Trick gives helicopters more 'puff' – DLR tests the influence on airflow when blowing air out of rotor blades

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Researchers at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) in Göttingen have discovered a way to make helicopters more manoeuvrable. In a globally unique wind tunnel experiment, they have been blowing air through holes in the rotor blades to actively influence airflow.

As though someone is wielding a sledgehammer

The rotor gives the helicopter its unique ability to take off and land vertically. But this also has its aerodynamic disadvantages. During rapid forward flight or manoeuvring, airflow stalls on the main rotor blade of a helicopter as the blade moves backwards, giving rise to what is referred to as 'dynamic stall'. This causes turbulence, lift is lost and enormous forces act on the rotor. Air resistance increases and the rotor head control rods are subjected to enormous dynamic loads.

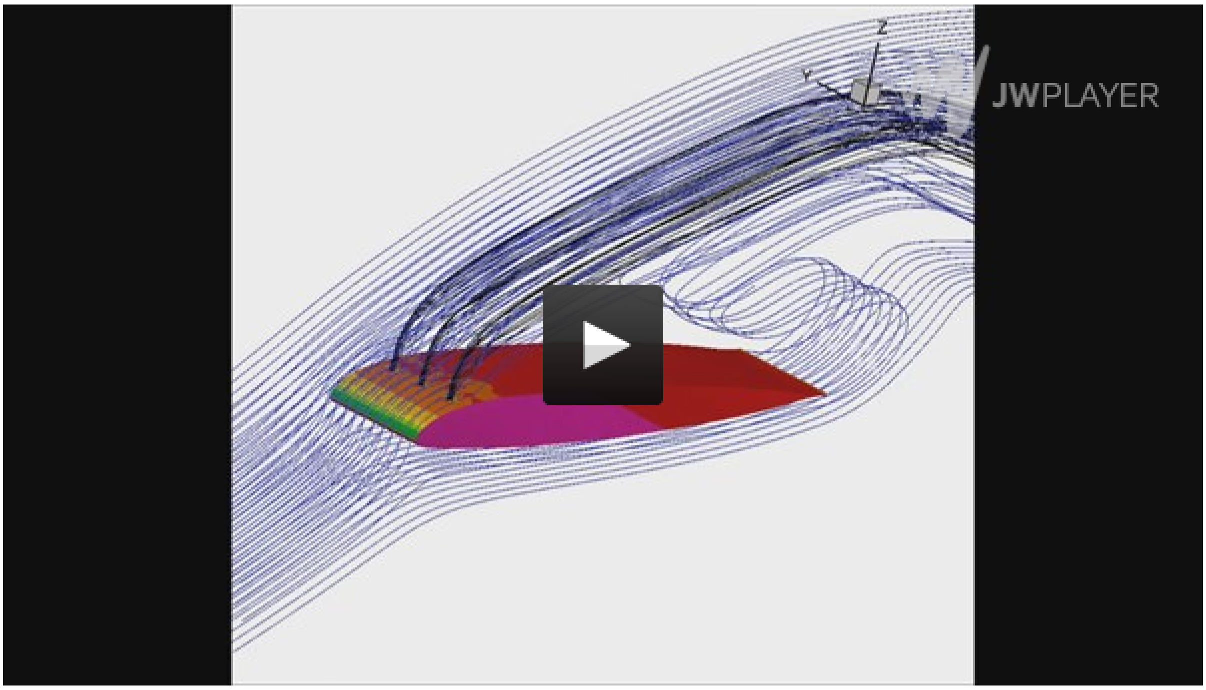
"It is just as though someone is striking the rotor with a sledgehammer," explains Anthony Gardner from the DLR Institute of Aerodynamics and Flow Technology. The result is that the maximum speed and the manoeuvring capability of helicopters are restricted, especially at high altitudes.

The concept devised by the researchers in Göttingen acts like a kind of aerodynamic damper on helicopter rotors. Air is forced outwards through small holes in the rotor blades, which reduces the amount of harmful turbulence when stalling occurs. This enables the pitching moments exerted on the rotor blades – that restrict performance – to be substantially reduced. "During difficult flight manoeuvres, the pilot has the option of engaging this function for brief periods. At this point," continues Gardner, "aerodynamic forces cease to act like sledgehammer blows on the rotor, becoming more akin to taps with a rubber mallet."

A complex experiment

There is nothing new about the idea of actively influencing aircraft aerodynamics by blowing air in this way. Back in the 1940s, researchers in Göttingen were already working on this. Now, for the first time, their successors have successfully demonstrated that the idea works on helicopters – in a wind tunnel experiment under realistic conditions. "This experiment is the most complex ever performed in the field of dynamic stall control," says Kai Richter from the DLR Institute of Aerodynamics and Flow Technology. He is head of the STELAR (Stall and Transition on Elastic Rotor Blades) project, which has been carried out jointly with the DLR Institute of Aeroelasticity.

Recently, DLR researchers in Göttingen tested a passive method for influencing airflow, drawing their inspiration from the bumps on the pectoral fins of humpback whales. "It was only very recently that we acquired the computational power to be able to calculate what a wind tunnel model of this kind should look like," says Gardner. The apparently trivial questions of how widely spaced and how large these holes should be to obtain a positive effect have now been resolved with the help of the supercomputers at DLR.



Animation: Air being blown out of a rotor blade

Forty-two holes

These experiments took place in the Transonic Wind Tunnel in Göttingen, a wind tunnel unique in Germany in terms of its speed range capability. This facility, measuring 50 metres in length and 12 metres in height is able to simulate how aircraft behave when travelling at close to the speed of sound in what is known as the 'transonic range' (about 1000 kilometres per hour) and beyond – at speeds of over twice the speed of sound or Mach 2.2. For these tests, a one-metre segment of a rotor blade was installed in the wind tunnel. "It was equipped with the latest measuring technology," says Gardner. A compressed air system with a complex set of valves blows air through 42 openings each measuring three millimetres in diameter. Seventy-four sensors measure pressures on the rotor blade up to 6000 times a second; this enables the airflow to be depicted precisely.

In a next step, these results will be checked on a new rotor test bench with a rotating rotor.

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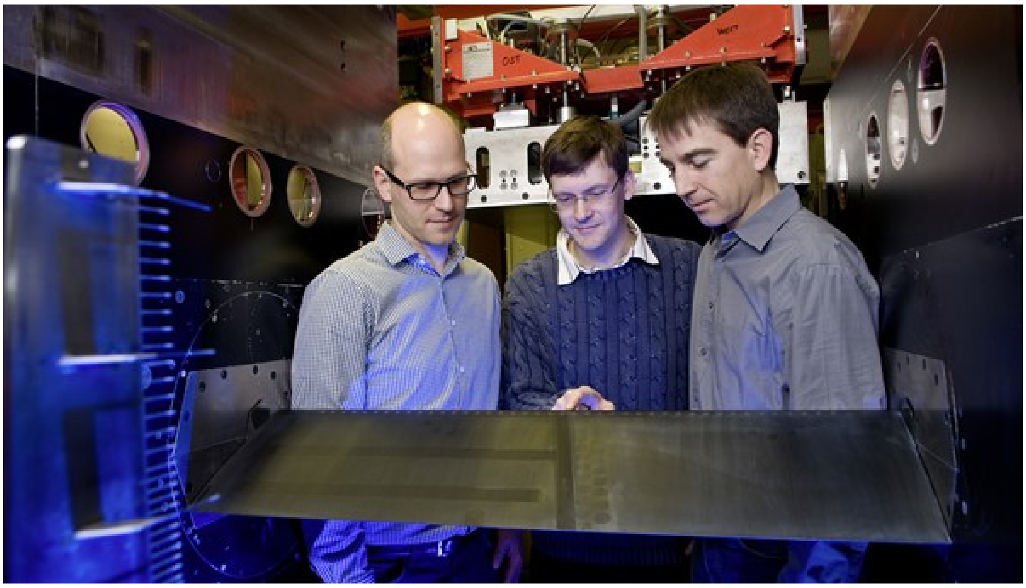
Helicopter in flight

Helicopters like the FHS at DLR owe their unique manoeuvrability to the rotor. However, aerodynamic phenomena prevent their performance from being fully exploited.

Credit: DLR (CC-BY 3.0).

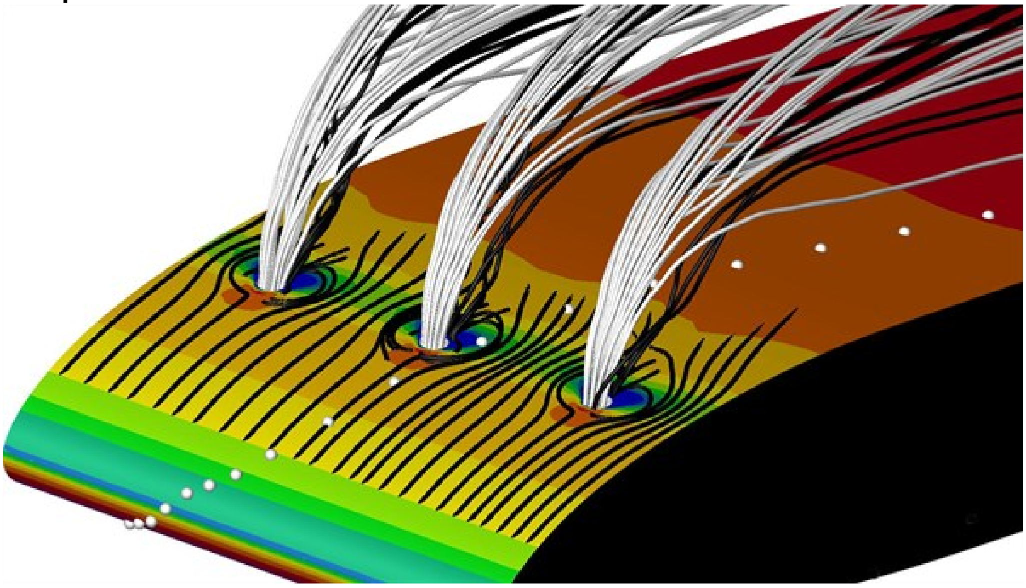
Researchers with the wind tunnel model



From left to right: Kai Richter, Anthony Gardner and Holger Mai.

Credit: DLR (CC-BY 3.0).

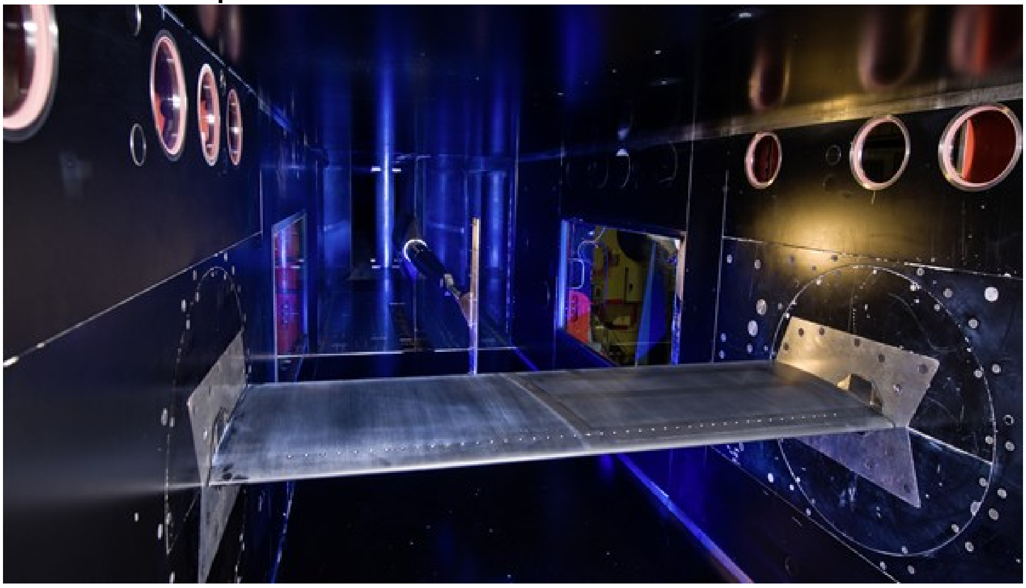
Computer simulation of airflow



Computer simulation of the complex airflow over a rotor blade.

Credit: DLR (CC-BY 3.0).

Model of a helicopter rotor blade in the wind tunnel



Model of a helicopter rotor blade in the transonic wind tunnel. Air is blown through openings near the leading edge in order to improve the aerodynamics.

Credit: DLR (CC-BY 3.0).

DLR FHS research helicopter

Helicopters like the Flying Helicopter Simulator (FHS) at DLR owe their unique manoeuvrability to the rotor. However, aerodynamic phenomena prevent their performance from being fully exploited.

Credit: DLR (CC-BY 3.0).
