test section:	2.1 x 2.1m^2	Max. speed:	70 m/s	Re-number:	1.45 10^6
Test length:	4.3m	Ma-number:	0.175	Model scale:	1 : 31.8

Tab. 1: Characteristics of LSWT Bremen

Figure 2 shows the A3XX half-model with its wing half span of 1.26m. The angle of attack of the mean airfoil was choosen to be fixed at 8^o.

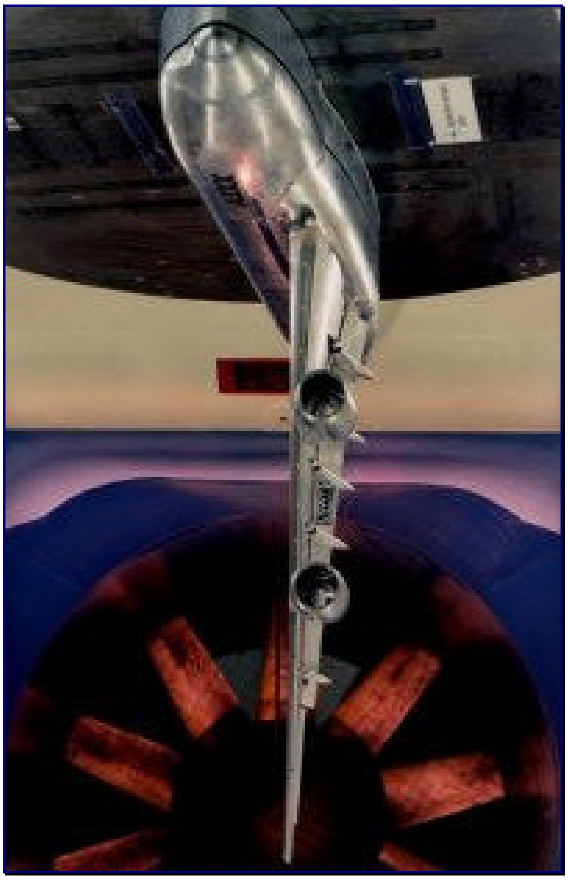

Fig. 2: Megaliner wind tunnel half-model in the test section of LSWT

Fig. 3: 2D laser Doppler velocimeter mounted on a 3D traversing unit

Velocities were measured by means of a Pitot probe as well as with a two-component laser Doppler velocimeter (DANTEC). As light source for the LDV measurements a 5 W Argon laser was used. The two-component system used each the blue and the green laser light for both components. Signal analysis was obtained by means of two DANTEC BSAs, which were operated at coincidence mode to obtain the two velocity components simultaneously. A time window of 50ms was used to reject the non-coincident signals [2]. To allow automatic measurements of the flow field, the laser-optic probe was mounted on a 3D computer controlled traversing system (figure 3).

A particle seeding system consisting of an aerosol generator and a movable seeding rake as illustrated in figure 6 were used for the LDV-measurements. The mean diameter of these seeding particles was $d_p \approx 1\mu m$. The seeding rake connected to the aerosol generator releases the tracer particles and dispersed them over a cross section of about 0.5m. In this way the air flow was seeded locally around the A3XX half-model in the wing/engine area [2].

Results

Engine simulations in wind tunnel testing had been performed successfully in the high speed regime (fan speed n=64000 rev/min) as well as in the low speed regime (n=11000 rev/min) by application of the Turbo-Powered Simulator (TPS) technique [3]. The following investigations on engine/wing interferences had been conducted with a 3.45´´ TPS (TDI 1079).

The locations of the measurement planes (- 1.0 ≤ x/D ≤ 3.5) are illustrated schematically in figure 5. The jet development in the form of the measured velocity profiles behind the TPS for n = 64.000 rev/min is illustrated in figures 7 and 8. Figure 7 illustrates the results of the Pitot probe while in figure 8 the results from the LDV measurements are shown. The results are summarized in these diagrams as a function of the location of different measurement planes (0.1 ≤ x/D ≤ 3.5). In these figures the position of wing and pylon are also illustrated as yellow lines.

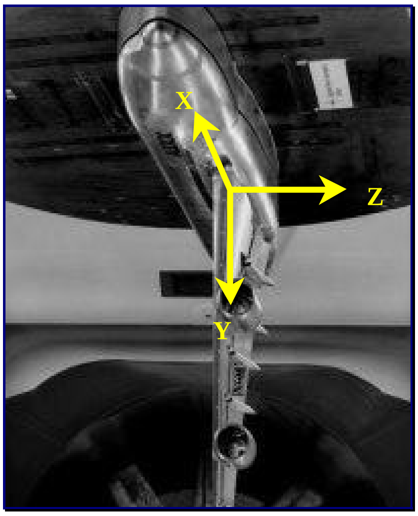

Fig. 4: Axis convention on A3XX model

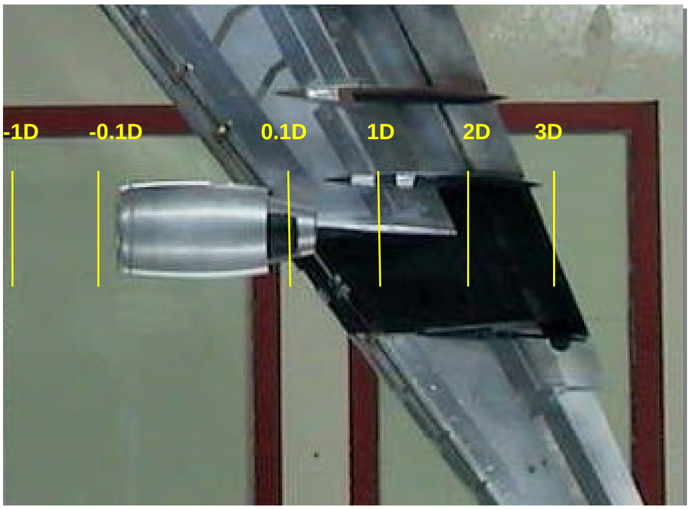

Fig. 5: Schematic view of the location of the measurement planes in the wing/engine cross section

As figure 7 shows, the application of Pitot probes is restricted to the area outside the central fan jet. The TPS produces a model fan jet which is cold due to highly compressed air. This leads to icing effects at the probe´s sensitive head. In addition to icing effects, pressure probes are restricted by their local resolution ability (diameter of the probe: 3mm). This leads to faulty data, when Pitot probes are applied at areas of high velocity gradients, such as the region between outer-flow and central-fan jet flow.

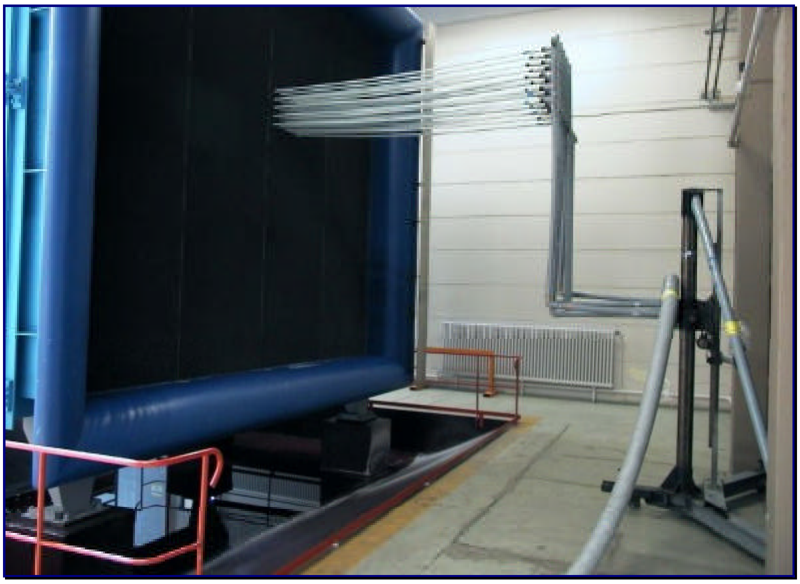

Fig. 6: Seeding rake at wind tunnel intake of LSWT

In contrast to the Pitot probe measurements it was possible with the LDV-technique to detect the whole velocity profile including the central-fan jet as shown in figure 8. The results will be discussed on the workshop in detail.

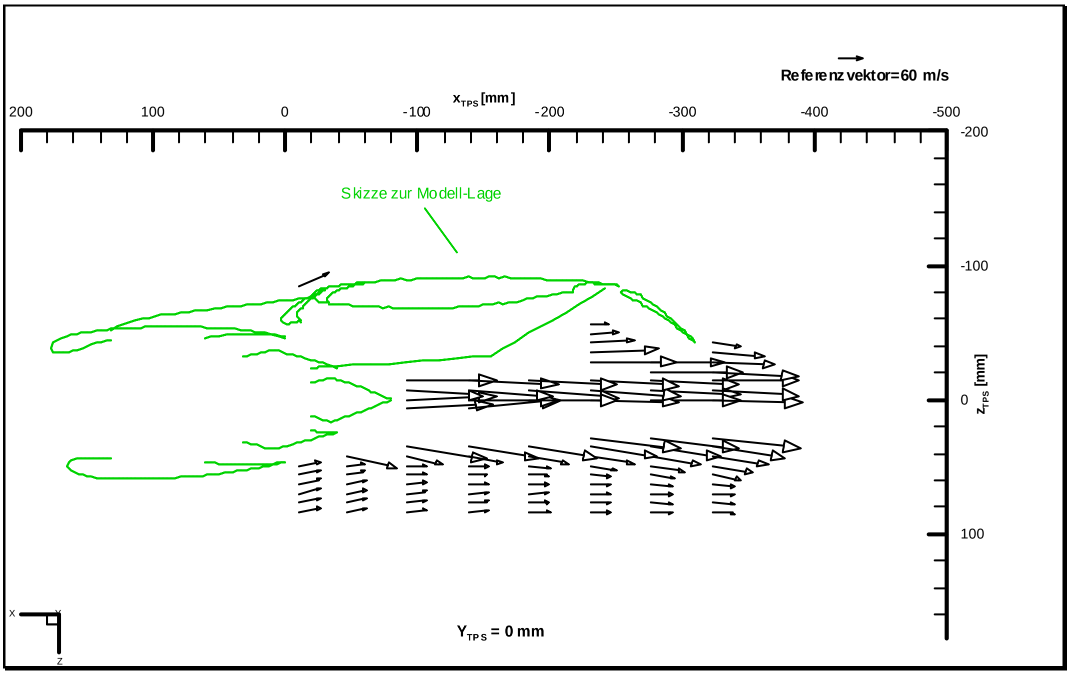

Fig. 7: Velocity profiles behind TPS; fan speed 64.000 rev/min (Pitot probe)

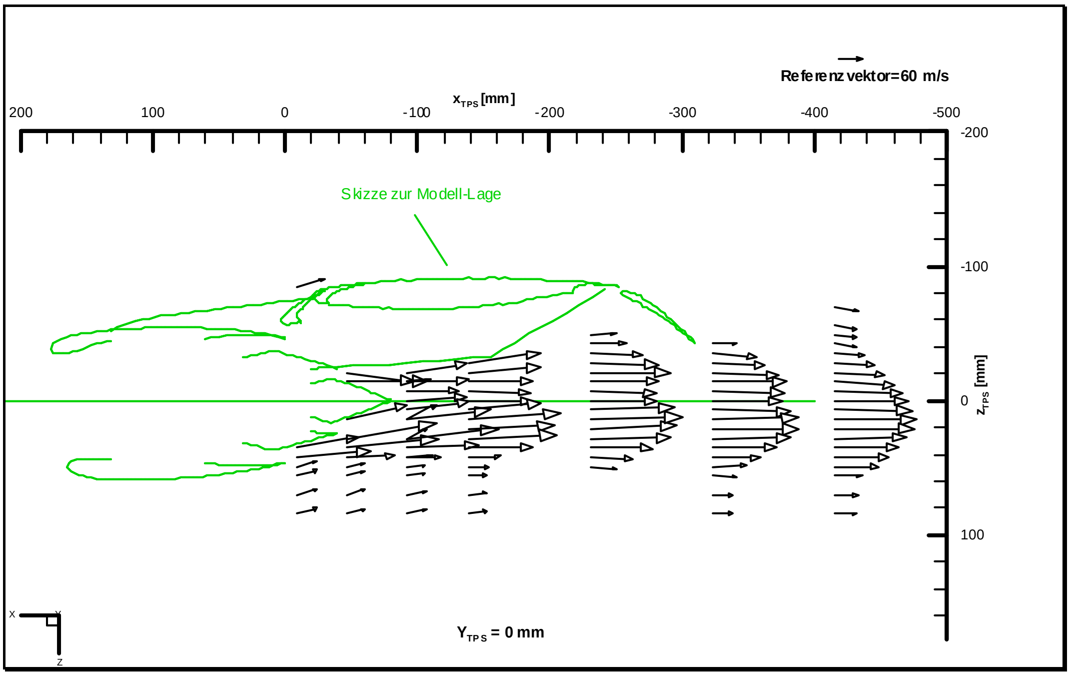

Fig. 8: Velocity profiles behind TPS; fan speed 64.000 rev/min (LDV)

Basically, the Pitot probe and LDV measurements are in good agreement to each other. Below, some exemplary results are shown in wing-cross sectional, respectively engine-cross sectional view. Differences between both measuring techniques are also mentioned.

As an example, two display types have been chosen for representing just a selection of data results: wing-cross-sectional view (xz plane) as illustrated in fig. 7 and fig. 8, and engine-cross-sectional view (yz plane) as illustrated in fig. 9 and fig. 10.

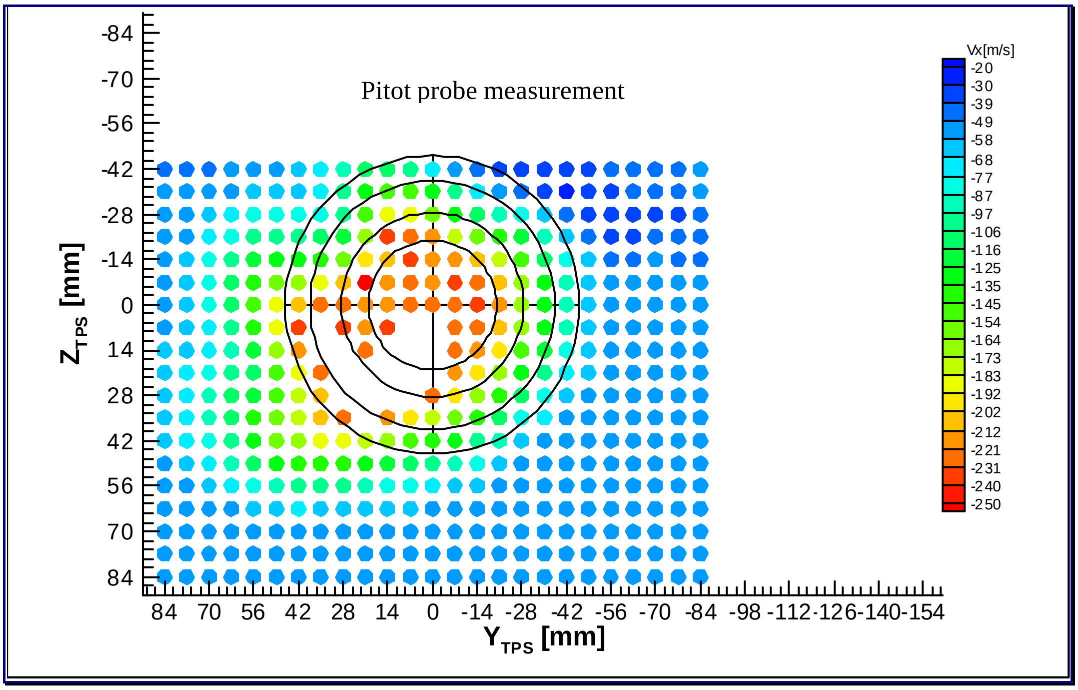

Fig. 9: Pitot probe results for V_X component at fan speed n=64000 rev/min, engine-cross section X/D=3.5

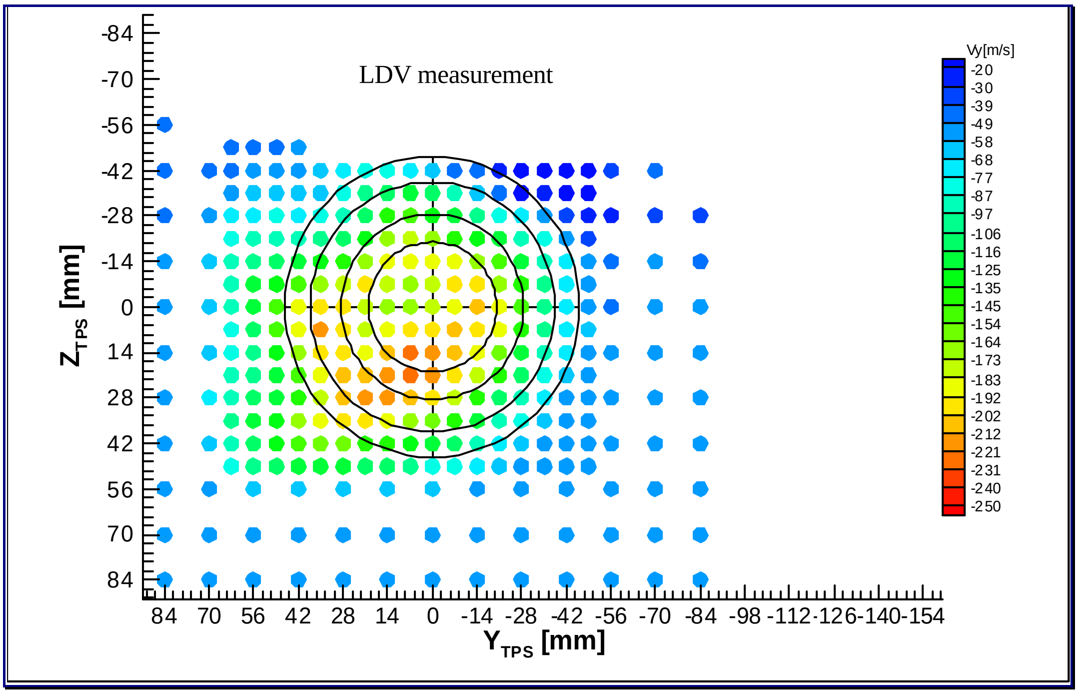

Fig. 10: LDV results for V_X component at fan speed n=64000 rev/min, engine-cross section X/D=3.5

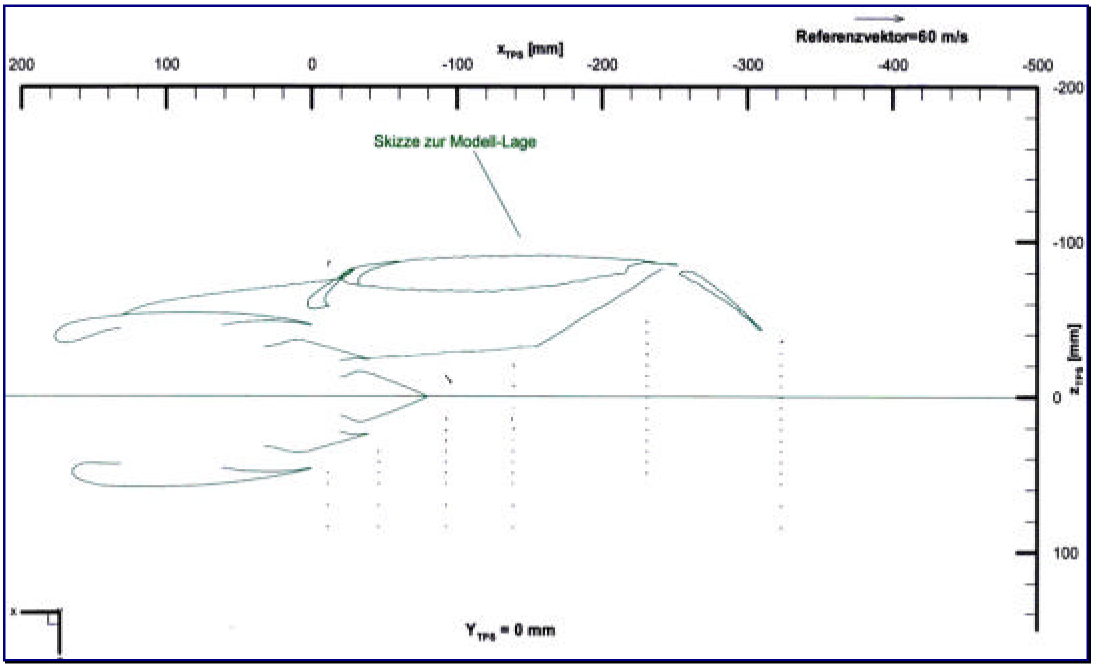

Fig. 11: Differences between Pitot-probe and LDV measurements, fan speed at n=64000 1/min

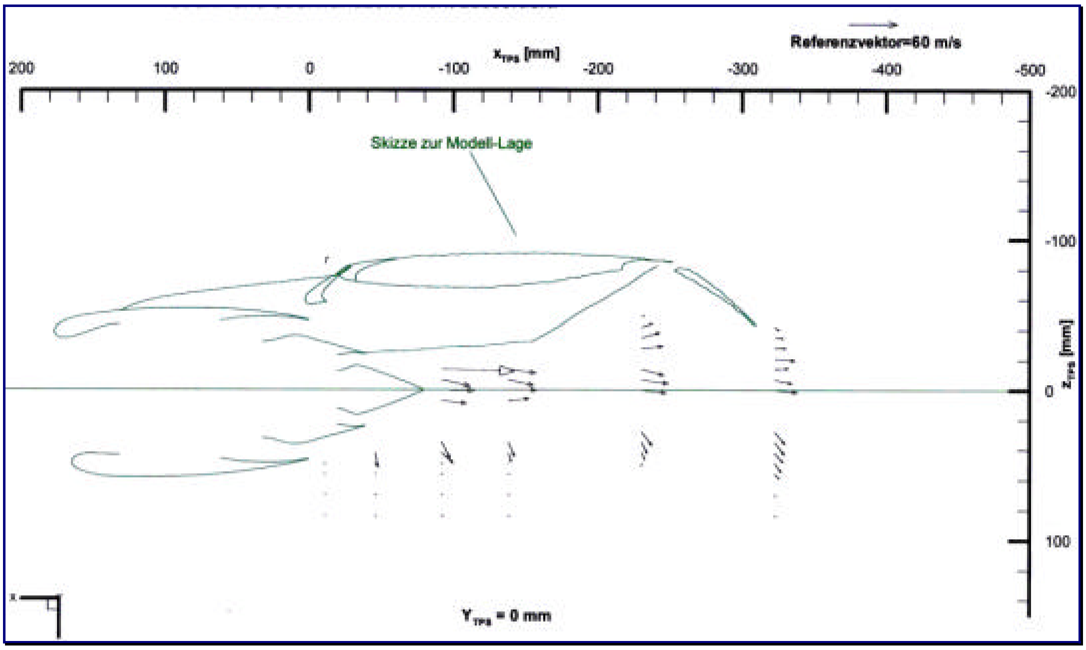

Fig. 12: Differences between Pitot probe and LDV values, fan at 64000 1/min, central-fan-area values erased

Figure 7 and figure 8 show a few different measuring planes. With the Pitot probe it was possible to measure in higher wing-cross-sectional resolution. Besides this, with the LDV technique it was possible to measure in additional planes (e. g. X/D=4.5). Thereby, the fan jet became slightly deflected by the main airfoil stream.

The non-measuring value section in the central-fan jet area is also shown with the engine-cross-sectional views in figure 9 and figure 10. The concentric circles represent the engine's location within the measuring field. Basically, the field of investigation had been observed in higher resolutions with the Pitot probe, because of the probe's higher operating speed.

Each vector in the diagram represents a statistical average of about 200 up to 300 observed single values. This was the result from setting the criterion for terminating the measuring interval to 2000 events, and respectively to 10 seconds of observation time. These criterions have been chosen under aspects of economic efficiency (wind tunnel operating time) and statistical confidence. This proved right in terms of data rates, since there is a limit to apply for the amount of seeding used.

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References

[1] Hoheisel, H.: Aerodynamic aspects of engine-aircraft integration of transport aircraft, Aerospace, Science and Technology, no. 7, 475-487, (1997)

[2] Beyer, W., Mahnken, M. & Milde, U.: Vermessung des Strömungsfeldes eines Triebwerkssimulators, Bericht DASA, Airbus (FKZ: 20 A 9701 B) (1999)

[3] Ewald, B. & Burgsmüller, W.: The adventure of starting a new wind tunnel technique. In: Proc. of DLR-workshop. Aspects of Engine-Airframe Integration for transport aircraft, DLR Mitteilung 96-01, (1996)