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Airbus Concept Ingests Boundary Layer to Reduce Drag

Boundary layer ingestion (BLI) promises a significant increase in fuel efficiency, but poses challenges in integrating propulsion and aerodynamics in a way that realizes the benefits while minimizing the penalties.

In BLI, an aft-mounted propulsor ingests the slow-moving boundary-layer airflow over the fuselage and reenergizes the wake, improving propulsive efficiency and reducing drag. But the propulsor must be designed to operate in distorted airflow, reducing the fan's efficiency and increasing its weight.

Examples of narrowbody airliner concepts incorporating BLI are Aurora Flight Sciences' D8 and French research agency Onera's Nova. Where the D8 has two turbofans mounted semiburied on top of a broad aft fuselage, the Nova has its two engines buried in the tail with large inlets on the fuselage sides.

The Nova design ingests about 40% of the fuselage boundary layer, for a cruise power saving of 5% compared with a similar design with conventional podded engines on the aft fuselage, calculates Onera.

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DEC 10, 2018
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The Week in Technology, December 10-14, 2018
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The main aerodynamic challenge of the configuration is to how to prevent flow separation where the rear fuselage divides into two. Moving the propulsors farther apart increases the flow separation and reduces the amount of boundary layer ingested. Moving them closer together and adding a "beaver tail" between the nacelles improves aerodynamic performance.

"Among the next steps in this project, further iterations . . . will be performed to suppress the remaining areas of flow separation in order to be able to quantify the maximum potential of the concept in regard to propulsive power gains," the paper says. A Nautilius-dedicated fan will also be designed taking into account the concept's specific flow distortion pattern.

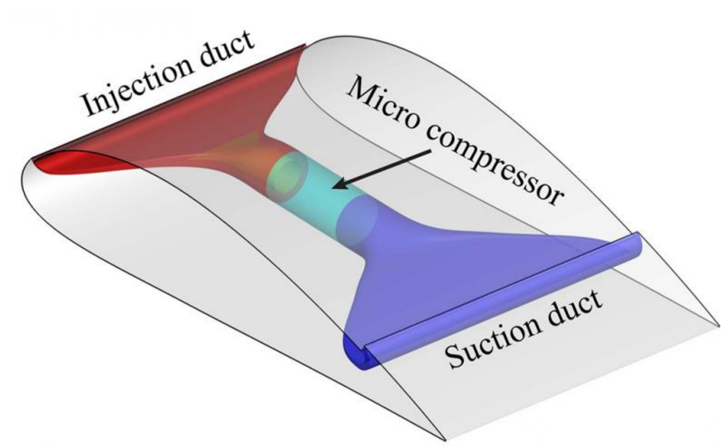
Coflow-Jet Airfoil Shows Super-Lift Capability

An active-flow-control airfoil that generates both extremely high lift and thrust has been tested by researchers at the University of Miami under a project funded by DARPA. The coflow jet (CFJ) airfoil promises to improve cruise efficiency and enable extremely short takeoff and landing (ESTOL), says its inventor.

The latest test was the first in which the CFJ flow-control airfoil was actuated by embedded microcompressors, a crucial step toward its practical application, says Gecheng Zha, the concept's developer and a professor in the university's College of Engineering.

The test also provided the first experimental proof that a CFJ airfoil can achieve a "super-lift coefficient" that exceeds the theoretical limit of potential flow theory, he says. This could be applied to ESTOL and vertical-takeoff-and-landing (VTOL) aircraft.

In the CFJ concept, a small amount of air is sucked into the airfoil at the trailing edge, pressurized by a microcompressor inside the airfoil, and injected tangentially into the flow over the airfoil near the leading edge. This does not add any mass, making CFJ a zero-net-mass-flux system.



CFJ airfoil sucks in air at the trailing edge, pressurizes it and ejects a jet at the leading edge. Credit: Gecheng Zha/University of Miami

Turbulent mixing between the injected jet and airflow over the airfoil energizes the boundary layer and enables the flow to overcome a severe adverse pressure gradient and remain attached to a high angle of attack, producing an "extraordinarily high" lift coefficient, he says.

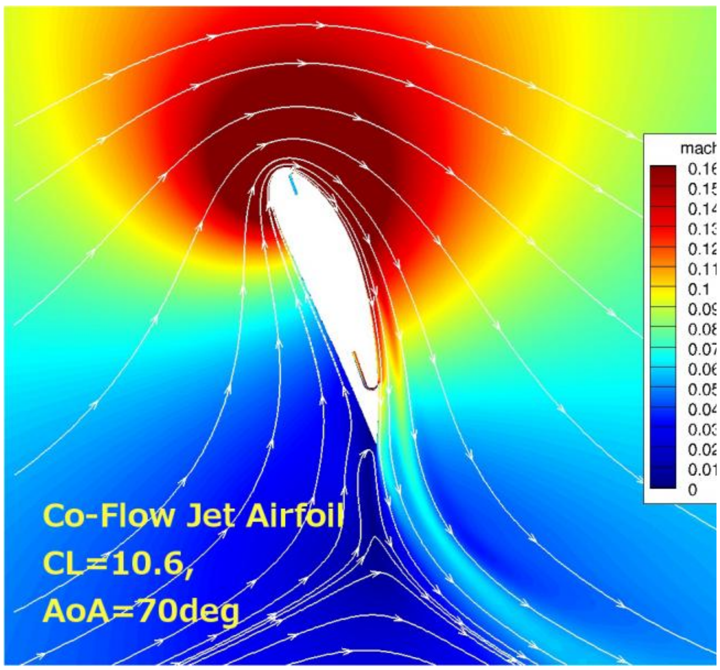
At low angles of attack (AOA), CFJ increases lift coefficient and efficiency in cruise from subsonic to transonic speeds, Zha says. At higher AOA, CFJ enables a flapless high-lift system for lower noise, weight and cost. The airfoil can also generate thrust, enabling a new form of distributed electric propulsion.

"A CFJ wing has its best efficiency at low AOA, usually a little higher than a conventional wing," says Zha. "When CFJ is applied, both lift and thrust (or drag reduction) will be generated simultaneously. The key to CFJ's high cruise efficiency is that its power consumption is low at cruise when AOA is low."

The high lift coefficients are generated at higher AOA, during takeoff and landing. "We can generate ultra-high lift at extremely low speed," he says. The DARPA project is for ESTOL military transports.

"The drawback [with CFJ] is that it is expensive at this time because the microcompressors must be custom-designed and there are few manufacturers that can manufacture them," he says. "We only found one company in Switzerland."

The latest tests in Texas A&M University's low-speed wind tunnel involved two airfoils: one with a larger injection slot size for high cruise efficiency and low CFJ power consumption; and one with a smaller slot to achieve high maximum lift coefficient for takeoff and landing.



CFJ active flow control can maintain high lift coefficient up to extreme angles of attack.
Credit: Gecheng Zha/University of Miami

Five microcompressors were embedded in a 3.3-ft.-span wing section, which achieved a lift coefficient of 8.6, above the theoretical limit of 7.6. The maximum limit coefficient that current wings with high-lift flaps can achieve is usually less than 3, says Zha.

The CFJ has low energy expenditure, Zha says, because the jet is injected at the leading-edge peak suction location, where airflow pressure is near its lowest, requiring low power to eject the pressurized air. Air is sucked in at the trailing edge, where pressure is near its highest and power required is low.

"The loss in the injection duct and suction duct is low. [And] It does not rely on engine bleed, which makes the overall system design much simpler and more efficient," he says. "We can use the same fixed slot size from takeoff to cruise with ultra-high efficiency and high lift coefficient."

The concept mimics a bird's wing, which generates both lift and thrust because of a super-suction effect at the leading edge on the powered downstroke. Zha initially studied the CFJ airfoil for jet engines, to reduce the number of compressor stages, but was unable to apply the idea to thin compressor blades.

High lift from CFJ would enable aircraft to have a small wing that is more efficient in cruise. Credit: Gecheng Zha/University of Miami

Besides DARPA, work on applying the concept to aircraft wings has been supported by NASA, the U.S. Air Force Office of Scientific Research, the Army Research Office and Italian research agency CIRA. Now, with support from the Emil Buehler Perpetual Trust the university has formed the Center for Green Aviation to apply CFJ to VTOL, ESTOL and other aircraft.

"The technology is becoming mature enough that we have formed a startup, CoFlow Jet, to push it to the market," Zha says. "The purpose of the startup is to develop a prototype for flight testing to demonstrate the technology's superiority."

The CFJ-Seagull is a concept for an all-electric four-seat light aircraft with a coflow-jet wing as part of a distributed propulsion system. The CFJ airfoil increases energy efficiency and range by 30% or more, says Zha, allowing the aircraft to fly 320 mi. at 114 mph on a 250 Wh/kg energy-density battery.

The cruise lift coefficient is 1.3, compared with about 0.5 for a conventional aircraft, he says. This results in a smaller wing with high wing loading, which improves comfort by reducing its response to turbulence. Currently, the startup is working on an ultra-high-efficiency, quiet CFJ-VTOL concept with NASA support.

TsAGI Advances Container Transporter Concept

Russian aerohydrodynamic institute TsAGI has conducted a new series of wind-tunnel tests on a large container-carrying ground-effect vehicle. The aircraft is designed to speed cargo transportation while improving security, reducing emissions and eliminating pollution.

The latest tests involved the smallest variant of TsAGI's Heavy Air Freight System (HAFS) concept, the 95-m (310-ft.)-span Heavy Cargo Aircraft with Lifting Body (HCA-LB). With a 500-metric-ton (550-ton) payload, this aircraft is designed to carry 48 20-ft. cargo containers 6,000 km (3,250 nm) at 450-550 kph (240-300 kt.).

The ground-effect vehicle flies at 3-12 m above the ocean on a cushion of high-pressure air between the wing and surface. This increases lift and reduces drag, improving efficiency and enabling a wing with a low aspect ratio of 3-4 to achieve a high lift-to-drag ratio of 25-30.

For the tests, the HCA-LB model was positioned close to a screen simulating the surface. Dependence of the aerodynamic characteristics on flight altitude above the screen was determined, says TsAGI, as were the changes in stability and controllability compared with tests without the screen.