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EDITORIAL

Numerical and experimental studies on high-speed stall phenomena

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This special issue summarizes research findings on high-speed stall phenomena with a focus on transport aircraft obtained during the first phase of the research initiative jointly funded by the German Research Foundation (DFG) within the research unit FOR 2895 "Unsteady flow and interaction phenomena at High-Speed Stall conditions" and the Helmholtz Association of German Research Centres (HGF). All papers have been peer reviewed according to the standards of the *CEAS Aeronautical Journal*.

The aerodynamics of transport aircraft at the borders of the flight envelope is characterized by complex interactions and nonlinear, unsteady flow phenomena. The overall goal of the research initiative introduced above is the detailed numerical and experimental investigation of the flow-physical mechanisms and phenomena for these conditions up to flight-relevant Reynolds numbers. A prominent feature of the initiative are extensive measurements in the cryogenic European Transonic Windtunnel (ETW) on the Airbus XRF-1 aircraft research configuration. In addition to polar measurements, static pressure distributions are measured by numerous pressure taps, while unsteady pressures are recorded by Kulite sensors in relevant areas of the XRF-1 wing, horizontal tail plane (HTP), and ultra-high bypass ratio (UHBR) flow-through nacelle. To provide a comprehensive characterization of the flow, sophisticated optical methods are applied to measure the unsteady surface pressure distribution by the unsteady pressure-sensitive paint (PSP) technique and the flow field by means of unsteady particle image velocimetry (PIV). One goal of the research initiative is to provide a comprehensive, high-quality experimental database for future scientific use, both within and outside the present research initiative.

The measurements are supplemented by detailed numerical simulations ranging from RANS via hybrid RANS–LES to LES simulations to enable synergistic flow physics analyses of the buffet mechanisms and the evolution of the wing wake including its interaction with the HTP. In addition, the fundamental flow phenomena are studied numerically and experimentally on a generic tandem wing configuration at reduced Reynolds number, which allows spatially higher resolved measurements in relation to the relevant scales of the boundary layers.

The present special issue contains eight peer-reviewed contributions from the DFG/HGF research initiative as well as one guest contribution. Numerical results and experimental results for the XRF-1 aircraft configuration as well as for generic wings and tandem wings are discussed.

Herr et al. present their work on a scale-resolving hybrid RANS–LES technique applied to an engine nacelle configuration under transonic flow conditions with the DLR TAU solver. To mitigate the gray area issue of the RANS–LES interface, they propose the addition of a synthetic turbulence generator. The results show a development of a well-resolved turbulent boundary layer with a broad spectrum of turbulent scales, which demonstrates the applicability of the mesh and method for aircraft configurations. However, the results remain sensitive to the positioning of the synthetic forcing and the interplay with the numerical scheme. These effects need to be studied in future.

The paper of Luerkens et al. investigates numerically the effects of engine nacelle installation on the airfoil shock dynamics. Their WMLES of a planar nacelle–airfoil configuration predicts a reduced effective angle of attack and Mach number in the flow to the airfoil. The changes in the topology of the flow to the airfoil caused by the nacelle lead to a reduced strength of the airfoil shock and a less developed buffet, which resembles the behavior close to the stability limit. The occurrence of a shared DMD mode of the nacelle and the airfoil shock suggests that the existence of a coupling mechanism requires further investigation.

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The paper by Yorita et al. describes the cryo PSP measurement technique used in the ETW campaigns to measure the steady and the unsteady surface pressure distributions on the wing and the HTP of the XRF-1 aircraft configuration. The contribution also presents measurement results for selected wind tunnel conditions in the transonic buffet regime. Comparisons to unsteady pressure measurement data impressively demonstrate the high quality of the cryo PSP technique for quantitative surface pressure measurements.

As part of the research initiative, the effect of a newly designed UHBR flow-through nacelle on the wing flow and the buffet characteristics is being investigated both numerically and experimentally. The paper by Spinner et al. discusses the influence of the UHBR nacelle on the shock formation and flow separation on the lower wing surface at negative angles of attack. The results of steady and unsteady PSP measurements in the ETW are presented, and a detailed analysis of the flow physics is performed.

In the work by Zahn et al., a hybrid deep learning reduced order model is applied for the prediction of wing buffet pressure distributions on the Airbus XRF-1 configuration. The machine learning model is composed of a long short-term neural memory network that predicts the temporal evolution of the pressure distribution and an autoencoder for feature compression. Unsteady pressure measurements from the ETW campaign serve as training data for the supervised approach. Comparison with the experimental data shows that the main buffet flow features are captured by the developed model.

In the paper of Kleinert et al., a 2D configuration of a wing/tail-plane interaction is investigated for high-speed stall conditions by means of hybrid RANS/LES simulations. The authors investigate the variation of the wake downstream of the front wing over the buffet cycle depending on the separated flow and resulting in strong variations of the wake. Furthermore, the impact of this unsteady flow field on the downstream wing, resulting in a varying effective angle of attack of the downstream wing, in a change of the effective inflow velocity and in a modified pressure distribution on the downstream wing surface, is investigated in detail.

The contribution by Blind et al. presents an approach on how to couple two simulations. They introduce a time-accurate inflow condition for coupling a precursor simulation with a high-order CFD solver. In their work, interpolation is used to bridge the gap between the different spatial and temporal resolution requirements of the target discontinuous Galerkin framework FLEXI and the heterogeneous source data. To validate the time-accurate inflow coupling, a hybrid RANS/LES simulation provides the inflow data for a subsequent simulation in FLEXI, which resolves all relevant flow scales in the turbulent wake of a cylinder. In the context of the FOR 2895, this method is designed to investigate the influence of separated wakes of a wing on the flow around a horizontal stabilizer.

The paper by Schauerte and Schreyer reports on wind tunnel experiments of a 2D wing with aspect ratio = 8/3 mounted between the sidewalls of an adaptive-wall quadratic test section at transonic flow conditions and moderate Re numbers. Optical measurement techniques, namely a combination of Schlieren and PIV measurements, are employed to characterize the dynamic flow during a typical buffet cycle. Certain emphasis is put on the development of the downstream boundary layer into the near wake close to the trailing edge. Large parts of the work are devoted to an extensive qualitative description of the phase-averaged flow fields in terms of density gradients. The phase averaging is based on an innovative phase estimation technique.

Scharnowski et al. finally present an experimental study on the effect of a pitching degree of freedom on the dynamics of the shock in a buffet flow field over an OAT15A airfoil model at transonic flow conditions. A fixed version and a spring mounted version of the model were used to investigate the effect of the pitching degree of freedom on the shock buffet. Planar PIV measurements with an acquisition rate of 4kHz allowed for the detection and analysis of the shape and the motion of the compression shock. The authors analyze the coupling between fluid and airfoil structure for a quasi-two-dimensional airfoil model with a pitching degree of freedom whose natural frequency is close to the buffet frequency.

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