

Development of stereoscopic Background Oriented Schlieren Method (BOS) and Laser Light Sheet technique (LLS) for study of Reynolds number effects on wing tip vortex positions under cryogenic conditions

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Introduction and objectives

Wake vortex turbulence induced by large transport aircrafts is problematic for airports capacity because of their hazardous impact on following aircraft. Safety rules defining minimum distances between landing and taking off aircrafts are based on the strength and temporal duration of dissipation of the vortex turbulence. The wing tip vortex position is of major interest because interactions with vortices generated from e.g. the elevator of the airplane are desired to accelerate their decay.

Experimental data are needed to enable quick and accurate vortex modelling. These data are coming up to now mostly from wind tunnels which can not simulate the 'real' Reynolds and Mach number. Thereby it is usually assumed that this mismatch does not affect the results. Klinge *et al* [1] showed that wing tip vortices can be localised quantitatively with high accuracy during wind tunnel tests by means of stereoscopic BOS and additional software tools.

The objective of this experiment was to find out, whether the Reynolds number has a significant impact on the vortex position of a wing tip vortex.

Procedure

The experiments were carried out in the European Transonic Windtunnel (ETW) in Köln, Germany, which is a pressurised wind tunnel operating under cryogenic conditions. This wind tunnel is utilized due to its capabilities to change the Reynolds number without changing the wing load over a wide range of Reynolds numbers up to 'real flight' Reynolds numbers.

Optical measurement techniques are difficult to implement in this wind tunnel, so Particle Image Velocimetry (PIV) could not be applied, because the beam of a pulsed laser could not be inserted through the pressure shield due to safety reasons. However, it was possible to setup a stereoscopic Background Oriented Schlieren (BOS) system and a stereoscopic Laser Light Sheet (LLS) system to observe the vortex position about one half wing span behind the wing tip utilizing a continuous wave laser and a optical fibre. Different angles of attack and Reynolds numbers were investigated. The flow speed was kept constant at Mach = 0.2. The temperature range varies between 285 K and 115 K. Fig. 1 gives an overview about the setup within the test section and the model.

Results

Using in-house developed algorithms (VRIEDER) the position of the vortices trajectories were derived in space from the stereoscopic BOS-data for different Reynolds numbers conditions and angles of attack. The LLS pictures were dewarped to observe the vortex phenomenology precisely.

Conclusions

With BOS as an easy to install measurement technique, it is possible to obtain the position of the wing tip vortices in space precisely by applying new post processing algorithms (VRIEDER) also under cryogenic conditions, even for low Mach numbers. It is possible to apply LLS even under cryogenic conditions.

Vortex positions have to be measured under 'real flight' Reynolds and Mach number conditions, because there may be an effect of these numbers on their locations in space.

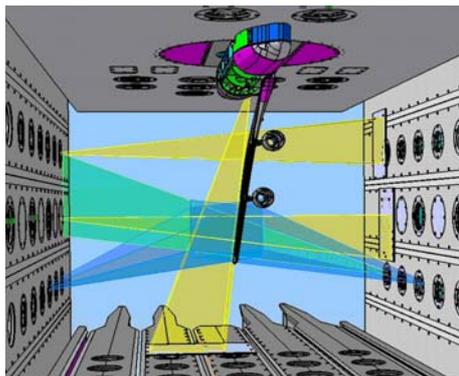


Figure 1: Setup and view of the cameras into the test section of ETW with the half model; view in flow direction
Green: BOS-Cameras, blue: Laser Light Sheet Cameras, dark green: Laser light sheet.
The backgrounds (dot pattern) for BOS are also visible.



Figure 2: Laser Light Sheet image.
The three dark holes are due to the high centrifugal forces in the vortices' cores which take away the seeding material and thus mark their locations.

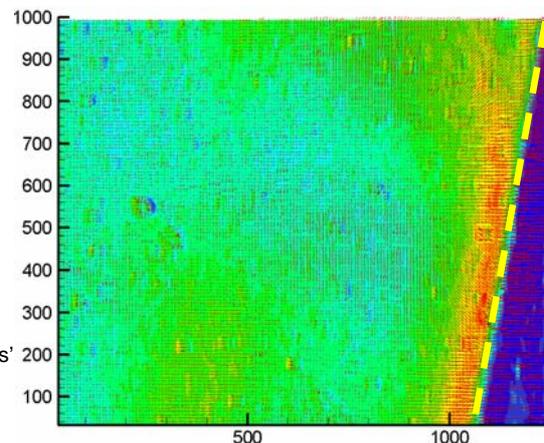


Figure 3: Evaluated BOS image, vectors indicating 'displacements' of the background pattern due to density gradients within the observed flow volume. At the left hand side of the blue field, the vectors are changing their orientation, which is the center line of the vortex (dashed yellow line).

Literature:

- [1] Klinge, F., Kirmse, T., Kompenhans K.: Investigation of the density and velocity distribution of a wing tip vortex by means of stereoscopic Background Oriented Schlieren Method (BOS) and stereoscopic Particle Image Velocimetry (PIV), 12. Int. Symp. on Appl. of Laser techniques to fluid mechanics, Lisbon 2004, Paper Nr. 2.6