ON THE TRAIL OF WAKES


WILL TIDMARSH

Research at the University of New South Wales could help pilots dodge dangerous wake turbulence, writes Jason Middleton.

IT'S A PACIFIC ISLAND PARADISE, but Lord Howe has perils for pilots. The spectacular sand dunes to the east and mountains to the south of the airstrip can generate topographic wake turbulence – disturbances to air flow around obstacles. The vicious eddies that got the island a mention in ERSA underline the dangers of topographic wakes.

The pilot's perspective The dangers of wake turbulence are gravest during takeoff and landing.

In operations from any airport downstream of hills, mountains or even large buildings, fixed wing and helicopter pilots should be aware of all meteorological circumstances.

In addition to carefully noting ATIS, a sensible approach would be to spend time watching the windsock, listening to reports from other pilots, and taking note of all salient indicators.

Leaving aside mountain and lee waves, which may occur at a range of altitudes, topographic wake dangers also exist in climb, en route or descent, although increased airspeed increases the safety margin.

Wake turbulence can make valley or mountain flying, common to VFR operations, dangerous under any strong wind conditions. Multiple wakes often occur simultaneously and interact in cities and in mountainous areas.

The problem with wakes, however, is that they are difficult to predict. It is also hard to estimate how far they extend downstream of the obstacle causing them.

My colleagues and I are attempting to unlock the secrets of the physics of wakes, with a major research project now under way. The project is aimed at taking some of the guesswork out of flying near tall struc-

DARLENE BLASL

Perilous paradise The spectacular topography of Lord Howe Island (above and left) presents a variety of challenges for pilots.

tures with the potential to generate hazardous wakes.

Topographic wakes – disturbances to flow in the air and ocean – have been the subject of intense research for centuries. Leonardo da Vinci was one of the first to study them. He drew sketches of the often complex three-dimensional flow fields in wakes behind stones in shallow streams.

Two-dimensional wakes Two-dimensional wakes occur when air goes around an obstacle, not over it. They form when the object is taller than the fluid layer. Examples are flows around mountain peaks or in strongly stratified fluids.

In slower flows, horizontally-circulating eddies form but they remain the same size and are attached to the object. Pilots would experience turbulence close to the obstacle.

At higher air speeds, wake flows become unsteady, with eddy pairs swept downstream in a regular structure called a von Karman vortex street. These structures are common over mountain ranges, and the wake can be felt up to 100 kilometres downstream.

For very fast flows, wakes descend into a state of chaotic turbulence extending a huge distance downstream.

The shape of the obstacle affects the wake. Bluff bodies generally have larger and more energetic wakes than slender bodies with small incident cross-sections.

Three-dimensional wakes The picture becomes more complicated for three-dimensional flows, including the wake of an isolated small hill or building, in which the air moves over and around the obstacle.

Vortices can produce both updrafts and downdrafts as well as horizontal eddies. The aircraft can be buffeted in any direction.

Vertical wind shear in the atmosphere boundary layer causes horseshoe vortices, which present extreme aviation hazards.

Vertical wind-shear occurs because the wind velocity drops to zero at the Earth's surface. This creates a drag on any flow in the boundary layer. Vertical wind shear in the upstream flow creates a vorticity field that lies perpendicular to the flow direction but parallel to the surface. This upstream flow has a "circulation" as a result of the slower flow near the surface.

As the faster airflow at height wraps around the obstacle, a horseshoe vortex is produced which has a downstream circulation pattern similar to trailing vortices.

A horseshoe vortex begins directly upstream of the obstacle, and can cause severe downdrafts on its flanks, particularly if the sides are sloping, as on a small hill.

Depending on the strength of the shear and the size of the object, the horseshoe vortex might result in two separate vortex trails downstream. These might merge into a single wake.

Strong individual roll vortices may be semipermanent features in valleys, and may be difficult to predict, even when the inflow wind is steady. The ability of these vortices to remain coherent for long distances downstream is analogous to the stability of wake vortices occurring as a consequence of lift, and the horseshoe vortices may also contort and twist themselves together, leaving an unpredictable but strong wind-shear hazard.

The combination and interaction of a three-dimensional wake and a horseshoe vortex usually results in a fully chaotic turbulent wake flow some distance downstream of the obstacle.

Long clear summer days see buoyant convection above scorching ground. This can further destabilise wakes, often lifting them far above the object generating them. In contrast, stably stratified boundary layers tend to keep the wakes confined in a thin layer near the ground in a near two-dimensional structure, perhaps letting them retain their integrity much further downstream.

Research The University of New South Wales is currently conducting laboratory and field experiments, and mathematical modelling, to investigate wakes.

The energy and extent of wakes depend on some 15 variables, including the incident wind velocity, the obstacle width and height, the air viscosity and temperature-related stratification of the air.

In the lab work, conducted with the Australian National University, researchers will see how these parameters affect the characteristics of wakes.

They will use water to simulate air flow over objects of differing size and shape. Since lab simulations do not necessarily represent reality, we will back this work up with field studies.

One method centres on the use of smoke and aerial photography to trace air flow around tall obstacles, including silos outside country towns.

Another method involves airborne lidar (light detection and ranging). Laser light shone from an aircraft is reflected off air particles and returns to a receiver in the aircraft. The Doppler shift in the returning light reveals the velocity of the particles and therefore of the air.

A third line of investigation, conducted with the University of Colorado, will involve the computer modelling of turbulence. Results from the other two methods will be fed into the computer models. Results from all three methods should help in the prediction of wake flows.

Professor Jason Middleton holds a CPL and heads the Department of Aviation at UNSW.