ETW NEWS

EUROPEAN TRANSONIC WINDTUNNEL

Issue No. 15 | June 2008

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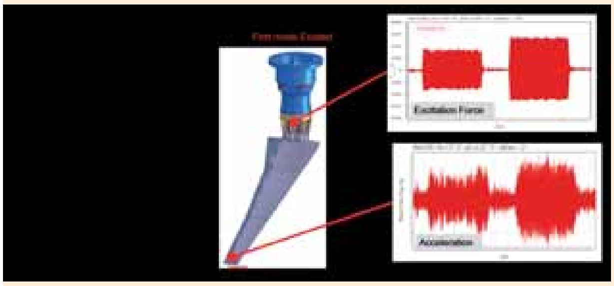
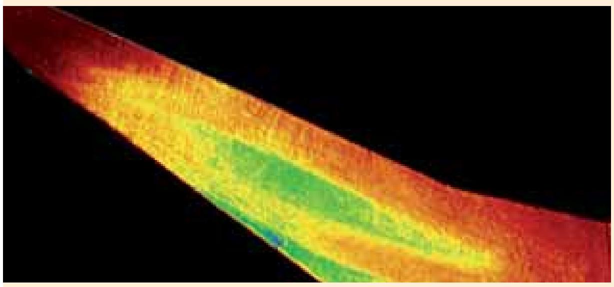


In the frame of the HIRENASD Project the first aeroelastic experiment was successfully performed in the entire test envelope of ETW using a half model assembly. The main objective was to improve the understanding of aero-structural interaction in the transonic speed regime up to flight Reynolds numbers of transport aircraft.

Various commercial aircraft and EU test campaigns were performed successfully and the high test productivity was demonstrated in several overlapping client campaigns. By using all three client areas for model preparation in parallel 12 client campaigns were performed in 2007.



The main topics of the development work at ETW were concentrated on further improvements of existing techniques such as TSP and PSP for industrial application. Especially in the ongoing EU projects, Pressure Sensitive Co-Polymer, Hot Film and Hot Wire techniques were enhanced and applied.

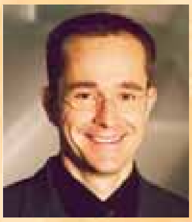
EDITORIAL

20 Years European Transonic Windtunnel ETW

20 years ago, the cryogenic European Transonic Windtunnel ETW in Cologne started to become reality. The ETW Company was founded on 28 April 1988 by the four governments of France, United Kingdom, The Netherlands, and Germany with the associates ONERA, UK Ministry of Defence, NLR, and DLR as shareholders. On the occasion of the Company's 20th anniversary, the ETW team met its Supervisory Board in Cologne. Today, ETW is established as the worldwide leading aeronautical wind-tunnel facility.

The history of this unique enterprise started even earlier: In 1978, the four participating countries initiated the preliminary design of the ETW. A highly experienced multi-national integrated team advanced the project, involving future industrial users. A minimum set of functional key specifications were developed, validated by feasibility studies including a pilot facility PETW, and linked by a simple set of detailed interfaces. These basic specifications remained unchanged during the construction which started on the Cologne site in 1990. In 1992, the ETW facility was completed within schedule and under budget. With the first fully paid test campaign in 1996 ETW started to be used by aircraft manufacturers from all over the world.

The flow in the European Transonic Windtunnel ETW consists of pure nitrogen gas, which can be cooled down to minus 163° C (-261° F) and pressurized up to 4.5 bar. This cryogenic operation enables ETW to provide data which fit to in-flight data of modern large transport aircraft with an absolutely unique accuracy: Scaled to flight, the ETW data match flight-test data better than 99%. In this way, ETW offers a very cost-effective substitute for flight testing and also complements advanced numerical simulation techniques by providing reliable data even in complex flow conditions. Aircraft performance and its flight envelope limits can be checked accurately long before flight testing of the first prototype. Thus, ETW provides exclusive risk mitigation capabilities, and enables the aircraft manufacturers to design competitive and environmental-compatible aircraft with a maximum time-cost-quality benefit. Furthermore, ETW contributes to accelerate the innovation speed from science to application by providing easy, riskless access to real-flight conditions in a ground-test facility to the academia.



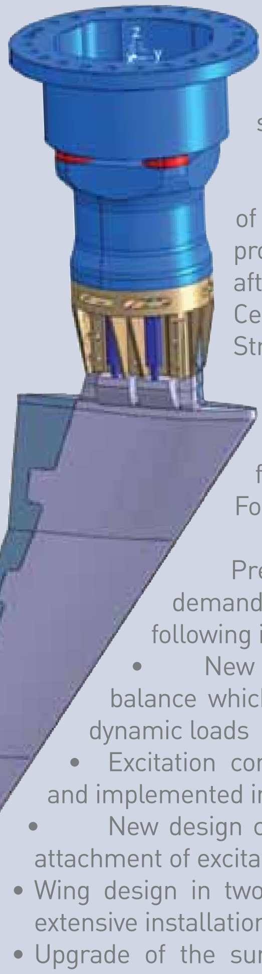
Dr.-Ing. Guido DIETZ was appointed Managing Director of the European Transonic Windtunnel GmbH from 1st July 2007.

Dr. DIETZ was born 1967 in Cologne. He graduated in aerospace engineering at the RWTH Aachen University in 1992. Following graduation, he started his professional career as a scientific assistant at the Institute of Aerodynamics of the RWTH Aachen University where he obtained his doctorate degree. From 1999 to 2003, he worked for the German Aerospace Center DLR at the Institute of Aeroelasticity in Goettingen where he gained extensive experience in the area of nonlinear transonic aeroelasticity. Later he was responsible for aeroelastic testing at DLR as head of department.

Dr. DIETZ has worked with colleagues in universities, research establishments and industry partners across the world. He was awarded four prizes, and has published more than 30 articles, as well as other publications and inventions as author or co-author.

AERO-STRUCTURAL DYNAMICAL INTERACTION
at High Reynolds Numbers

The HIRENASD Project (High Reynolds Number Aero-Structural Dynamics) funded by the German Research Foundation DFG was performed at ETW during an extensive test campaign in November 2006 by a research team under the leadership of RWTH Aachen University. The main objective was to improve the understanding of aero-structural interaction in the transonic speed regime up to flight Reynolds numbers of transport aircraft.



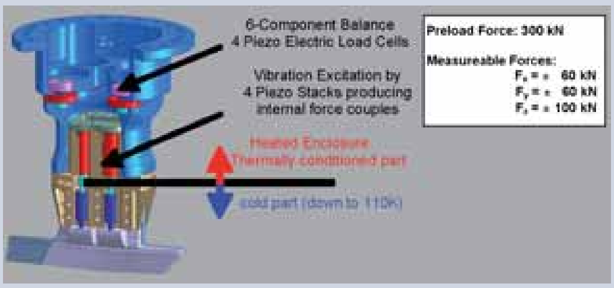
The inherently nonlinear transonic flow is assumed to cause two well-known aeroelastic phenomena in the interaction with a typical transport-aircraft structure: firstly, in the "transonic dip", the flutter speed shows a noticeable minimum between the critical Mach number where local supersonic regions occur in the flowfield and the Mach number where massive flow separation possibly limits the operational flight regime of an aircraft; secondly, amplitude-limited oscillations of the structure, so-called limit-cycle oscillations (LCOs), may occur instead of "classical" flutter where exponentially growing and destructive structural oscillations occur at flight speeds above the critical flutter speed. Shock-wave dynamics, shock-wave / boundary-layer interaction and flow separation govern the flutter boundary shape and the LCO manifestations. Thus transonic aeroelasticity is highly Reynolds-number dependent. Numerical simulation methods for predicting the related unsteady aerodynamics still need to be improved significantly. However, so far little information has been gained in wind tunnel experiments with oscillating elastic wings in the transonic regime at flight Reynolds numbers of large transport aircraft, which may be used to select the appropriate simulation methods and to validate the resulting tools.

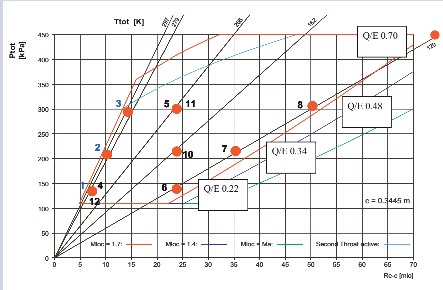
Such a validation of numerical methods, investigations on aero-structural dynamic interactions during forced vibration excitation and subsequent oscillation decay, the assessment of wing deformation with frequencies up to 350 Hz and the availability of aeroelastic data freely accessible for aeroelastic research were special objectives defined by the client RWTH Aachen University for this challenging project. Using the important advantage of ETW of independently varying the parameters of Mach number, Reynolds number and structural loads the influence on the aeroelastic behaviour of the wing was investigated systematically.

With continuous involvement of ETW, the detail planning of the project was started immediately after the Collaborative Research Center Flow Modulation and Fluid-Structure Interaction at Airplane Wings (SFB 401) at RWTH Aachen University received the approval in December 2003 from the German Research Foundation (DFG).

Preparatory work for several demanding requirements included the following items:

- New Piezo load-cell based half model balance which is very stiff, and admits high dynamic loads
- Excitation compartment to be designed for and implemented in the cryogenic environment
- New design concept for half model wing for attachment of excitation system
- Wing design in two half covers in order to allow extensive installation of wing instrumentation
- Upgrade of the surface model-deformation measuring system with new high-speed link using fibre-optic cables and new high-frequency flash lights
- Clamping mechanism for the ETW turntable to sustain the expected highly dynamic model loads
- High-speed dynamic data-acquisition system for more than 300 channels to be incorporated
- Huge amount of cabling to be routed through wind tunnel and to be connected





This preparation included the removal of the complete top wall structure of Model Cart 1 to install a clamping device for the model assembly and the new equipment inside the support structure for the half model balances.

The selected supercritical wing model was constructed with focus on dynamic dimensioning with clearly separated modal frequencies. Additionally the internal structure was designed to achieve the highest Reynolds numbers at a dynamic pressure of up to 130 kPa.

A fuselage substitute was used to alleviate the influence of the test section ceiling boundary layer. To avoid mechanical contact with the wing a round arch labyrinth sealing was implemented in the substitute.

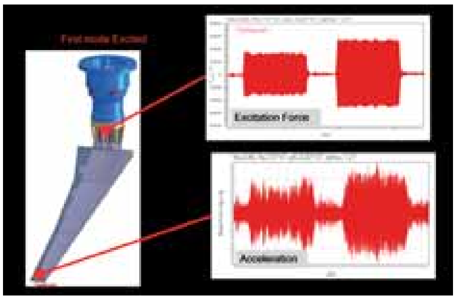
The test assembly was checked extensively in a laboratory set-up prior to delivery to ETW. The calibration of the Piezo Balance was performed in September 2006 at ETW and the rigging started in October.

The complex installation of all instrumentation and measuring techniques involved in the test assembly required significant effort and very careful procedures of all participants.

The model is equipped with 259 Kulites in 7 spanwise cross sections, 28 strain gauges of which 22 are distributed in the wing structure, 11 wing accelerometers and several temperature sensors. All this instrumentation was recorded synchronized with the model excitation by the mobile DLR data-acquisition system TEDAS. Selected balance, accelerometer and strain gauge signals were also monitored simultaneously by the ETW data-acquisition system.

The Stereo Pattern Tracking (SPT) system of ETW was upgraded within the project to a high-speed deformation measuring system for capturing oscillation frequencies up to 400 Hz. The existing illumination by a flash light system was improved to 1 kHz system with increased intensity by factor 8. Flexible reflector settings and new lamp housings combined with a sophisticated high-voltage control system had to be developed. The final steady-state calibration was performed by using the existing ETW calibration frame.

During the test campaign performed in November 2006, Mach numbers up to M=0.88 could be achieved at a Reynolds number of 73 million using a tunnel temperature of 120 K. The tunnel envelope boundary was successfully reached in these conditions. The experimental data have been gathered in a wide range of Reynolds numbers and aerodynamic loading as indicated in the test envelope.



By summarizing the first experience of this unique experiment the following points can be highlighted:

- Half-Model Dynamic-Test capabilities successfully demonstrated at Reynolds numbers between 7 and 73 million
- High-speed model-deformation assessment at different pressure levels
- Excitation-synchronized DLR acquisition system used to acquire high-speed data
- 9 Test Points between 300K and 120K
- 4 Q/E Levels between $0.22\ 10^{-6}$ and $0.7\ 10^{-6}$
- 6 Mach numbers between 0.7 and 0.88
- Detailed analysis of the valuable data sets ongoing
- Follow-on test with client models under consideration

The present test significantly increased the ETW capabilities and experiences in gaining data sets of unsteady aerodynamic responses to forced model oscillations, e.g. for aeroelastic assessment or tool tuning. The applied test techniques may also be used in full-span model forced-oscillation testing using the ETW-AVS anti-vibration system in active mode as exciter.

References:

Ballmann, J. et al.: Experimental Analysis of High Reynolds Number Aero-Structural Dynamics in ETW. 46th AIAA Aerospace Sciences Meeting and Exhibit (ASME) 2008, Reno, Nevada, paper no. 2008-841

Reimer, L., Braun, C., Chen, B.-H., Ballmann, J.: Computational Aeroelastic Design and Analysis of the HIRENASD Wind Tunnel Model and Tests. International Forum on Aeroelasticity and Structural Dynamics (IFASD) 2007, Stockholm, Sweden, paper IF 071

Dafnis, A., Korsch, H., Buxel, C., Reimerdes, H.-G.: Dynamic Response of the HIRENASD Elastic Wing Model under Wind-off and Wind-on Conditions. International Forum on Aeroelasticity and Structural Dynamics (IFASD) 2007, Stockholm, Sweden, paper IF 073

CLIENT TESTING

Business as usual

Airbus

performed several test campaigns in preparation for the A350 XWB programme during the first half of 2007. In the second half, several project campaigns were performed, including twin sting investigations. All tests used ETW's SPT (Stereo Pattern Tracking) deformation measurement system. In addition, half model testing for several high lift configurations was finished in time. The tight time schedule was kept as originally planned and the data provided to the client were of high value at this early stage in the development. ETW's flight Reynolds-number test capability allows to distinguish aeroelastic and Reynolds-number effects.

The Boeing Company

performed a test in ETW at transonic speeds and high Reynolds numbers with a full-span scale model of a twin-engine transport aircraft. The test evaluated data quality, productivity and efficiency in detailed test sequences covering the entire test envelope of ETW for several aircraft configurations. The same aft-sting mounting structure was used in both ETW and related tests at NTF (National Transonic Facility at NASA Langley in U.S.A.) to allow back-to-back comparison of test results obtained in these unique cryogenic facilities that enable testing up to flight Reynolds numbers. After successful completion of the test at the ETW, Boeing confirmed that excellent data quality was achieved while maintaining high test productivity and efficiency at the extreme tunnel conditions.

EU Projects - FLIRET

The FLIRET (Flight Reynolds Number Testing) R&T project aims at improving the quality of aircraft performance predictions, utilising advanced design rules for wind-tunnel model mounting devices and improved scaling / data correction procedures. Different sting and half model mounting devices were designed and used in several test campaigns performed at the end of 2007 and beginning of 2008. A front blade support was tested successfully, using the ETW Piezo Anti-Vibration System in a reversed installation at the front of a rear fuselage balance. These tests will allow further understanding of flow phenomena and Reynolds- / Mach-number effects on mounting devices in order to minimise their effects in the wind tunnel. All experimental data will be compared to extensive CFD analysis performed in parallel.

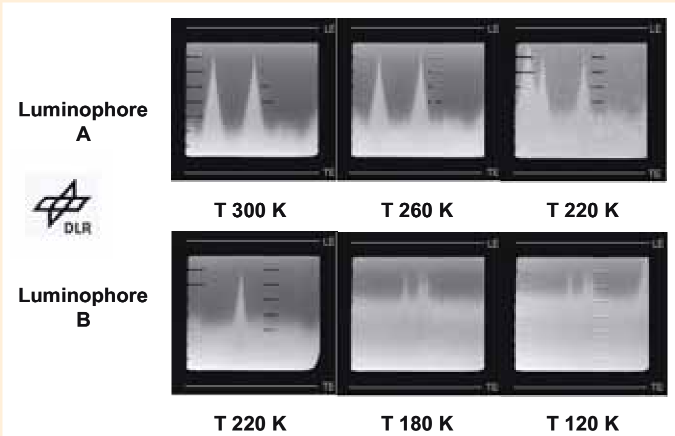
DEVELOPMENTS
for increasing testing capabilities

Temperature Sensitive Paint TSP covering the full temperature range (co-operation with DLR, ETW/DLR patent)

- A new bi-luminophore paint has been developed and successfully tested firstly in PETW followed by tests in ETW in 2007.
- An improved flashlight system and housings for UV-application have been developed as well as the capability for unsteady measurements up to 1 kHz.
- New camera housings with full pan & tilt capability have been developed with integrated LED illumination for the temperature range below 220 K.
- A new interface has been developed to enable faster communication with the ETW-Main Control.
- Software improvements have been incorporated for quick post-processing using DLR's TOPAS software.
- The new TSP system is now able to simultaneously perform transition assessment on upper and lower wing surfaces in lateral testing (generated by pitch & roll); by using 4 flash-lights and 4 cameras.

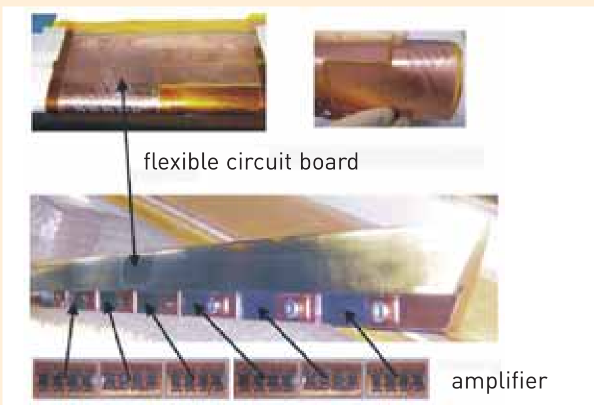
Pressure Sensitive Co-Polymer PSC Hot Film in co-operation with DLR; Hot Wire in co-operation with TU-Berlin

- Hot-film and hot-wire arrays have been adapted, validated and successfully tested down to 120K in PETW / ETW within the EU project EUROLIFT2.
- Pressure Sensitive Co-polymer (PSC) have been developed for installation / embedding in model surfaces offering the ability to acquire frequency responses up to 100KHz.
- PSC has been used in the EU projects FLIRET (PETW & ETW) and TELFONA (PETW).
- Manufacturing and handling have been improved due to "lessons learned" from the EU project TELFONA during tests in ETW.
- TU-Berlin was the partner responsible for the operation and analysis of the PSC technique.
- A calibration procedure is under development to enable quantitative measurement in future applications.



Pressure Sensitive Paint PSP for application in cryogenic environment (co-operation with DLR)

- The new paint improves the luminescent intensity by a factor of 10. The image acquisition time has been reduced from 30 s/image to 3 s/image.
- A reference dye is now used to reduce errors due to model deformation.
- The light source has been modified to make use of LED technology which is able to excite PSP uniformly.
- Image and data acquisition processing is now able to be achieved in real time during the test using DLR's TOPAS software.
- The interaction of all enhancements together was successfully evaluated in a pre-test in PETW and will be followed by an entry in ETW in 2008.
- Further enhancements by alternative polymers and lifetime technique are also being assessed and are currently awaiting the outcome of ambient development tests.
- The application of PSP to unsteady and low speed cryo tests is currently under discussion.



European Transonic Windtunnel

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ETW – DLR Co-operation Contract

Long-term cooperation contract signed 8 October 2007 by Prof. Dr. Dillmann and Dr. Dietz

Main objectives: Get Temperature-Sensitive Paint TSP, Pressure-Sensitive Paint PSP, and Particle-Image Velocimetry PIV cryo-proof and productive for industrial testing

Recent Conferences and Exhibitions

45/46 AIAA Aerospace Science Meetings Reno
January 2007 and 2008

Aerospace Testing Expo Europe München
April 2007

AIRTECH Frankfurt
October 2007

ILA Berlin
May 2008

PETW

The Pilot facility of ETW has a test section size of 0.23m x 0.27m and identical operating conditions to ETW. Nowadays it is used for special development work aiming for the standard use of dedicated measuring and visualization techniques for client testing. I.e. test equipment, paints and test techniques were developed in close co-operation with DLR for Temperature Sensitive Paint and Pressure Sensitive Paint. The delicate injection of pure oxygen was performed in test trials within the Pressure Sensitive Paint development. The application of Liquid Crystals was done first in PETW as well as the installation of Hot Wire Probes, Hot Film elements and Pressure Sensitive Co-polymer. Laser techniques (DGV, PIV) were installed first at the PETW since the external insulation box concept of the Pilot facility allows easy access to the test section area. Different methods of particle injection were tried and further improvement of these techniques is currently ongoing. Calibration of 5-hole Probes was performed for clients.