Analysis

ANALYSIS: Why Airbus foresees laminar wings on next-gen aircraft

By Michael Gubisch | 10 July 2018

In the quest for greater efficiency of large transport aircraft, efforts to reduce wing drag through conventional aerodynamic tweaks have largely been exhausted, in the view of Airbus senior vice-president of research and technology Axel Flaig.

Flaig says that employment of carbonfibre for new aircraft types was a key move, as the material enabled manufacturers to build longer, slimmer wings than had been possible with aluminium. But in order to achieve the next step change in efficiency, airframers will need to reduce drag by building laminar-flow wings, he says.

While the theory and potential benefits of avoiding turbulence in the boundary layer around the wings have been known since the 1980s, the challenge has been the industrial-scale manufacture of wings that are both smooth enough to achieve a laminar airflow and aerodynamically robust enough to sustain the desired effect in daily airline operations.

"Very high" accuracy is required in the wing's design and assembly, says Flaig, as small disturbances – for example, gaps around retractable leading-edge slats, fasteners, surface deformations, and contamination from dirt, de-icing fluid and rain droplets – can break up the laminar airflow. Flaig thinks the move to carbonfibre has finally made it possible to design a wing with an appropriate 3D profile and surface properties to achieve laminar flow on a future aircraft.

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Airbus estimates that laminar-flow wings could reduce drag by around 10%, cutting fuel burn by up to 5% on an 800nm (1,480km) sector.

In September 2017, the airframer started flight tests using a modified A340 fitted with reshaped wing sections outside the outboard engines. The experimental wing sections are designed to generate natural laminar flow – as opposed to hybrid laminar flow, which is artificially induced through hardware in the wings.

By April this year, when Flaig discussed the project at the ILA air show in Berlin, some 66 flight hours had been completed under the partly EU-funded project dubbed Breakthrough Laminar Aircraft Demonstrator in Europe (BLADE), which involves a range of industrial partners and research institutes, in addition to Airbus.

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SURPRISING ROBUSTNESS

Flaig says laminar flow could be observed from the aircraft's first flight and that the team was "surprised" at the stability of the flow. A key objective of the BLADE project is to assess the robustness of the flow while the wing flexes and becomes distorted in flight, and to find the sweet spot of a wing profile that ensures sustainable laminar flow in airline operations while delivering notable savings.

The tests showed that Airbus can "relax the shape" of the wing and allow for "slightly larger tolerances" than previously thought, Flaig says. Furthermore, the team learned that aerodynamic benefits could be sustained during the flight tests at Mach 0.78 – a typical cruise speed for A320-family jets – where Airbus had previously predicted that an aircraft would need to fly at M0.75 to deliver the fuel savings.

Ahead of the flight tests, Airbus said that natural laminar flow could not be sustained on a wing with a comparatively high sweep angle. The A340's original wing – which is designed for cruise speeds of M0.82-0.84 for long-haul flights – has a sweep angle of approximately 30°, while the experimental laminar-flow sections have a sweep of around 20°.

Flaig acknowledged, at the time, that natural laminar flow was not an option for long-haul aircraft as speed could be compromised on such missions. Stabilising air flow over a wing with comparatively high sweep angles requires a hybrid laminar-flow system that produces a suction effect through perforated surfaces – either passively, by exploiting the pressure differential between the upper and lower surfaces of an aerofoil, or actively, with a pump system.

For short-haul aircraft, Flaig suggests, a speed reduction to M0.75 would not make a big difference. However, he says the possibility of maintaining natural laminar flow at M0.78 came as a surprise to the team.

AERODYNAMICS VERSUS MANUFACTURING

The approximately 9m (30ft) experimental outer wing sections on the A340 represent around two-thirds of a single-aisle aircraft's wing size. Flaig acknowledges small differences in aerodynamic performance between the test aircraft's port and starboard wings, as Airbus employed different construction concepts for the two experimental aerofoil sections. But he says both wings sustainably generate the desired effect.

In order to avoid any joint in the laminar-flow path, Swedish project partner Saab constructed an upper wing surface with an integrated leading edge. The carbonfibre component is fitted to the metallic wing structure through internal attachment points and represents an "elegant" solution to the challenge of building a near-perfect surface, says Flaig. But he admits that the panel's production is demanding and costly as it requires an extremely high degree of accuracy.

On the starboard side, Airbus and its industrial partners followed a more conventional design with a carbonfibre upper-wing surface – supplied by UK composites specialist GKN – and separate, metallic leading edge.

Flaig says it has not yet been decided which of the manufacturing concepts Airbus would adopt for a laminar-flow wing. He asserts, however, that tests have shown "the door is wide open" for the technology to be employed on a potential next-generation single-aisle aircraft from the late 2020s, and that the manufacturer is "very confident" the BLADE project will achieve "more than we targeted".

A further 60-70 flight hours are planned before the test programme ends in late 2018 or early 2019. The BLADE project was launched in 2008 under the EU's Clean Sky programme, and will be concluded next year. The second run of flight tests will concentrate on assessing the flow's sensitivity to wing degradations. Engineers will place stickers on the wing to simulate contamination or surface deformations.

Additionally, the team will install fixed Kruger flaps along part of the outer wings' leading edges. Kruger flaps – which would retract into the lower-wing structure, aft of the leading edge – are being considered to serve both as high-lift devices for take-off and landing, and as a shield to protect the leading edge from insect contamination and potential damage from foreign object debris.

NEW INSTRUMENTATION

A further finding of the flight trials to date is that the test instrumentation – some of which has been specifically designed for the project – works better than expected. This includes a set of video cameras monitoring the reflection on the laminar-flow wings' surface of a black-and-white stripe pattern painted on to a fairing between the conventional and new sections. This is to measure any movement of the laminar-flow section's surface.

Infrared cameras at the top of the aircraft's vertical stabiliser determine the extent of laminarity on the upper wing through minute temperature changes as turbulent air cools the wing's surface more quickly than laminar flow.

Airbus intentionally interrupted the flight-test programme during winter as it predicted the sun would be at too low an angle to warm the wings' surface for the infrared measurement. But Flaig says the instrumentation reaches such precision that test flights would be possible at night.

Some 75 patents have been filed as a result of the BLADE programme. Flaig describes the A340 as the largest technology demonstrator, with the most extensive test equipment, in operation today, and says that the investment in the project is "really paying back".

He says the project was only feasible as a collaborative effort under the EU's Clean Sky future technology research programme because the BLADE initiative is "too big" for Airbus on its own.

The project – which is jointly led by Airbus and Saab – has 21 core partners, including Dassault, Romania's Romaero and Spanish aerostructures specialist Aernnova. But a total of around 500 participants – including small and medium-sized enterprises, and research centres – are involved. "Without the European framework and support, it [BLADE] wouldn't have been possible," says Flaig. "We can only be grateful to the EU."

The current Clean Sky II initiative – a 10-year programme running to 2024 that includes other projects to mature technology for more efficient aero engines, helicopters and onboard systems – has a budget around €4 billion ($4.7 billion). The EU is contributing €1.8 billion to the initiative.

Airbus has previously said that the BLADE project represents the largest part of its estimated €330 million contribution to Clean Sky II.

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