ORDER IN CHAOS

Illustration: Peter Markmann

Australian scientists are working on a revolutionary system for controlling lift and drag, writes Cheryl Jones.

THE GURUS OF CHAOS theory say the flap of a butterfly's wings in Brazil can set off a tornado in Texas. It is aeroplane, not butterfly, wings preoccupying some of Australia's own chaos experts, however.

Scientists at Monash University in Melbourne are attempting to harness the energy of chaos to alter the lift and drag characteristics of aeroplane wings in a bid to enhance controllability.

The work, funded by Monash and the Australian Research Council, could lead to "smart" wings that would eliminate the need for use of flaps or ailerons in most situations. The futuristic "fluidic" control technology even has the potential to prevent wing stall.

At the macroscopic level, lift depends simply on parameters that include the air density, the square of the velocity of air approaching the wing, the wing area and the lift coefficient. This coefficient changes with the shape of the wing and the angle of attack

Pilots can alter lift by changing their speed or increasing their angle of attack, either by getting the nose up or by extending the ailerons or flaps to alter the camber of the wing. The control surfaces increase drag, however.

The lift equation is at best an approximation. It gives an average value for the entire wing. At the microscopic level, the physics of lift is much more complex. The air flow is turbulent, or chaotic, and difficult to predict through classical fluid mechanics. Air velocity, assumed in the lift equation to be constant across the wing, in fact varies widely between different points on the structure.

To the Monash scientists, turbulence is an untapped source of energy. But to harness that energy, the team, at the Laboratory for Turbulence Research in Aerospace and Combustion, first has to find order in the chaos – patterns in air flow that are, at least to an extent, predictable.

"The task is daunting," says Julio Soria, director of the laboratory. Turbulence has been described as the last big unsolved problem of classical physics. Despite centuries of research aimed at reducing it to an orderly set of equations, it has not yet yielded.

The Monash team's work centres on shear layers within the air flow. These regions, where adjacent layers of air slide over each other at different velocities, are the sites of unstable, turbulent flow. Instabilities in the shear layer near a wing produce big vortices, or swirls of air, that are shed, first at the leading edge and then over the entire wing. They affect lift and drag by changing the air velocity.

"If we can manipulate these instabilities to make them do what we want them to do, we can change the lift and drag properties of the wings," says Damon Honnery, deputy director of the laboratory.

The scientists are conducting their first experiments in a water tunnel. Water tunnel experiments are easier to perform than air tunnel tests, and the results are roughly equivalent.

The researchers force water laden with tiny particles over small wing sections, and illuminate the particles with lasers.

Snapshots taken at microsecond intervals with a high-resolution digital camera trace the propagation of vortices in the flow. The scientists are able to calculate the velocity of the fluid at various points on the wing with a resolution close to hundredths of a millimetre.

From these readings, the scientists evaluate how lift and drag change with position on the wing and over time. This points to ways of suppressing or amplifying turbulence to alter lift and drag characteristics.

"Our results so far suggest that it will be entirely possible to control the airflow over the wing in a particular way to achieve the same effect as an aileron or flap," says Honnery.

"If you wanted to roll the aircraft, you could change the shear layer on either side of the wing and get a similar effect as you would by changing the ailerons."

Tiny jets or nano-sized (billionths-of-a-metre-sized) vibrators would be installed on the wings to manipulate air flow.

"These mechanisms can produce instabilities when you want them, suppress them when you don't want them, and shift the flow to where you want it just by using the chaotic nature of the flow," Honnery adds.

In a fluidic control system, the entire wing would act as a control surface. And in contrast to ailerons and flaps, the system would respond to pilot commands instantaneously.

However, the system is unlikely to replace mechanical control surfaces. "You'll always want some manual control," Honnery says.

One of the biggest benefits would be the prevention of wing stall, which happens when an increase in the angle of attack fails to produce additional lift.

The stall point, at which control of the aircraft becomes difficult, depends on the type of wing section and its aspect ratio. It typically occurs at an angle of attack of 14 to 16 degrees.

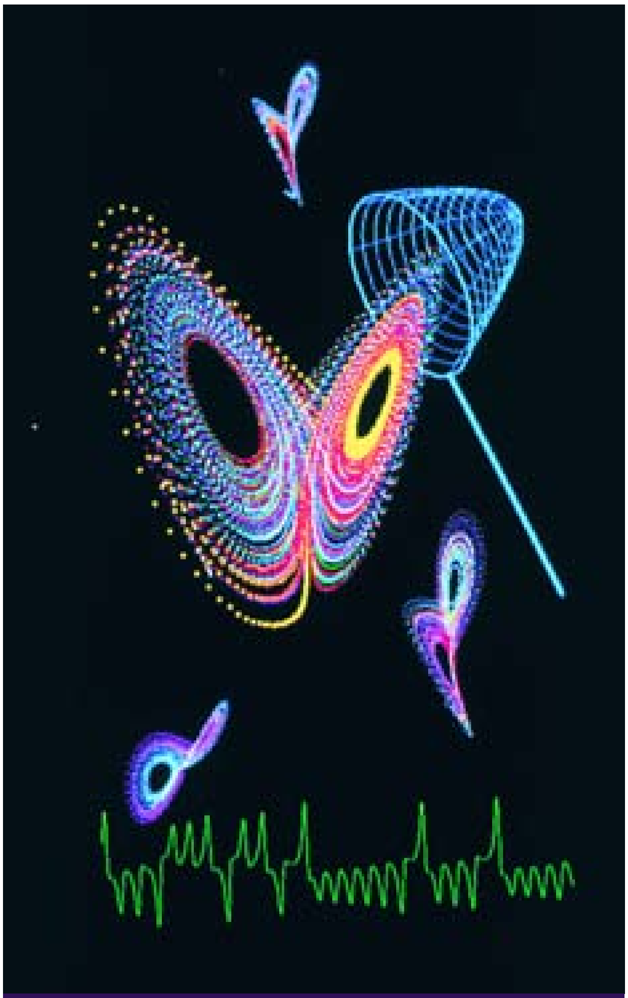
Pilots can overcome wing stall only by changing the angle of attack. But if stall occurs during takeoff, it is usually impossible to recover.

Sensors measuring air pressure could be used to detect wing stall, signalling the fluidic control system to kick in and restore lift.

Just as it took some time for flaps to win widespread acceptance, it is likely to take several years for fluidic control to take off. "We're a long way off this yet," Honnery says.

The first application would probably be in the military, with its focus on manoeuvrability and strong culture of innovation.

But would fluidic control take all the fun out of flying? "The reason for doing this is to enhance efficiency and safety," Honnery says. "If that dampens the fun, it's a price worth paying."



The chaos butterfly generated from solutions to the Lorenz equations for fluid flow. Courtesy Bruce Henry (UNSW) and Murray Batchelor (ANU).

Flow over an oscillating aerofoil. This image was generated in a Monash University experiment on heaving and pitching aerofoils.