European Transonic Windtunnel GmbH
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News

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Client's views about ETW:
Modern Windtunnel Testing for a Challenging Design

After three test campaigns performed at ETW in 2002 and 2003 with the F7X Half Model, the following article was published in the internal *"Dassault Magazine"* n°129, winter 2003. It was partly translated and copied for this *ETW Newsletter* with the kind authorisation of Dassault Aviation.

State of the Art Aerodynamics for the Dassault FALCON 7X

The commercial success of our Falcons over the past thirty years has relied on the reputation of the Dassault aircraft in various domains, among them the quality of their aerodynamic conception. Therefore, the performance specifications for the Falcon 7X constituted a real challenge for our aerodynamicists.

The major challenge for the Falcon 7X lies in the design of a new wing, which will equip the complete family of our future Falcons.

The complexity of the aerodynamic phenomena required the establishment of a new approach in aerodynamic design: the intensive use of the most advanced computational software, together with the most modern wind tunnel tests and technical means, like ETW (the European Transonic Windtunnel).

The combined use of the most elaborate theoretical analysis and of the direct comparison with the most modern experimental results allows a reduction of the total number of iterations before defining the final wing shapes selected for the aircraft.

Started in 1993, the European Transonic Windtunnel is a world class wind tunnel which allows to simulate with reduced-scale models the actual flight conditions of an aircraft in cruise flight at high altitude. This wind tunnel is particularly adapted to the validation of a new wing and the improvement of the understanding of local flow phenomena.

The progresses made in numerical modelling and experimental techniques complement each other in perfect harmony: the tests at ETW allowed validation of the design choices for the new falcon 7X wing, and validation in the finest details of the actual accuracy of the computation results. Without this cryogenic windtunnel, it would be impossible to know the reliability and applicability limits of the numerical models.

The results obtained in early 2002 at ETW confirmed the pertinence of our new approach. The comparison between tests and computations has been very satisfying and this has validated the methodology for use of the numerical models. The knowledge of the performances at real flight conditions allowed an improvement of the operating modes and of the transposition rules for all the traditional windtunnels used for the complete development of the Falcon 7X.

The final definition of the aircraft is a long and hard process, and there is no 100% guarantee of success until the first flight tests take place in 2005, however the results obtained so far are very promising.

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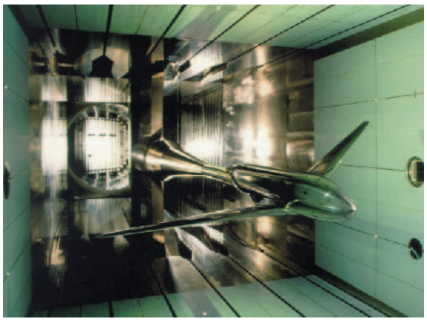
Translation by ETW

HiReTT - High Reynolds Number Investigations Completed at ETW

The collaborative research project HiReTT (**Hi**gh **Re**ynolds Number **T**ools and **T**echniques for Civil Aircraft Design) is focused on understanding the effects of scale on aircraft performance and establishing a capability to account for these effects within the aircraft development and design process. The project, performed by a consortium of industry and research centres*, including ETW, was launched in January 2000 as part of the Key Action Aeronautics within the Fifth Research Framework Programme of the European Union. The HiReTT project aims to deliver a capability to accurately predict aircraft flight performance to the European aerospace industry, using appropriate wind tunnel test and CFD methods, and to be able to exploit the benefits of designing at flight Reynolds number. The project activities at ETW encompassed the following key objectives from the complete HiReTT project:

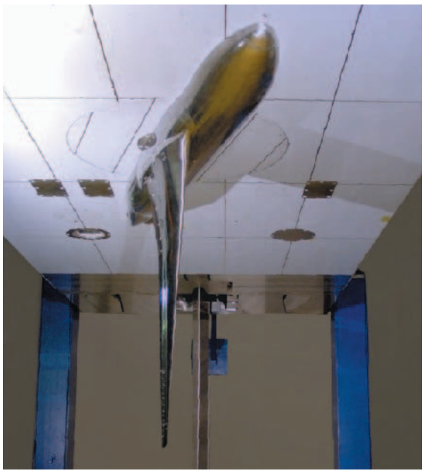
- To obtain high quality experimental data for a modern aircraft research configuration with and without control devices, at flight representative Reynolds numbers at high subsonic Mach number (mainly within range 0.85 to 0.89) compatible with the operating conditions of future, conventional, medium to long range commercial aircraft.
- To derive accurate sting interference effects using two alternative twin sting techniques and to assess the merits of these methods for closely coupled wing-fuselage configurations at high Reynolds numbers.

The first experimental investigations to be performed within the HiReTT project were a series of single sting tests. These tests used an existing cryogenic wind tunnel full span research model with free and fixed transition across a Reynolds number range from 4 to 42 million. The test programme was devised to separate the Reynolds number and wing deformation effects, and measurements including forces, moments, surface pressures, and transition detection. The model was equipped with pressure plotting at seven spanwise stations and in line with standard practice at ETW these were acquired simultaneously with the forces and moments measured by a high quality six component balance. The tests also included the measurement of wing deformation using ETW's Model Deformation Measurement System (MDMS).

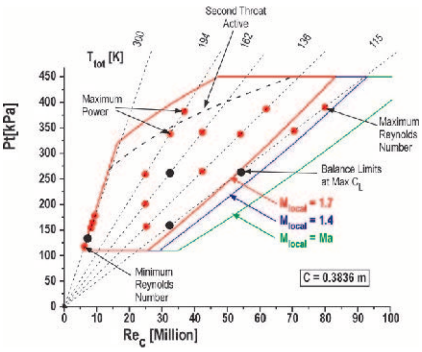


The main test objective of the second part of the HiReTT programme was to commission and develop the capability to establish a database, using two different measurement techniques, from which sting interference effects on lift, drag and pitching moment may be derived and subsequently applied to the single sting database described above. The first method used the 'Live Rear Fuselage' (LRF) twin sting technique to derive sting corrections from the net measurements on a metric rear fuselage. The second method used the 'Live Complete Model' (LCM) twin sting technique to derive sting corrections from the net measurements on the complete model by using newly developed twin wing mounted six component balances. The application of the resulting sting corrections to the single sting dataset will enable a fully corrected dataset to be created for a substantial range of test conditions.

The third part of the HiReTT experimental programme was performed in August 2002. It used a half model version of the same generic design used in the first two entries. Again, the test programme was devised to separate the Reynolds number and wing deformation effects including extension of the clean wing database up to flight design Reynolds numbers of 80 million at high transonic Mach numbers. In addition several control deflection combinations were tested to assess control effectiveness over a wide range of design and off-design conditions.



This was the first half model test to cover the complete range of ETW's operating envelope and an example is provided below for the design Mach number.



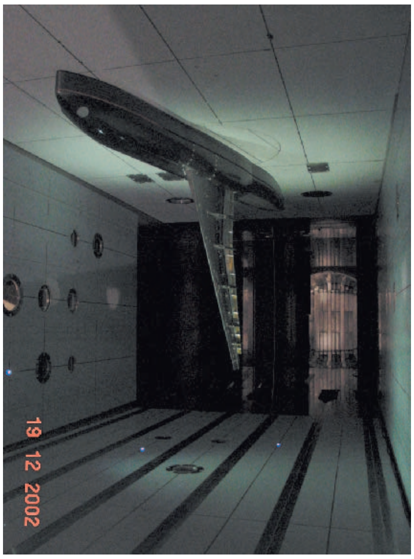
The completion of the HiReTT experimental investigations at ETW has produced a valuable database that is complementary to the CFD work packages and will allow code validations for high Reynolds numbers. The results will assist industry by providing and validating the tools and techniques required to determine aircraft performance at flight Reynolds numbers within the design process.

* The HiReTT project is a collaboration between Airbus UK, Airbus Germany, Airbus France, ETW, DLR, ONERA, NLR, QinetiQ, RWTH Aachen, and Politechnika Warszawska.

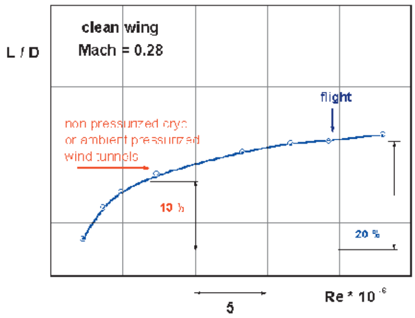
EUROLIFT - High Reynolds Number Investigations in Low Speed with High Lift Systems

Three project phases of the EUROLIFT programme were completed successfully in ETW during the period July 2000 to December 2002. The first entry with the 1/13.6 scale A321 half model targeted for validation testing of ETW for low speed testing of high lift configurations. After extensive comparisons with relevant results from different wind tunnels, the good agreement of data convinced the participating partners to proceed and ETW was declared generally qualified.

The second test campaign was performed in May/June 2002 using a generic design of an A380 type aircraft in four high lift configurations and two clean wing versions. The main objectives of this phase were to improve the knowledge relating to Reynolds number effects on performance and stall behaviour as well as providing an experimental data base at high Reynolds numbers for the assessment and improvement of CFD codes. Special attention was given to model deformation effects and its influence on aerodynamic data. Since ETW has the capability to vary the dynamic pressure and temperature independently, pure deformation and Reynolds effects were measured directly.



KH3Y Model in ETW Test Section



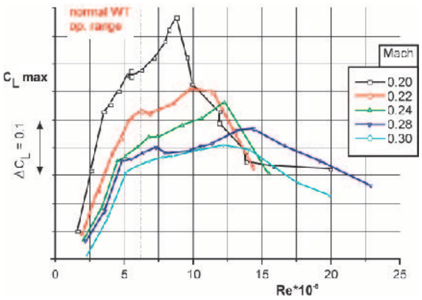
Lift over drag may increase nonlinearly with Reynolds number avoiding classical scaling based on ambient or low Reynolds number results and can lead to substantial errors.

The excellent results were used to prepare the next phase in the EUROLIFT programme.

This third and final phase was performed in November/December 2002. The KH3Y model was tested in 12 different high lift configurations. The main objective of this task was to provide an experimental data base for an advanced high lift system of a realistic aircraft configuration at high Reynolds numbers. At several temperature levels a range of Reynolds numbers was covered, varying the dynamic pressure from 4.3 up to 12 kPa. Then, in order to get pure model deformation effects, data were taken at 2 or 3 different dynamic pressure levels keeping the Reynolds number constant. In phases 1 and 2 the achieved Reynolds number was $20x10^6$, which was increased in phase 3 to $25x10^6$.

Minitufts were used as a common test technique for flow visualization in all three campaigns. In phase 2 the wing was equipped with nearly 500 pressure ports. During this campaign infrared images were also taken and the flap gap deformation was measured with a high resolution miniature CCD camera installed inside the model fuselage.

The test summary pointed out that Reynolds number effects significantly influence the maximum lift values. Even for moderate effects on overall forces the spanwise stall behaviour changes dramatically with Reynolds number. The effects on drag are a mixture of global Reynolds number effects, transition and wing deformation. However, it was obvious that this is strongly dependent on model configuration.



Testing the clean wing configuration of a realistic aircraft revealed an unexpected Reynolds number behaviour of maximum lift. Substantial adverse Re-effects changing with Mach number have been identified. The appearance of complex 3D boundary layer behaviour, combining relaminarisation effects, attachment line transition and separation was quoted by the analysts, underlining the benefit of the capabilities of the wind tunnel.

The final conclusion by the cooperating partners of this European project stated in the final EUROLIFT meeting in March 2003 is cited below:

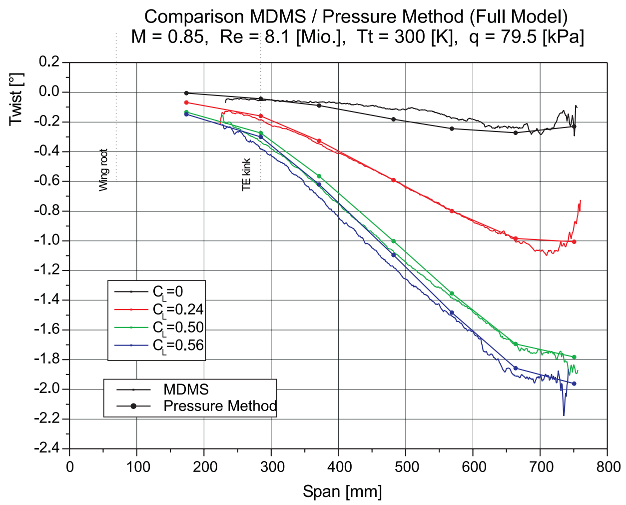
"Experience based extrapolation from low Reynolds number tests to flight is nearly not possible. Detailed measurements in ETW including trailing edge pressures and model deformation in a well balanced combination with validated CFD tools are necessary for true flight predictions."

Techniques for Measuring Model Deflections

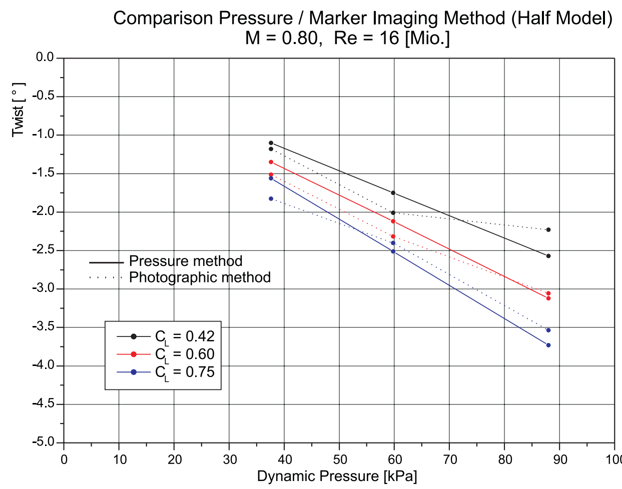
ETW is currently offering its clients three independent methods to determine the wing deflection of a wind tunnel model, the main features are:

Method	Model Requirements	Deflection Information	Applicability
MDMS (Model Deformation Measurement System)	Non-shiny surface	Bending and twist inside an area ≈ field of view of the camera	Full models
Wing Pressure Comparison	6-8 pressure taps per wing section	Twist as function of lift and dynamic pressure at each measured section, bending estimate	Full and half models
Luminiscent Marker Imaging	Inserts with luminiscent paint in the wing tip (or flap track fairing)	Bending and twist at the wing tip (or flap track fairing)	Half (and full) models

In addition, a photogrammetric stereo pattern recognition (SPR) technique using paint targets on the wing is under development to provide an alternative to the luminiscent marker imaging method for half models with only sparse or no pressure plotting.



Wing twist of a full model determined with MDMS and Pressure Comparison Method



Twist of a half model wing tip determined with Pressure Comparison Method and Luminiscent Marker Imaging Method

ETW participated in the recent **Aerospace Testing Expo 2003**, the world's first international exhibition for aerospace testing and testing equipment, held at the International Exhibition and Conference Centre, Hamburg, Germany, from 26 to 28 February 2003.

ETW was represented with a stand in the exhibition hall displaying written information on its capabilities and showing the revised ETW film with the commentary selectable in three languages.

ETW will participate again in the **Aerospace Testing Expo 2004** in Hamburg.

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