LPA PLATFORM 1

XDC
Cross Demo Capabilities

Common Numerical Methods and Experimental Means

- Final Workshop –

Wednesday, the 20th of September 2023, 14:10 - 18:20, Room: Willi-Bleicher-Haus | Raum 1
Thursday, the 21st of September 2023, 09:00 - 15:40, Room: Willi-Bleicher-Haus | Raum 1

Abstract: *The XDC workshop is intended to provide the latest achievements of numerical methods and experimental means developed and demonstrated by the DLR researchers for the CleanSky 2 LPA Cross Capability Demonstrator (XDC). These developments have been made in order to establish design processes and tools for the prediction, assessment and measurement of the integration of future propulsion systems for large passenger aircrafts. The XDC thus provided high-fidelity CFD and CAA tools as well as further developed prediction tools for noise and aero-elastics and advanced testing means. For each of the methods a short introduction is given and their applicability is described using examples from the project helping to find the right method supporting future design and integration work.*

The XDC is part of the Large Passenger Aircraft Platform 1 (LPA-PF1) funded by the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 945583.

20.09.2023

Opening Session

Opening words	U. Herrmann	14:10
The XDC - an overview on the CleanSky 2 demonstrator on common numerical methods and experimental means	F. Boden	14:20

Session I – Numerical Methods I

Hybrid wing body as a low noise aircraft from a multidisciplinary point of view	M. Mößner	14:40
Fast prediction of fan broadband noise with a physics-based aerodynamic model suited for transonic rotor blades.	A. Moreau	15:10

Session II – Numerical Methods II

Investigations of future shielding solutions for aircraft rear ends against debris	Y. Toso	16:10
Design and Integration of UHBR propulsion systems - An overview of the Clean Sky 2 ASPIRE and SA2FIR projects	R. Schnell	16:40
Flutter assessment of a passenger aircraft with standard and UHBR engines	J. Arnold	17:10
Parametric Structural Modelling for Aeroelastic and Aeroacoustic Analyses of an Aircraft Rear Fuselage	W. Krüger	17:40
Exploring the impact of rotational effects on boundary-layer instabilities based on an open rotor blade	A. Theiß	18:10

End of Day 1

21.09.2023

Session III – Experimental Means I		
Improving source localization with SODIX for far-field measurements in static engine noise tests	H. Siller	9:00
Advancements and challenges of MEMS microphones in aeroacoustics: A comprehensive overview	C. Spehr	9:30
Session IV – Experimental Means II		
Structural design of a generic high bypass ratio fan	P. Ebel	11:00
Developments of DIC techniques for propeller blade deformation measurements and in-flight applications	T. Kirmse	11:30
Measurement methods fusion and application for fluid-structure coupling analysis using PSP/TSP and event-based-imaging-techniques	K. Henning	12:00
Session V – Experimental Means III		
Experimental vibroacoustic characterization of a A320 wing	S. Zettel	14:10
STB – high-resolution Lagrangian particle tracking for large and small scale aerodynamics	D. Schanz	14:40
Full-scale particle image velocimetry under open-air conditions	R. Geisler	15:10

End of the Workshop

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Session I – Numerical Methods I

Hybrid wing body as a low noise aircraft from a multidisciplinary point of view

M. Mößner et. al.

One important goal when reducing the environmental impact of an aircraft is the reduction of noise. There is a lot of potential for less noise impact when noise is a major objective from the beginning of the design phase. Within this contribution a hybrid wing body concept as a mid-range aircraft will be presented together with detailed studies of different disciplines like aerodynamics, acoustics structure and also handling qualities. How much noise reduction can be achieved? What are the advantages, where are the difficulties and weaknesses of such an aircraft configuration?

Fast prediction of fan broadband noise with a physics-based aerodynamic model suited for transonic rotor blades.

A. Moreau and R. Meier zu Ummeln

The usual and affordable way to predict broadband noise generated by aero-engine fans relies on empirical correlations established by NASA since the 70's. The present contribution depicts an alternative approach, based on analytical models for the noise sources and their aerodynamic key driving parameters. A simple but physical new loss model suited for slender fan blades improves the rotor wake size prediction and the sensitivity of fan broadband noise to incidence and working line variations.

Session II – Numerical Methods II

Investigations of future shielding solutions for aircraft rear ends against debris

Y. Toso

Simulation methodologies for the assessment of the impact behaviour of materials against potential threads were developed within the European Clean Sky II Program. In the scope of the project, four materials were selected: an aluminium AL2024T3, a unidirectional T700 fibre reinforced M21 epoxy, a tri-axially braided AS4c fibre reinforced M36 epoxy and a tri-axially braided Zylon AS fibre reinforced Cycom 890 epoxy. The missing basic parameters for numerical investigation were then determined from results of material characterization tests conducted during the project. Three high velocity impact test campaigns were performed to assess the performance of the selected materials. A simulation methodology was developed and validated for the different target materials using the results of selected high velocity impact tests. At the end of the investigations, appropriate meshes and the corresponding specific material card parameters were chosen within the validated simulation results to assess the impact behaviour of shieldings for non-tested high velocity impact test cases. The investigations evidence that a large number of effects/mechanisms occurs in high velocity impact events when considering various threads and that simulations are unavoidable in the selection of appropriate shielding solutions.

Design and Integration of UHBR propulsion systems - An overview of the Clean Sky 2 ASPIRE and SA2FIR projects

R. Schnell

A propulsion system for future aero engines with ultra high bypass ratio (UHBR) engines was designed and evaluated. The propulsion unit under consideration featured an engine representative, robust and highly efficient fan stage as it was designed by DLR, as well as a nacelle and intake designed by the industrial partner Airbus. The presentation focuses on the design process with subsequent high-fidelity analysis, first of all of the full-scale fan stage, aiming at balancing all kinds of performance related as

well as structural and operational requirements at various operating scenarios. We address the application of efficient multi-disciplinary (MD) optimization and simulation techniques e.g. to better understand different phenomena stemming from integrating low fan pressure ratio fans, such as fan operation under cross wind conditions or rotor flutter sensitivity due to an acoustic feedback loop with the intake.

Flutter assessment of a passenger aircraft with standard and UHBR engines

J. Arnold

Focus is the stability assessment of an aircraft equipped with the currently introduced high-efficiency engines of ultra high bypass ratio (UHBR) and to compare the critical flutter onset to the same aircraft using standard engines with a smaller fan diameter. The D150 configuration modelled in-house by DLR was chosen, since it is similar to the Airbus A320 in terms of size and dynamic behaviour. The setup of the aeroelastic model is shown and results from the flutter assessment clarify differences between the investigated standard and UHBR engine types with respect to the flutter onset. Here, the sensitivity study includes varying locations of the UHBR engine in front of the D150 wing and is based on unsteady aerodynamic forces from doublet lattice method (DLM). The aeroelastic models are analyzed with the commercial ZAERO aeroelastic software package.

Parametric Structural Modelling for Aeroelastic and Aeroacoustic Analyses of an Aircraft Rear Fuselage

W. Krüger, T. Klimmek

For the development of numerical methods for aeroelastic analysis and vibration analyses on future aircraft configurations, representative reference models for the aerodynamics and the aircraft structure are necessary. Only very few models with a sufficient level of detail are publicly available. The DLR tool MONA is used for the for the generation of parametric aircraft models, i. e. finite element models and linear aerodynamic models, to realistically represent the global structural and aeroelastic dynamics of an aircraft. In the project, the focus was on the extension of the modelling capabilities of MONA to the generation of fuselage models of sufficient detail for aeroelastic and vibroacoustic analysis. Those models were then passed on to project partners for the respective analyses.

Exploring the impact of rotational effects on boundary-layer instabilities based on an open rotor blade

A. Theiß, S. Hein

In a rotating reference frame, terms corresponding to Coriolis and centrifugal forces appear in the linearized disturbance equations. However, the effect of these rotational terms on the stability of boundary layers is only partially understood. The talk will consider how the rotational terms affect the transition mechanisms on an open rotor blade, specifically by examining the impact of neglecting or including rotation in the linear stability equations.

Session III – Experimental Means I

Improving source localization with SODIX for far-field measurements in static engine noise tests

S. Oertwig, H. Siller

The source localization method SODIX is able to determine the individual contributions of the engine components to the overall radiated noise. The method is now applied to new far-field measurements of a short-cowl engine. SODIX is used to evaluate the effect of an intake liner on the sound field radiated from the engine intake by comparing different engine configurations with and without the

intake liner. The source localization results show that SODIX is able to quantify the effect of the intake liner even when the overall sound pressure levels are dominated by other sound sources like jet noise.

Advancements and challenges of MEMS microphones in aeroacoustics: A comprehensive overview

T. Ahlefeldt, C. Spehr, D. Ernst

The application of micro-electro-mechanical systems (MEMS) microphones in the field of aeroacoustics has gained significant attention in recent years. Traditional measurement techniques often struggle with size, weight, and cost limitations, making MEMS microphones an attractive alternative. The utilization of MEMS microphones for aeroacoustic measurements is discussed regarding the field of application (aircraft, wind tunnel), data acquisition, calibration and typical implementation problems.

Session IV – Experimental Means II

Structural design of a generic high bypass ratio fan

P.-B. Ebel, P. Winkelmann, R. Schnell, J. Belz

Novel engine concepts for climate-friendly propulsion come along with more or less deviations from today's aero engines. Finding feasible propulsor designs for these concepts is a highly multidisciplinary task and has to unite aerodynamic goals with structural requirements at least. The presented work gives an insight into DLR's approach on turbomachinery optimisation and layout. Focus is on structural design of a generic high bypass ration fan that was carried out in advance of the ADEC project.

Developments of DIC techniques for propeller blade deformation measurements and in-flight applications

T. Kirmse, F. Boden

For the development of design tools for the optimization of advanced propulsion system adequate validation data is required. Especially measurements on aircraft engines and their components are a special challenge. With increasing fan diameters or Open Rotor concepts the knowledge of the blade deformation becomes more significant. Within the Cross-Demonstrator- (XDC-) activities Large Passenger Aircraft (LPA) Platform the optical non-intrusive DIC-method IPCT of the DLR was further developed with special focus on blade deformation measurements and in-flight application. This included the further development of tools to optimize the measurement set-up as well as the improvement of the evaluation software and post -processing routines. Within the presentation it will be demonstrated on blade deformation measurements performed on a rotor test stand and measurements on the Dassault Falcon 2000EX DLR-ISTAR.

Measurement methods fusion and application for fluid-structure coupling analysis using PSP/TSP and event-based-imaging-techniques

K. Henning, M. Hilfer, T. Kirmse, F. Boden

Flow-structure coupling is the study of fluid flow causing deformation of a surface or structure. Several measurement techniques exist to extract position and deformation information of the surface. A combination of deformation measurement and PIV has been applied with success in recent years. In this work the combination of temperature and pressure measurement with TSP/PSP and simultaneous measurement of the position/deformation using event-based camera-imaging (EVB), STB or IPCT and/or PROPAC is evaluated. A combination of EVB and high-speed camera set-ups for high-speed measurements up to 10 kHz is implemented, and the cross-talk between the system and resulting error is investigated. Timing and synchronization of PSP/TSP-System and deformation is optimized. For the

deformation measurement with the EVB cameras, a laser based random dot pattern is generated using DOE optics. Calculation of deformation with preceding triangulation of the model using location fixed and pattern fixed markers using one of the deformation detection methods (STB, PROPAC or IPCT) is carried out. Combinations of the mentioned measurement techniques are upcoming challenges and are more and more interesting to understand the flow physics and correlation to the deformations/positions. The investigated measurement techniques are applied on a flexible wind tunnel model.

Session V – Experimental Means III

Experimental vibroacoustic characterization of a A320 wing

S. F. Zettel, M. Norambuena, R. D. Dewald, R. Winter, M. Gröhlich

The wing is the main transfer path for engine induced vibrations into the fuselage. Therefore, investigating the high frequency behavior of wings is of importance for cabin acoustics. In cooperation with Airbus the DLR conducted a vibroacoustic experiment on an actual A320 wing. The goals were to create an updated numerical model of the wing and quantify the vibrational power input into the fuselage utilizing structural intensity calculated from measurement data.

STB – high-resolution Lagrangian particle tracking for large and small scale aerodynamics

D. Schanz, A. Schröder, M. Novara, R. Geisler, T. Jahn, S. Gesemann, P. Godbersen, J. Agocs, J. Bosbach, C. Voß

Shake-The-Box is a 3D Lagrangian Particle Tracking method measuring position, velocity and acceleration along typically ~105 trajectories in a measurement volume instantaneously. Using HFSB and pulsed LED illumination large volumes in m^3 -scales can be investigated in low-speed flows and multi-pulse STB approaches are available for high-speed aerodynamics. FlowFit, a data assimilation method using Navier-Stokes constraints, interpolates the scattered particle data and provides the full (coarse grained) time-resolved velocity gradient tensor and pressure fields. The STB methodology and examples of applications in various fields will be presented.

Full-scale particle image velocimetry under open-air conditions

R. Geisler, J. Agocs, F. Boden, O. Erdogdu, S. Ewald, C. Fuchs, T. Kirmse, T. Kleindienst, L. Koop, F. Philipp, A. Schröder, M. Achmus, J. Heider, J. Hammer, T. Schulze, O. Sturm

Particle Image Velocimetry (PIV) is a well-established tool for flow field measurements in laboratory experiments as well as in industrial wind tunnel environments. However, real-scale aircraft investigations are still a challenging task especially when performed under open-air conditions. In this publication main problems and possible solutions are highlighted.

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