Laminarität für zukünftige Verkehrsflugzeuge
Überblick, Anforderungen und Status
Ergebnisse des Airbus-Technologieprogramms
Low Drag Aircraft (TOP-LDA)
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1. TOP LDA Introduction & Overview
2. Requirements and selected Approach
3. Structure Concepts Status
4. Manufacturing and Flight Test Demonstration
5. Summary & Outlook
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Jet Fuel Price as Driver for Performance Improvement

Drag reduction (by laminar flow) and efficient engines are key elements for reduction of fuel consumption.
What is laminar flow?

- Laminar flow can reduce friction drag significantly.
- Friction drag contributes to total a/c drag with $\approx 50\%$.
- Biggest contributor to friction drag is wing and fuselage.
- Laminarisation of fuselage is very challenging.
- A laminar wing upper side has a bigger effect than lower side ($\approx 65\%$).

For a typical wing application a reduction of total drag in the order of up to 8% is possible by laminar flow on upper side.
What are major influence factors for laminar flow?

Natural laminar flow (NLF):
→ laminar boundary layer by wing airfoil shape only

Hybrid laminar flow (HLF):
→ active control (suction, cooling) of boundary layer & airfoil shaping

Laminar flow influenced mainly by:
- Wing pressure gradient (= airfoil shape)
- Reynolds number (= size, speed, altitude)
- Leading edge sweep (= Ma number)
- Smoothness of wing surface (waviness, steps, gaps, roughness)
- Three dimensional disturbances (fasteners, insects, scratches, ...)

Aero

Structure
Characteristics of laminar Airfoils

- accelerated flow needed to get large extent of laminar flow
- this has a negative effect on shock strength (especially at high Ma)
- wing box of laminar wing similar to turbulent but more volume aft
- leading edge: sharp, less space → front spar more aft

- thick & round leading edge
- max thickness far aft
- increased rear spar height

- narrow & sharp leading edge
- front spar moved back
How Hybrid Laminar Flow works

Hybrid Laminar Flow Control (HLFC) required at high sweep of leading edge (LE) and high Reynolds number. Can be reached by:

- Optimized aerodynamic shape of the airfoil and
- Small suction at the leading edge for stabilization of boundary layer
- Tight control of the manufactured shapes to remove perturbations at the skin, and

A320 VTP Flight Test with suction 1998
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What is different in comparison to the past?

Past: Aerodynamic basic research with glove technology and hand finishing of surface

Today: Realistic structure concept fulfilling aerodynamic requirements and manufacturing at acceptable cost; demonstration of concepts on ground and in FT
Surface Requirements: Experimental approach

- Adjustable leading edge step
- TSP coating

2D Step testing

- 2D Waviness in LE
  - + Step

Limit?

Surface imperfection increase

Realistic Structure Simulation

3D Waviness + Multiple Waves

Flow Direction

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CFD Validation for Surface Requirements

Experiment in KRG
Ma=.75 Cl=design
Re=13Mio

3D CFD Result

temperature distribution

3D Navier-Stokes including WTT wall effects
Surface quality measurements

Manufacturing Waviness is strongly dependent on build concept (stringer spring in, etc.)
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NLF Wing Structure Overview

• Box
  • Minimal change to turbulent box configuration
  • Lower Skin, Rear Spar and lower flange of Front Spar construction unchanged
  • Upper Skin certification challenges for “no fastener” joints and integral front spar cap

• Leading Edge
  • Change to LE design key to meeting NLF requirements
  • Joint to box critical, challenging build requirements and life management
  • Slats replaced by Krüger-Flaps
    • which provide both high lift and bug protection
  • Electric WIPS introduced
Krüger High-lift and Shielding Concept and Testing

Definition of acceptable values for Krueger setting
Constraints for structure and kinematics concept

Coating Studies

Kinematics Validation

Numerical Experimental Validation

125° Krueger
NLF Leading Edge Skin sub assembly

Deployed Krüger

Stowed Krüger

Leading edge with high lift installation

Thermoplastic sheet

electrical WIPS

Sub-structure

Erosion shield
Examples of Joint and Fastener Head Options

The joint area and the filler application is a very critical zone for a laminar wing structure concept.

Several partners are working on that topic and flight demonstration in BLADE is planned as well.

AGI filler cover

DLR floating joint
Ground Based Demonstrators in context of TOP-LDA

- **Airbus metal LE concept**
  - metal LE self supported

- **GKN CFRP LE concept**
  - machined joint

- **DLR CFRP LE concept**
  - floating joint

- **BLADE demonstrators**
  - Saab
  - GKN
  - & machined metal LE

- **Ground Based Demonstrator in SFWA**
  - 4.5m span NLF leading Edge

Check several approaches and select the best mix out of the different demonstrators
Upper Cover DLR NLF Manufacturing Demo

Major Objectives:
Development of new CFRP wing cover structure concept and manufacturing demonstration for laminar wing application
GKN Ground based NLF LE Demonstrator

Ground based NLF leading edge demonstrator including Krueger and WIPS integration

4.5m length

Major Objectives:

Demonstration of full LE integration of all NLF leading edge components and manufacturing and assembly quality of large leading edge parts
**Major Objectives:**

- Design and manufacturing of NLF outer wing
- Flight testing of NLF wing with **two different structure concepts**
- Demonstration and validation of aero design and CFD tools
- Validation that selected structure concepts are feasible and deliver expected surface quality
- Testing of artificial disturbances and operation simulation
- Testing of Kruegershielding
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Summary and Outlook

- Surface quality is a major challenge for laminar flow application and detailed knowledge about surface requirements is needed to find best compromise between structure solution and aero performance.

- Specific wind tunnel tests have been designed to get such precise requirements.

- CFD capabilities further improved and validated to predict such effects.

- Small, medium size and full wing demonstrators and validation experiments including large scale flight tests with A340MSN1 will be used to get confidence in what is possible.

- There are several activities with different partners running to find the best structure and manufacturing concept for the leading edge and upper cover of a laminar wing.

- Operability of such laminar wings and surface quality degradation effects will be an additional important topic in the future.
What will come next?

- Manufacturing of BLADE large FT demonstrator
  - SAAB
  - AERNNOVA
  - GKN
- Final assembly
- Flight test with NLF outboard wings on A340 BLADE demonstrator end of 2017
- Flight test with simplified HLFC on the VTP of the A320 DLR ATRA aircraft in 2017
- Wing LE HLFC Ground Demonstrator