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TELFONA

Testing for Laminar Flow on New Aircraft

FP6 - Specific Targeted Research Projects (STREP)

Priority T4 – Aeronautics and Space

Final Publishable Summary

Period covered: From **01/05/2005** To **31/10/2009** **Date of preparation: 29/04/10**

Start date of project: 01/05/2005 **Duration:** 54 Months (revised)

Project coordinator name: David Sawyers

Project coordinator organisation name: Airbus UK **Revision:** v1

Summary of project objectives

The 2020 ACARE targets present a challenge to the aircraft manufacturers to reduce CO_2 emissions through engine efficiency and aircraft design improvements. A “pro-green” aircraft configuration was proposed that had a significantly higher aspect ratio wing and lower wing sweep than today’s standard designs. This reduction in sweep opens the possibility to design a wing for natural laminar flow (NLF). Such a wing could enable 20% wing drag reduction compared to today’s designs.

Therefore, the main objective of TELFONA was to demonstrate the ability to predict NLF aircraft performance in flight based on wind tunnel test and CFD results. This capability would allow industry to validate the design of such an environmentally friendly aircraft concept.

In order to achieve this objective, a number of supporting objectives were defined as listed below:

- Calibration of the ETW facility for testing laminar flow aircraft
- Integration of receptivity modelling into transition prediction methods
- Flight performance methods for a laminar flow aircraft
- Development of technology for future hybrid laminar flow control testing
- Validation of developed methods

Contractors involved

The TELFONA consortium consists of 17 organisations from 9 different countries whose researchers have significant experience in the areas of wing design, laminar flow technology and wind tunnel testing. Airbus (three sites involved) and Piaggio Aero Industries are aircraft manufacturers. There are two other industrial partners - the European Transonic Windtunnel (ETW) is the operator of Europe’s cryogenic wind tunnel facility while Alma Consulting Group is a supplier of project management expertise. CIRA, DLR, FOI, ONERA, VZLU and TsAGI are national research agencies. Instituto Superior Tecnico, Imperial College, KTH, TU Berlin and ITAM are universities.

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Note – Airbus Operations Limited in the new business name for Airbus UK Limited.

Public Summary of Project Activities

The major part of the TELFONA project has been focussed on developing the capability to design natural laminar flow wings and to test them in the European Transonic Windtunnel (ETW).

The first stage of this activity was to establish calibration data for stability analysis methods for ETW. Stability analysis methods can be used to predict where laminar to turbulent boundary layer transition occurs, but they need to be calibrated to the operating environment before being useful.

The TELFONA Pathfinder Wing was designed with this calibration task in mind. The wing geometry was designed by DLR with support from CIRA and ONERA to have specific transition behaviour at different flow conditions. The wing had very low taper in order to minimise spanwise variations in pressure distribution over the majority of the wingspan. The wing was designed to be used with an existing wind tunnel model fuselage of a very large passenger aircraft.

The wind tunnel model of the Pathfinder Wing was designed by Airbus and manufactured by DLR with support from TU Berlin. The instrumentation on the wings consisted of two rows of pressure tappings on upper and lower surfaces separated by zones of Temperature Sensitive Paint (TSP). The use of TSP enables the spanwise variation of transition location across the TSP zones to be measured using cameras installed in the walls of ETW. Application and evaluation of this technology was performed by DLR. An additional piezo-foil sensor was installed by TU Berlin on the lower surface of the port wing in order to be able to detect boundary layer disturbances. The Pathfinder Wing instrumentation was upgraded between tests.

The Pathfinder Wing model was tested in ETW several times during the project. During these tests, data was gathered for the methods calibration task at a number of different Reynolds numbers at the design points defined during the wing design phase. In addition to data gathered from the measurement devices built into the model, flow quality measurements were made by ONERA using cryogenic constant temperature hotwires and acoustic sensors installed in the walls of the ETW test section.

The results from the TSP measurements initially showed a number of turbulent wedges. This was originally thought to be due to model surface imperfections but was realised to be due to particle contamination in the ETW test section attaching itself to the wings. The quality of the results improved as the project partners learned how best to use ETW to minimise this contamination.

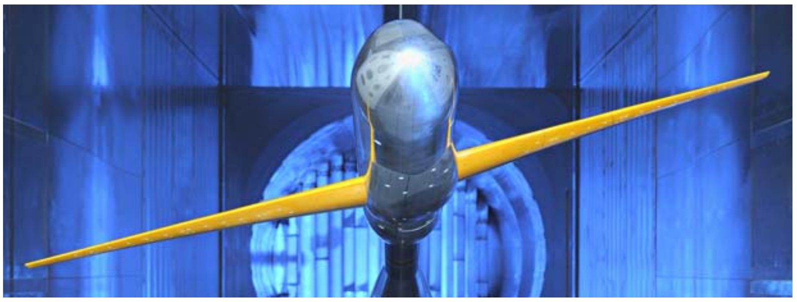
The TSP images were analysed after the test to determine the transition location on both upper and lower surfaces of the wings over the range of test conditions. This information was used along with the pressure measurement information to calibrate the partners' stability analysis methods. The Pathfinder Wing was equipped with a large number of pressure tappings in order to adequately capture the variation of pressure around the wing's leading edge which is essential for calibrating transition methods. Airbus, CIRA, DLR, FOI, Imperial College and ONERA all participated in this calibration activity. The result of this task was that each partner had an understanding of how their particular transition method predicted the laminar flow behaviour in ETW.

The Pathfinder Wing was also used for a number of support tasks related to wind tunnel to flight performance scaling. IST and ONERA performed CFD calculations at low and high Reynolds numbers with fixed and free transition in order to establish the size of likely drag differences. This was followed by an examination of transition zone models, which allow the length of the transition process to be calculated. A further task evaluating the drag impact of transition bands used during low Reynolds number testing was done by VLZU using a wind tunnel model based on the Pathfinder Wing's aerofoil section.

The second stage involved the design and testing of the Performance Wing. Initial aerofoil design studies were done by CIRA and DLR while IST examined the issue of modelling shock/boundary layer interaction using RANS CFD methods. The wing itself was designed by Airbus to be representative of the type of wing that might be used on a future large commercial aircraft. The design process accounted for the knowledge gained in designing and testing the Pathfinder Wing. The wing was designed in the presence of a research fuselage model that is representative of a short range aircraft. The behaviour of the Performance Wing at the proposed ETW test points was calculated by ONERA with support from Imperial College.

The wind tunnel model of the Performance Wing was designed and manufactured by Airbus. The wings were fully coated with TSP in order to get confirmation of the spanwise variation of transition across both surfaces of the wing that hadn't been done for the Pathfinder Wing. The size of the model's wings meant that fewer pressure tappings could be installed than had been used for the Pathfinder Wing.

The Performance Wing model was tested twice in ETW. The model was tested at two different Reynolds numbers and over a range of Mach numbers and CLs. The transition behaviour on the wings was measured using TSP by DLR using an improved process developed along with ETW.



Analysis of the test results from the Performance Wing represented a challenge because the wind tunnel model was not equipped with as many pressure tappings as the Pathfinder Wing had. This situation was overcome by combining wind tunnel test pressures with previous CFD results. The partners involved in transition method calibration used their stability analysis methods to evaluate these test results. The calibration results were then compared with those from the Pathfinder Wing analysis.

The Performance Wing test results were used along with CFD results by Airbus and Piaggio to develop a method of predicting the in-flight performance of an NLF aircraft. These calculations showed how the drag due to turbulent wedges could be accounted for.

Alongside these two major design and test activities, other partners performed support tasks aimed at improving the tools and techniques associated with laminar flow wing design. ITAM worked to develop a new cryogenic hotwire technique based on using a constant current anemometer. This new device was tested in the smaller pilot ETW facility. ETW also collaborated with DLR and TU Berlin to examine how the existing model manufacturing and test techniques would have to be extended if a hybrid laminar flow control (HLFC) wing were to be tested. HLFC introduces the additional complexity of using suction through a porous wing skin along with the aerofoil shape to delay transition.

Additional wind tunnel testing was done by KTH and TsAGI to gather data for calibrating receptivity models. Receptivity models are currently not used during the wing design process but will allow the wing's surface quality and the turbulence and noise levels in the environment to be accounted for when predicting transition. DLR, Imperial College, KTH and TsAGI have contributed to the development of these receptivity models although the original objective of integrating these techniques into transition prediction methods remains to be achieved.

Project management activities have been done by Airbus with significant support from Alma Consulting Group throughout the 54 month duration of the project.

Future application of results

The wind tunnel tests performed within TELFONA were all aimed at generating data that will be used by the partners to increase their understanding of transition mechanisms. Testing has been done in a number of different European wind tunnels including the cryogenic PETW and ETW facilities. It is intended to release some of the Pathfinder Wing ETW test data to the wider research community for further studies.

The tools and design knowledge that has been gathered in the project is now being applied within the Smart Fixed Wing Aircraft part of the JTI Clean Sky to design a Natural Laminar Flow flying demonstrator.

The research organizations and universities in TELFONA will continue to build upon the knowledge gained within the project to develop receptivity modelling software. These new tools will be deployed by industry in the longer term.

A number of new measurement techniques will be available for future use including cryogenic hotwires and pressure sensitive copolymers.