German Aerospace Center

Unique wind tunnel test for slower landing approaches

12 February 2014

Slower landing approaches by aircraft lead to less noise. How slow, steep and hence quiet a modern commercial aircraft can arrive at a destination airport is determined by the performance of the high-lift system with its retractable slats and flaps on the wings. Another advantage of reduced landing speeds is that shorter runways can be used. The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) has joined with Airbus, and the European Transonic Wind Tunnel (ETW) in the three-part project HINVA (High lift INflight VAlidation), consisting of wind tunnel experiments, flight tests and computer simulations. The aim is to combine computer models and wind tunnel tests to substantially improve predictions of high-lift performance and hence pave the way for slower and quieter approach flights. In early February, the project performed unique wind tunnel experiments at cryogenic temperatures in the ETW in Cologne. Equipped with laser measurement technology and other advanced measurement systems, the researchers achieved hitherto unknown precision in detecting the flowfield around an Airbus A320 with extended landing flaps and slats under flight-representative conditions. The researchers had constructed a high precision wind tunnel model specifically for the tests, based on flow measurements performed during in-flight tests with the DLR A320 ATRA research aircraft.

A global first in research

"The HINVA research project is globally unique when it comes to advancing the development of modern high-lift technologies," explains Rolf Henke, a member of the DLR Executive Board and responsible for aeronautics research. “With the A320 ATRA research aircraft, the European Transonic Wind Tunnel and the high-performance TAU computer program, DLR is making use of its unique research infrastructure and deploying its world-leading measurement techniques," continues Henke. Indeed, this is the first time that DLR, in its high-lift research, has combined computer simulations with in-flight and wind tunnel experiments for such a complex configuration.

This unique approach is supported by Airbus as part of its research activities because the desired accurate prediction of the flow features during takeoff and landing are an essential contribution to the optimisation of future aircraft developments. The results of these experiments will be important for the entire aviation industry. " When it comes to new products, the sector will be in a position to plan in greater detail, assessing the deviations between predicted high-lift performance and the actual values," emphasises Henke. "Aeronautics research will acquire valuable insights into how combining the three methods – simulation, cryogenic wind tunnel testing and in-flight testing – can deliver an unprecedented level of precision in aerodynamic analysis and development for commercial aircraft."

An interaction between flaps and gaps

Besides the landing flaps themselves, the gaps that open up between the leading-edge slats, fixed wing and trailing edge flaps play an important role in defining the performance of a high-lift system. All elements must be precisely positioned. Simulating highly complex maximum lift behavior at the limits of the flight envelope remains a daunting challenge for modern computer models. "At DLR, we could make substantial progress with respect to with Computational Fluid Dynamics (CFD) simulations, making use of Europe's largest data centre for aeronautics research, the Center for Computer Applications in Aerospace Science and Engineering ($C^2A^2S^2E$)," says Cord-Christian Rossow, head of the DLR Institute of Aerodynamics and Flow Technology in Braunschweig. "But to further improve the models we urgently need real flow data from in-flight and wind tunnel tests."

Turbulent flow in laser light

The world's leading wind tunnel, unique in Europe, offers the capability for testing aircraft under realistic in-flight conditions. The researchers used their measurement equipment to put a dedicated newly manufactured, cryogenic half model of an A320 through its paces. Using a laser measurement technology called Particle Image Velocimetry (PIV) allowed detailed analyses of areas where vortex formation and flow separation occurs. The airflow is not ideal in these zones, prompting complex aerodynamic interference effects that limit the high-lift performance. "The laser measurement technology PIV was developed by our colleagues in Göttingen. We are now able to conduct simultaneous measurements of the flow velocity in many critical areas of the wing," says HINVA Project Coordinator Ralf Rudnik from the DLR Institute of Aerodynamics and Flow Technology. "Therein lies one of the keys to acquire a better understanding of where and why lift breaks down." PIV yielded the first experimental flow field data in a the low speed regime suitable for a direct comparison with in-flight test data and numerical calculations. Classic methods such as force and pressure measurements, alongside modern Stereo Pattern Tracking (SPT) for deformation measurement, Temperature Sensitive Paint for transition detection, and a microphone array for acoustic source location were used to complement these systems.

Flow measurements at 160 degrees below zero

The researchers increased the pressure inside the ETW to 3.3 times atmospheric pressure and cooled the nitrogen flow gas to minus 160 degrees Celsius to deliver the greatest possible precision in replicating real flow conditions for a commercial aircraft. "We evaporated 1281 tons of liquid nitrogen and fed it into the ETW for the HINVA test cycles," reports Guido Dietz, the head of ETW. The wind tunnel has the capability to test models with an onflow speeds up to 1.35 times the speed of sound, but for HINVA, flow speeds just below 0.2 times the speed of sound were used. "Around 30 percent of our tests are now concentrated on investigating high-lift at speeds representative for take-off and landing," Dietz continues. "ETW can produce flight-relevant data under these conditions, while standard wind tunnels most commonly cannot." ETW was developed and constructed by four nations: France, Germany, Great Britain and the Netherlands. DLR acts as Germany's stakeholder.

Research aircraft as wind tunnel models

The researchers used extensive measurement data collected with the DLR A320 ATRA (Advanced Technology Research Aircraft) over a three-weeks flight test campaign at Airbus in Toulouse in July 2012 to manufacture the A320 wind tunnel model with extraordinarily precise design features. At that time, the scientists, in cooperation with Technische Universität Berlin, equipped the research aircraft with several hundred sensors spread across the entire outer skin. A pressure measurement system using lightweight metal belts attached to the port wing and horizontal stabiliser delivered reliable flow data. The total of 10 test flights pushed the boundaries of the pilots' skills as they repeatedly approached the aerodynamic limits of the aircraft, initiating stall manoeuvres at low speed.

Further flight campaigns planned

The joint project HINVA receives funding from the German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie; BMWi) within the framework of its Aviation Research Programme IV. The project is designed to pool national capabilities in the performance evaluation of aircraft for Germany to maintain an international leadership in the field of high-lift research. A second flight campaign with the DLR–ATRA is planned for autumn 2014, within which flight tests are scheduled to measure flow velocity around the wings and flaps during flight. An important step will be the first direct application of PIV laser measurement technology on commercial aircraft. This combination of CFD simulation, wind tunnel experiments and in-flight testing has the potential to yield substantially more accurate predictions of drag values during high speed cruise.

Contacts

Falk Dambowsky
German Aerospace Centre (DLR)
Media Relations, Aeronautics
Tel.: +49 2203 601-3959
falk.dambowsky@dlr.de

Prof. Dr. Ralf Rudnik
German Aerospace Center (DLR)
DLR Institute of Aerodynamics and Flow Technology
Tel.: +49 531 295-2410
ralf.rudnik@dlr.de

Dr.-Ing. Guido Dietz
European Transonic Wind Tunnel (ETW)
Managing Director
Tel.: +49 2203 609-116
GD@etw.de

Observing a wind tunnel model at the ETW

In the wind tunnel, a model of an Airbus A320, which was created specifically for the experiments within the HINVA project (left to right): Cord-Christian Rossow, Head of the DLR Institute of Aerodynamics and Flow Technology, Rolf Henke, DLR Executive Board Member for Aeronautics, HINVA project manager Ralf Rudnik and Detlev Schwetzler (Airbus).

European Transonic Wind Tunnel (ETW) in Cologne

The ETW was designed and built by France, Germany, Great Britain and the Netherlands. DLR represents Germany.

Credit: ETW.

Wing of research aircraft Airbus ATRA Messensorik

The scientists want to predict the maximum lift of aircraft more accurately; future aircraft configurations and high lift devices should provide further aerodynamic improvements.

Credit: DLR (CC-BY 3.0).

At the ETW control centre

Joint Research for slower approaches (left to right): Detlev Schwetzler (Airbus), HINVA project manager Ralf Rudnik, Director of the DLR Institute of Aerodynamics and Flow Technology Cord-Christian Rossow, DLR Executive Board Member for Aeronautics Rolf Henke and ETW manager, Guido Dietz.

Credit: DLR (CC-BY 3.0).

DLR ATRA research aircraft

The Airbus A320-232 D-ATRA, DLR's largest fleet member, has been in operation since the end of 2008.

Credit: DLR (CC-BY 3.0).

Contact details for image and video enquiries as well as information regarding DLR's terms of use can be found on the DLR portal imprint.