Special Technology Session 8
Drag Reduction Technologies
ECCOMAS CFD 2006

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STS8 – Drag Reduction Technologies

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Programme:

• David Sawyers (AIRBUS), Introduction

• Karl-Heinz Horstmann (DLR) - “Overview on Drag Reduction Technologies”

• David Sawyers (AIRBUS) - “Overview of the TELFONA Project - Drag Reduction by Natural Laminar Flow”

• Eric Coustols (ONERA) - “Supersonic Laminar Flow Control Techniques investigated within the SUPERTRAC Project”

• Marcus Engert (TU Berlin) - “Active Cancellation of TS-instabilities in compressible flows using a closed-loop controller”
The challenge of ACARE2020 (1)

• ACARE has developed a vision for Aeronautics in the year 2020.
• The vision addresses the following areas:
  ‣ Quality and Affordability
  ‣ Safety
  ‣ Environment
  ‣ European Air Transport System
• The Strategic Research Agenda is being used to stimulate research activities in Europe.
The challenge of ACARE2020 (2)

• The environmental targets for aeronautics research are extremely challenging:
  ‣ To reduce fuel consumption and CO2 emissions by 50%
  ‣ To reduce perceived external noise by 50%
  ‣ To reduce NOx by 80%
  ‣ To make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products.

• The first goal translates into a reduction in fuel consumption of 50%.
  ‣ Initial estimates suggest half of this should come from improved aerodynamics.
The response from the research community

- The current configuration for commercial aircraft is mature
  - There are relatively few opportunities to substantially reduce aircraft drag levels
  - Research is needed to examine new configurations

- In addition, there is a clear need for “game changing” drag reduction technologies to be developed.

- Two main opportunities have been identified:
  - Laminar flow control – reduce drag through delaying boundary layer transition
  - Turbulent drag reduction – reduce drag levels through wall structure manipulation
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An Overview of the TELFONA project

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Previous European Laminar Flow research (1)

- Delaying boundary layer transition is a well-known method of reducing drag
- Significant work has been done on Natural Laminar Flow (NLF) research
  - DLR ATTAS aircraft flight tests
  - ELFIN project Fokker F100 aircraft flight tests
  - Development of Piaggio P180 aircraft
Previous European Laminar Flow research (2)

- NLF research activities fed into series of Hybrid Laminar Flow Control research projects
  - It is well known that NLF cannot be applied at very high Re
- European projects (ELFIN/HYLDA/HYLTEC/ALTTA) developed suction technology and identified major show-stoppers
  - Manufacturing surface quality including that of suction panels
  - Need for anti-contamination system
  - Weight of suction system
- New activities on active control of instability waves through use of sensors and actuators.
Why return to NLF research?

• Opportunities to further reduce aircraft drag beyond today’s highly optimised designs require a significant change in aircraft configuration

• HARLS concept = High Aspect Ratio Low Sweep wing configuration optimised for fuel burn rather than operating costs.

• Using a low sweep wing might unlock the option of NLF.

• European FP6 projects used as the basis for exploring this new configuration concept
  ‣ NACRE project will perform multi-disciplinary assessment of turbulent HARLS configurations and study application of NLF to Forward Swept Wing configuration.
  ‣ TELFONA project will develop design concepts for NLF HARLS wing.
Main objectives of TELFONA project

• The overall objective of TELFONA is to demonstrate the NLF aircraft performance in flight based on wind tunnel test and CFD results.

• Top level technical objectives
  ‣ Calibration of ETW for testing laminar flow aircraft
  ‣ Integration of receptivity modelling into transition prediction methods
  ‣ Development of flight performance methods for a laminar flow aircraft
  ‣ Validation of developed methods
TELFONA project structure

• TELFONA is structured around the design, manufacturing, testing and analysis of two wing concepts.

• Pathfinder Wing
  ‣ Objective = Calibrate transition prediction methods for ETW.

• Performance Wing
  ‣ Objective = Demonstrate the performance of the HARLS NLF configuration at flight Reynolds number

• Additional activities include transition methods development and development of new measurement techniques.
Development of the Pathfinder Wing
Pathfinder Wing objective

• The main objective for the first phase of TELFONA is to produce the data to calibrate transition prediction methods for ETW flow conditions
  ‣ Calibration required to enable methods to be used in design activities
  ‣ Different “N” levels apply in flight and in different wind tunnels

• This calibration will be done using a wing specifically designed for this purpose – the Pathfinder Wing
• This wing is designed to generate pressure distributions which give well-behaved N-factor curves
• Wing will be tested on existing Airbus wind tunnel model fuselage – X55.
Basic design specification

- Design Mach No - M=0.78
- Re = 20 million (close to limit of NLF)
- Leading edge sweep angle = 18 degrees
- Taper = 0.8
- Model wing span = 1.8 metres
  - Needs to fit inside ETW!
- Model can be yawed +/-4 degrees to vary cross-flow conditions
- 3D wing needs constant chord isobars over mid-span region
Aerofoil design activities (1)

• CIRA, DLR and ONERA have designed suitable aerofoils for the Pathfinder Wing using their preferred linear transition prediction methods

• CIRA02M6N aerofoil designed using genetic algorithm model linked to MSES Euler 2.5D flow code + ONERA/CIRA database transition method
Aerofoil design activities (2)

• ONERA aerofoil designed to have specific behaviour on u/s at –1deg and on l/s at +1deg.
Analysis of aerofoil designs

- Final aerofoils checked through 3 partners’ transition methods – DLR’s LV5 aerofoil selected for 3D wing
Wing design activities

• DLR was responsible for the 3D design of the Pathfinder Wing
• Wing designed using 3D inverse CFD method to have the same CP behaviour as the LV5 aerofoil
Selection of test points (1)

- The main test cases for the Pathfinder Wing need to be carefully chosen.
- CFD has been used to calculate pressure data at a range of \((\alpha, \beta, M)\) conditions.

\[ 0.300 < \eta < 0.6 \]
\[ CL = 0.2163 \]  
\[ M = 0.78 \]

\[ 0.300 < \eta < 0.6 \]
\[ CL = 0.2163 \]
\[ M = 0.78, C_l = 0.2163 (\eta = 0) \]
Selection of test points (2)

• Airbus have done linear stability calculations for the range of possible test cases.
• The aim for this is to select a number of cases demonstrating pure cross-flow (CF), pure Tollmien-Schlichting (TS) and mixed transition modes.
• Final selection still to be made as calculations continue.
Designing the wind tunnel model (1)

- Aerodynamic surface data supplied by DLR to Airbus
- Airbus is responsible for designing the model hardware – DLR is responsible for manufacture
- Three measurement techniques
  - Pressure tappings
  - Temperature Sensitive Paint (TSP)
  - Piezo-layer
- Location of pressure tappings need to avoid causing transition on TSP area.
- Pressure tapping locations proposed to ensure best possible input to laminar boundary layer (BL) solver around attachment line within practical constraints
Designing the wind tunnel model (2)

• TSP and Piezo-layers will be used to determine transition
  ‣ TSP over mid-span region of wing
• Piezo-layer on outer wing lower surface
  ‣ Best location for detection of TS waves

Example TSP image
Re = 12 mill
Validation of measurement techniques

• Proposed measurement techniques are to be validated using pilot ETW test on NLF aerofoil model as part of specific task on generating boundary layer receptivity data
• Model designed/manufactured by TU Berlin.
• Piezo-sensors to be used to detect high frequency BL disturbances (<100kHz)
• Initial non-parallel stability calcs by Imperial College – used to size wing chord
• Data to be supplied to TELFONA Receptivity task team
Pathfinder Wing – current status

• Model is designed and waiting for manufacture
• ETW test is now targeted at Q1/07 – delay from original plans but no impact on overall time schedules
• Test programme to be finalised
Development of the Performance Wing
Development of the Performance Wing

• The development of the Performance Wing is the main activity in the second phase of TELFONA
• The aim is to demonstrate the performance potential of the HARLS NLF configuration at flight Reynolds number
• Activity on this task has just started – development of design constraints
• Plan to use the NACRE HARLS baseline as the starting point for design studies
  ‣ Options for planform modifications to be studied using section design studies (CIRA, DLR, IST)
  ‣ Modified wing concept to be used as input to 3D wing design stage (Airbus)
• Wing to be tested in ETW in Jan 2008
• Tunnel-to-flight corrections to be made to provide aircraft performance standard.
Conclusions

• A new Pathfinder Wing geometry has been developed with the specific aim of calibrating transition prediction methods in ETW
• The wind tunnel model will use different measurement techniques to record flow characteristics
• The test is planned for early 2007
• The calibration of transition prediction methods using the Pathfinder Wing will take place after the ETW test
• A selection of test cases will be released to the wider research community
• The Performance Wing aerodynamic design is to start soon leading to a test in Jan 2008
• Further information is available via www.telfona.com