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Abstract #
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Corresponding author: STEGMÜLLER Julius
e-mail of corresponding author: julius.stegmueller@tum.de
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Title

Experimental analysis of the flow field over an aeroelastic wind tunnel model for tail buffeting analysis

Authors

Julius STEGMÜLLER [1], Andreas Molz [1], Christian Breitsamter [1]*

** Corresponding author*
[1] Technical University of Munich, 85748 Garching bei München, Germany, julius.stegmueller@tum.de

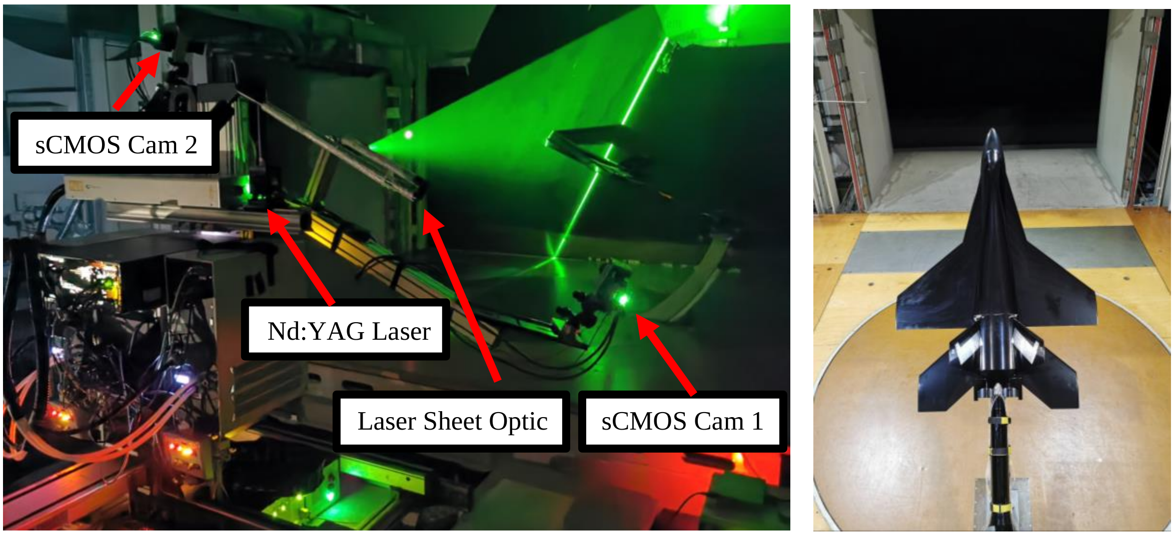
Abstract

Complex vortical flow structures and large areas of flow separation characterize the flow over modern high-agility aircraft configurations at subsonic speeds and medium to high angles of attack. With increasing angle of attack the vortices enter an unstable state resulting finally in vortex bursting. High turbulence intensities and burst frequency content at specific bandwidths occur downstream of the breakdown [1]. The oscillating pressure fluctuations in the unsteady flow field lead to structural dynamic excitation at the wing as well as at downstream located elements such as tail planes. The structural response to the aerodynamic excitation (buffet) through the unsteady flow field is commonly referred to as buffeting [2]. This can result in degraded handling qualities and heavy structural damage.

In order to analyze the buffeting effects experimentally, a wind tunnel full-span model with a $76°/40°$ swept double delta wing was developed at the Chair of Aerodynamics and Fluid Mechanics of the Technical University of Munich (TUM) using “rigid” components as well as flexible components scaled for structural elasticity and structural dynamics similarity rules [3]. Wings, horizontal tail planes (HTP) and vertical tail planes (fins) made of aluminum serve as a reference case with quasi-rigid properties. To provide structural elasticity, flexible wings, HTPs and fins 3D-printed from polylactide (PLA) can also be mounted at the modular designed wind tunnel model.

In the context of this work, stereoscopic particle image velocimetry (Stereo-PIV) measurements on the rigid and the flexible configuration are used to analyze the flow field with its burst vortices, which, acting as aerodynamic excitation, are responsible for the structural response or buffeting. The measurements are performed at the Göttingen type wind tunnel A at a Reynolds number of $Re_{1/m} = 3.1 \cdot 10^6$, which corresponds to a Mach number of $Ma_\infty = 0.15$ and a freestream velocity of $U_\infty = 51\ m/s$. Figure 1 shows the stereo-PIV measurement setup on the left hand side and the wind tunnel model integrated in the test section on the right hand side. Figure 2 shows measurement results of the rigid and the flexible configuration in form of nondimensional axial velocity u/U_∞ distribution at two measurement planes located at $x/c_r = 0.64$ and $x/c_r = 0.79$. In the first measurement plane over the $76°$ swept strake at $x/c_r = 0.64$, a stable vortex with increased axial velocities in the vortex core is clearly visible for both configurations. Major differences between the flexible and the rigid configurations can be seen at the second measurement plane at $x/c_r = 0.79$. In case of the rigid configuration, a larger area with negative axial velocities compared to the flexible case can be detected. This indicates a more upstream vortex breakdown for the rigid configuration.

Based on the results of the stereo-PIV measurements, the frequency content of the unsteady flow field in the area of the tail planes is analyzed with a fast response five-hole pressure probe. The main focus of the investigations lies on the comparison of buffet and buffeting effects related to “rigid” and flexible wing and tailplane components.



a) Stereo-PIV measurement setup b) Wind tunnel model

Fig. 1: Stereo-PIV measurement setup and wind tunnel full model integrated in the test section

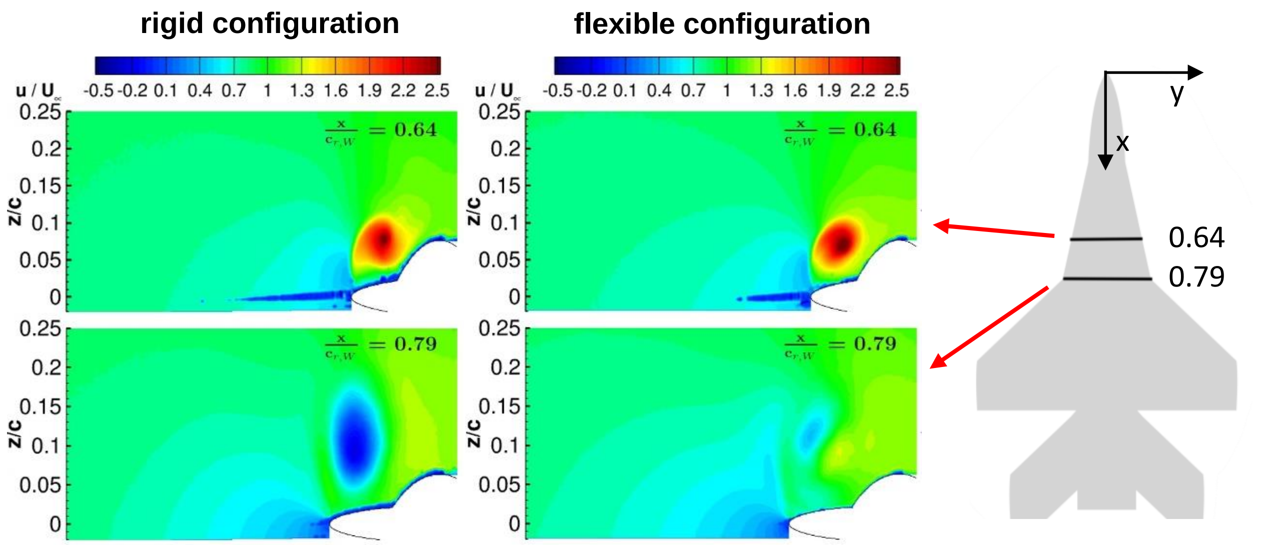


Fig. 2: Nondimensional axial velocity u/U_∞ distributions shown for cross flow planes at $x/c_r = 0.64$ and $x/c_r = 0.79$ and for an angle of attack $\alpha = 35°$

References

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