Mitteilung

Fachgruppe: Hochagile Konfigurationen

Experimental Investigations of Vortex Flow Phenomena on the DLR-F23 Combat Aircraft Configuration at Transonic Speeds

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Modern high-agility aircraft are designed to cover a wide range of flight maneuvers, from transonic and supersonic performance to high maneuverability at subsonic speeds. The required flight envelope and mission spectrum of future multi-role combat aircraft lead to the development of new configurations with low aspect-ratio hybrid-delta wing planforms, consisting of multiple swept leading edges (LE). The corresponding flow field is dominated by complex vortex flows even at small angles of attack (AOA), vortex-vortex interactions and vortex-shock interactions, as well as vortex breakdown [1]. These unsteady flow phenomena interact with the aircraft structure. The structural dynamics excitation, which is called buffeting, affects the maneuverability of the aircraft and reduces the lifespan of structural components. The design of the wing planform in terms of different leading edges with different LE sweep angles and additional leading-edge extensions (LEX) has, for this reason, a significant impact on the complexity of the vortex-dominated flow field and the occurring unsteady flow phenomena.

In order to analyze complex flow phenomena, numerical and experimental investigations were conducted at the German Aerospace Center (DLR) as part of the DLR project Diabolo in the framework of Defence Technology [2]. A new high-performance aircraft configuration was developed for the Diabolo project, which resulted in the DLR-F23 geometry [3]. The generic wing-fuselage half-span wind tunnel model consists of a triple-delta wing configuration with an ogival cosine-chined forebody, as shown in Fig. 1. The front wing part, comparable with a leading-edge vortex controller (Levcon), has a medium LE sweep of $\varphi_1 = 45°$, followed by a wing midsection (strake) with a high LE sweep of $\varphi_2 = 75°$ and the main wing section with the similar wing LE sweep as the front section $\varphi_3 = \varphi_1$. The DLR-F23 wind tunnel model consists of elliptic airfoils, that taper into a sharp trailing edge (TE). The LE of each wing section has a constant radius of 0.5 mm.

The experimental investigations are performed in the Transonic Wind Tunnel Göttingen (TWG), operated by the German-Dutch Wind Tunnels (DNW). The Göttingen-type wind tunnel allows continuous inflow in the subsonic, transonic and supersonic speed range. For the investigations presented in this paper, the closed test section with perforated walls with a cross-section of $1.0\,m\,x\,1.0\,m$ and a length of $4.5\,m$ was installed in the plenum chamber. With this wind tunnel setup, a Mach number range of $0.50 < Ma_\infty < 1.20$ was covered in the measurement campaign. Considering the mean aerodynamic chord of $l_\mu = 0.411\,m$ as a reference length, the Reynolds number is in the range of $2.15 \cdot 10^6 < Re_{l_\mu} < 3.30 \cdot 10^6$. The half-span wind tunnel model, installed on a peniche, is actuated by a rotary hydraulic cylinder, as shown in Fig. 2a. A stereoscopic particle image velocimetry (Stereo-PIV) measurement technique was used to analyze the vortex-dominated flow field of the triple-delta wing configuration. Figure 2b shows the stereo-PIV measurement setup with the DLR-F23 wind tunnel model integrated into the test section. The measurement planes are illuminated by a double-pulsed ND: YAG-Laser. Two sCMOS cameras are positioned outside the closed test section on the left and right side in the area of the viewing windows. Figure 3 shows the nondimensional vorticity for the PIV-measurement plane 2, located at $x/c_{r,W} = 0.30$, for an angle of attack of $\alpha = 9°$, a Mach number of $Ma_\infty = 0.85$ and a Reynolds number of $Re_{l_\mu} = 2.93 \cdot 10^6$. The vortex core of the forebody vortex (FBV), which forms from the shear layer on the chined forebody, can be identified in the inner region. In the area of the LE of the strake, the formation of the inboard vortex (IBV) from the vortex shed is observable.

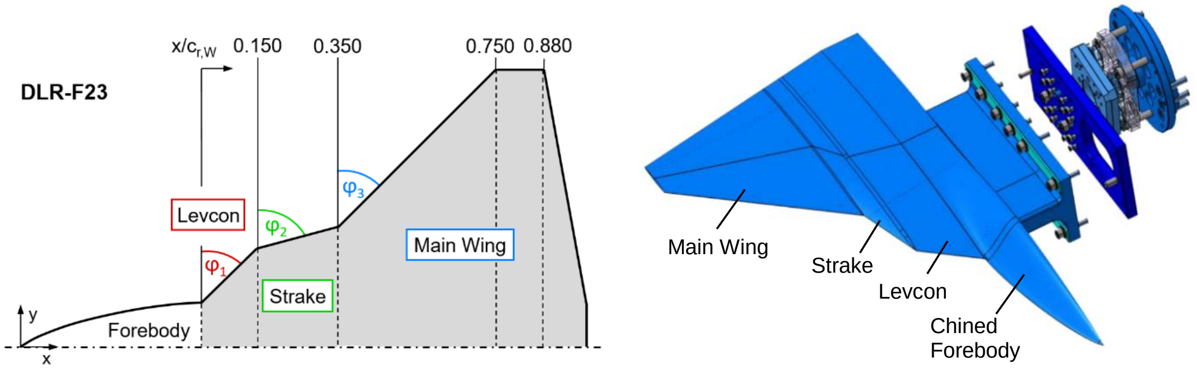
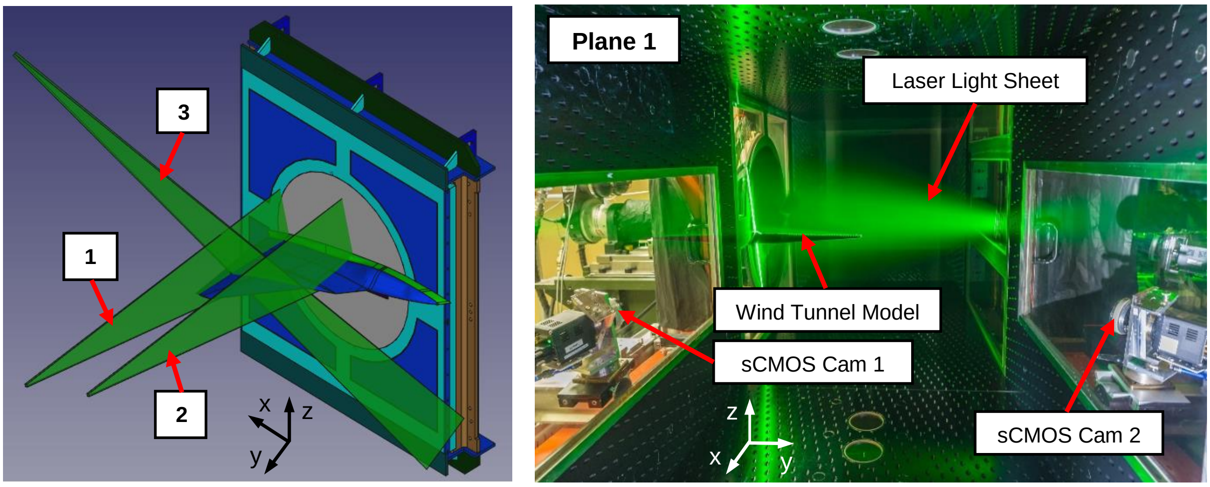


Figure 1: Geometry of the DLR-F23 half-span wind tunnel model



a) PIV measurement planes

b) Stereo-PIV measurement setup (Photo: J. Agocs)

Figure 2: Stereo-PIV measurement setup of the DLR-F23 in the test section of DNW-TWG

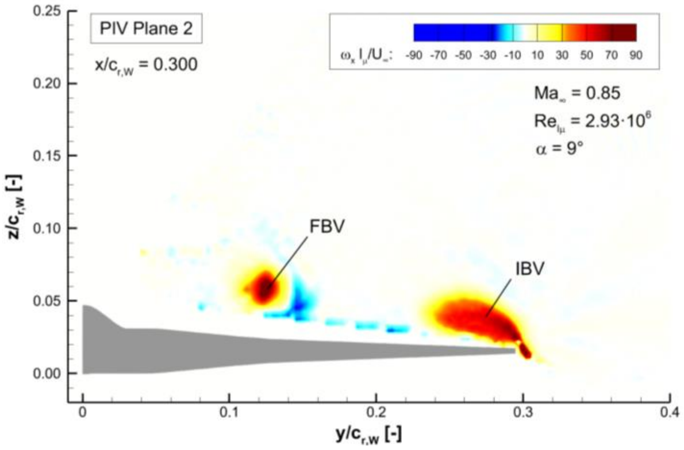


Figure 3: Nondimensional vorticity shown for a PIV-cross flow plane at $x/c_{r,W} = 0.30$ (plane 2); $\alpha = 9°$; $Ma_\infty = 0.85$; $Re_{l_\mu} = 2.93 \cdot 10^6$

References:

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[2] C. M. Liersch, A. Schütte, M. Kalanja. DLR Projekt Diabolo: *Technologien und Entwurf von Kampfflugzeugen der nächsten Generation*. DGLR Netzpublikation. Deutscher Luft- und Raumfahrtkongress 2022. 27.-29. September 2022, Dresden, Deutschland. DOI: 10.25967/570271.

[3] J. Zastrow, F. Oberdieck, U. Henne, C. Klein. *Numerical and Experimental Investigations on the DLR-F23 Combat Aircraft Wind Tunnel Model*. 33rd Congress of the International Council of the Aeronautical Sciences, ICAS 2022, 4.-9. September 2022, Stockholm, Schweden. ISBN 978-171387116-3.