NLF WingHiPer
NLF Wing High Speed Performance Test

State of the art – Background

The overall goal of the CleanSky Smart Fixed Wing Aircraft (SFWA) project was the development and implementation of an all new smart wing design to reach the “Vision 2020” goals of the European Union. Those targets comprise a significant reduction of greenhouse gases produced by air travel, a reduction of noise emissions and finally the increase of European competitiveness in the field of air transport.

The new smart wing design shall include a robust "laminar performance" under typical flight conditions. Natural Laminar Flow (NLF) is established as a key Technology Stream within the SFWA programme. As part of the process to mature that technology to a Technology Readiness Level of 6, wind tunnel tests at high Reynolds numbers have been performed in the past to investigate the impact of surface quality, e.g. waves and steps, on the robustness of laminar flow. As a next logical step performance tests were to be carried out in a suitable wind tunnel for the assessment of relevant aerodynamic coefficients around true flight conditions.

Objectives

The major aim of the tests was to perform reliable and high quality procedures for laminar wing testing under and near flight conditions at high Reynolds numbers in ETW. Besides confirming a number of already mature and successfully applied measuring techniques, these investigations allowed to validate a new evaluation process by quantitatively determining areas of turbulent flow on the wing, e.g. generated by turbulent wedges inside the laminar flow region. Calculating the difference in drag due to laminar and turbulent flow by post-processing forms a tool for correcting the overall drag as measured by the balance.

Description of work

ETW´s capabilities were used to investigate the impact of wing-surface imperfections such as surface steps and surface waviness to the aircraft performance. The model featured a separate pressure control system and internal pressure measurement; ETW provided and controlled inert gases at steady pressures up to 30 bar. The model instrumentation included conventional pressure taps on both sides of the wing and the half fuselage, internal pressure measurements, cryo-TSP areas on both, top and bottom wing surfaces, internal space and attachments to as well as a 6-component balance, accelerometers, and markers for optical wing deformation measurement. The wind tunnel entry was scheduled for the third and fourth quarter of 2014 covering Mach numbers from M=0.73 up to M=0.77 in 0.01 increments and Reynolds numbers of 6, 9, (12) and 16 million. The later interpretation of the gathered results was in the responsibility of the relevant SFWA team.

TSP images were taken at an agreed number of lift values allowing for an eventual correction of drag data acquired by the balance as part of the client’s post processing procedure. With regard to the high Re-number investigations carried out, special attention was given to a suitable surface quality of the temperature sensitive paint (TSP) as small imperfections may affect the results and, hence, reduce the quality of the results.

This allowed for a comparison of performance results gathered for different surface quality conditions like tiny transition bands at different chord positions, but also provided a platform for correction of drag due to accidentally appearing turbulent wedges. The surface quality, especially in the region of the leading edge, was inspected before and after each test block as far as the tunnel operation permitted the access.

Selected configurations were tested also under varied conditions for analysing the effect of individual parameters.

Results

The development of aircrafts with a large extent of natural laminar flow (NLF) on its surface represents the most promising aspect for a substantial reduction of drag. The objective of this project was therefore the sophisticated investigation of the effect of surface imperfections on the development and stability of laminar flow.

At a real aircraft, steps, waviness (either from manufacturing or deformation under cruise loads), 3D disturbances (by insects or rivet heads), and roughness at the leading edge (either from manufacturing or erosion under operational conditions) are seen as a design challenge. The results provide significant input to the design of the flight test planned within CleanSky SFWA using an A340-300 aircraft with both outer wings modified for demonstration of laminar technology. There, a complete new wing structure which is as near as possible to a production standard required for a laminar wing structure concept shall be used. Thus, the project directly contributes to mature laminar flow technology to a Technology Readiness Level of 6.

At the end of the testing the knowledge about the sensitivity of laminar flow development over wings on local shape imperfections was improved considerably. The gathered results will allow specifying manufacturing tolerances and surface finish for real aircraft level scale.

Regarding the wind tunnel the gathered experience allows improving model preparation and test sequences for such type of investigations and expanding the unique competence of the facility for further future similar investigations.

a) Timeline & main milestones

The test campaign started around calendar week 28, 2014.

When testing, provisional results were provided online during the scheduled 3 weeks test campaign. The final fully corrected data set was delivered one to two weeks after the end of the experimental investigations in the tunnel. A 10 weeks period was planned to deliver all TSP images and data, to complete the specified reporting and to cover the dissemination activities.

Milestone No.	**Milestone name**	**WPs involved**	**Expected date** (calendar weeks 2014)
M 1	Internal Pressure System ready	1	31
M 2	Model & WT ready for testing	2	36
M 3	WT Test completed	3	39
M 4	Project Completion	4	51

b) Environmental benefits

The experiments improved the understanding of the flow and the performance of airplanes and are an indispensable tool for airframe manufacturers. Aircraft designers, researchers and scientists will benefit from the provided additional information with respect to the physical interaction between flow and structures. Their findings may result in an enhanced knowledge on material properties, passenger comfort, flight safety as well as in the reduction of noise and greenhouse gases.

b) Dissemination / Communication

ETW informed about the project via press releases, its information brochure “ETW News” and the company´s documentation of European research activities – all available on the ETW website.

In agreement with Clean Sky and other relevant partners the project results will enter into presentations at international conferences.

The company also produced a video film demonstrating the progress in maturing laminar flow technology with special regard to the PSP and TSP technique applied in this project. It will be used to promote further research in this area and can be seen on the ETW website.

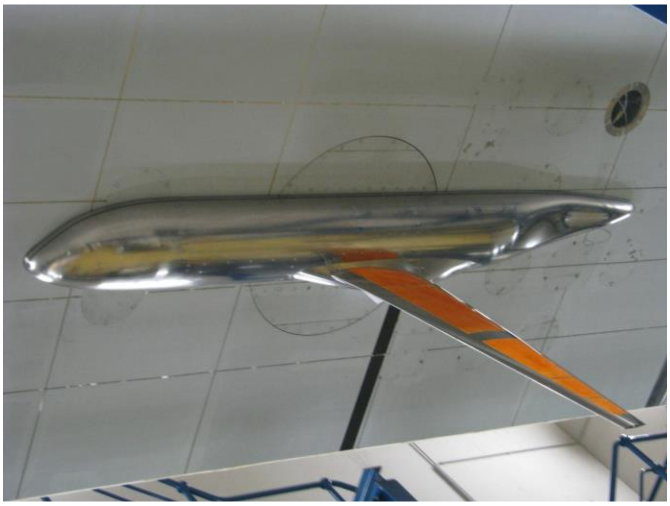

Figure 1: View on the wind tunnel ceiling mounted half model

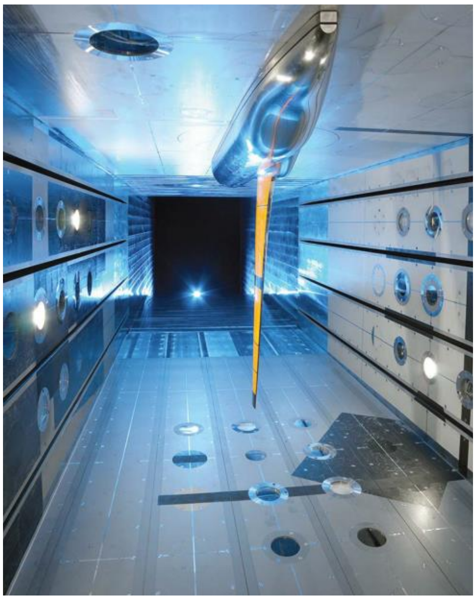

Figure 2: Half model with laminar wing mounted in the test section of the ETW

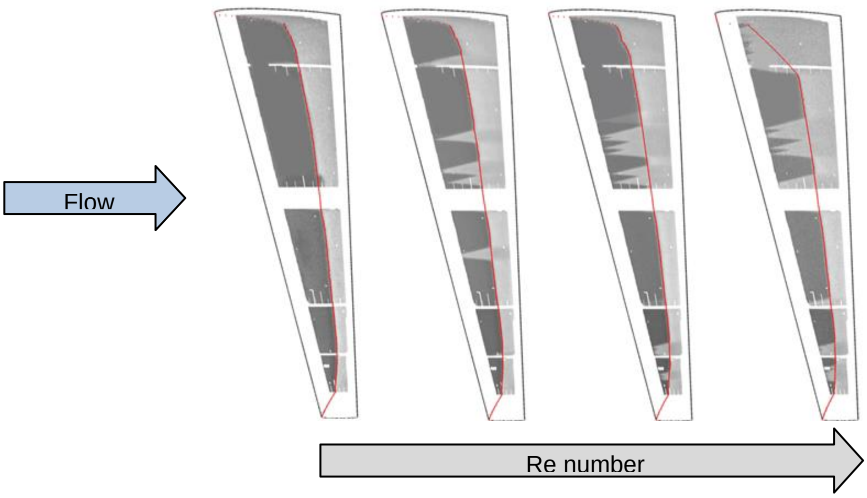

Figure 3: TSP results indicating areas of laminar (dark grey) and turbulent (light grey) flow on the upper model surface for increasing Reynolds numbers

Project Summary

Acronym:	NLF-WingHiPer
Name of proposal:	NLF Wing High Speed Performance Test
Involved ITD	Smart Fixed Wing Aircraft ITD
Grant Agreement:	641455
Instrument:	Clean Sky
Total Cost:	EUR 1 499 384
Clean Sky contribution:	EUR 1 124 538
Call:	JTI-CS-2013-03 SFWA-02-044
Starting date:	01/07/2014
Ending date:	31/03/2015
Duration:	9 months
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