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How To Deal With Induced Turbulence

Knowing the conditions of vortex generation and its characteristics will assist a pilot in better negotiating this phenomenon in flight.

by

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A light helicopter was on a southerly heading at 800 feet agl. Two jet fighters were on an easterly heading at approximately the same altitude. The first fighter passed about 1,000 feet in front of the helicopter, and the second passed to the rear. The helicopter reportedly nosed up and pieces fell from it before it crashed inverted.

A single-engine, fixed-wing aircraft entered traffic following a Chinook helicopter. The Chinook pilot made his approach over the active runway to a panel adjacent to the runway and terminated to a hover over the panel.

As the landing fixed-wing was starting its roundout, its left wing dropped suddenly. The pilot added full power and initiated a go-around. The airplane then rolled violently to the right, the right wing struck the runway, and the aircraft crashed.

For many years, the aviation accident-cause factors, "prop-wash" and, later, "jet wake" were blamed for accidents that were actually caused by an invisible culprit — **vortex wake turbulence.** When in flight, every airplane generates a pair of counter-rotating **vortices** that trail from the wingtips.

In addition to downwash generated while at a hover, helicopters in forward flight generate vortices that trail from below the rotor tips at the left and right extremes of the rotor disk. As illustrated by the introductory examples, vortex wake turbulence — more commonly referred to as simply wake turbulence — is a factor in the aviation environment of which all pilots must remain conscious.

Identifying Vortex Generation

As all pilots know, lift is generated by the creation of pressure differential over a wing's surface. As an aircraft moves through the air, the high-pressure area under its wings rolls up into the low-pressure area, causing a swirling action to occur behind and downstream of the wingtips in the form of two (one from each wing tip) counter-rotating vortices.

The strength of a particular vortex is governed by the weight, speed and shape of the wing producing lift. Vortex characteristics for a given aircraft can be changed by varying wing shape (via flaps, slats, etc.) and varying speed — the slower the speed, the stronger the vortex generated. Vortex strength increases proportionately with weight. The heavier the aircraft, the stronger the vortices.

The greatest vortex strength occurs during takeoff and landing when the generating aircraft is heavy, slow and at a high angle of attack.

The behavior of vortices is affected by wind and cannot always be accurately predicted. The vortex trailing behind the left wing rotates in a clockwise direction, and the one from the right wing rotates counterclockwise. Tests with heavy aircraft have shown that the diameter of vortex core ranges from 25 to 50 feet, but the area each vortex influences is much larger.

The vortices remain close together, about three quarters of the wingspan of the generating aircraft, until dissipation. When generated by a heavy jet, they begin to descend at a rate of 400 to 500 feet per minute and tend to level off after a descent of 800 to 900 feet. Time and distance behind the generating aircraft are the major factors for decreasing intensity and eventual breakup of the vortices. Natural atmospheric turbulence can shorten breakup time.

Lateral Movement is Spurred at Low Levels

Vortices generated low enough to reach ground level tend to separate and move laterally over the ground at about five knots. A crosswind at ground level, depending upon its speed, can cause upwind vortices to remain stationary on the runway. The wind also can increase the drift of downwind vortices to a parallel runway. A tailwind can move the vortices forward beyond the touchdown point of the generating aircraft.

The effect and seriousness of encounters with vortices depend upon several things. The greater the distance from the generating aircraft the less the effect on encountering aircraft. Low-altitude encounters can be more serious because there is less time to regain control of the aircraft.

Direction of flight also is a determining factor as to the seriousness of the encounter. The severity, as stated previously, depends upon distance from the generating aircraft and comparable size.

A "crosstrack" encounter, flight perpendicular to the long axis of the generated vortices, creates an updraft as the first vortex is encountered. As flight is continued out the other side of the vortex, a downdraft occurs, followed by another updraft as the second vortex is encountered.

A "long-track," which occurs when flying parallel and between the two generated vortices, produces a downdraft effect. This downdraft results from the two vortices rotating in toward each other. "Along-track," flight through a vortex center, is the most hazardous encounter, because it can produce a violent roll beyond the structural limits of the aircraft.

Handling Separation at Higher Altitude

At airports controlled by the U.S. Federal Aviation Administration (FAA), IFR separation standards are employed in an attempt to avoid vortex encounters. However, most VFR situations require the pilot to establish his own separation from other aircraft. Since he alone controls his potential encounter with vortices, he should be able to visualize their behavior and probable location.

The location of vortices at higher altitude is difficult to predict, because visual contact with the generating aircraft is not always established. When the location and flight path are known, the pilot should fly at, or above, the altitude of the generating aircraft. Since vortices tend to level off at 800 to 900 feet below their point of origin, if it is not possible to fly above the flight path of the generating aircraft, stay 1,000 feet below it until a lateral change in your flight path can be made.

How to Avoid Vortices

The following procedures are recommended to help avoid contact with unwanted vortices:

• Landing behind another aircraft on the same runway. Stay above a large aircraft's flight path; note its touchdown point and land beyond it.

• Landing behind another aircraft on a parallel runway that is within 2,500 feet. Stay at, or above, the flight path of the other aircraft; note its touchdown point, and land accordingly.

• Landing behind another aircraft on an intersecting runway. Cross above the other aircraft's flight path.

Dealing with Induced Turbulence

• Landing behind departing aircraft on the same runway. Note the departing aircraft's rotation point and land well before you get to the rotation point.

• Landing behind a departing aircraft on an intersecting runway. Note the departing aircraft's rotation point. If the rotation point is past where the runways intersect, continue the approach and land prior to the intersection. If the departing aircraft rotates prior to the intersection, avoid flying beneath its flight path. Abandon the approach unless a landing is assured prior to the intersection.

• Departing or landing after a large aircraft has executed a missed approach or touch-and-go. Because vortices settle and move laterally when close to the ground, a vortex hazard may exist along the entire runway. Allow at least a two-to-three-minute interval prior to takeoff or landing.

• Departing behind a large aircraft. Note the aircraft's rotation point and ensure that your aircraft is airborne prior to the previous aircraft's rotation point. Continue to climb above and upwind of the large aircraft's flight path. Avoid subsequent headings which will cross below and behind the large aircraft.

• Enroute VFR. Avoid flight below and behind a large aircraft's flight path. Adjust your flight path laterally, preferably upwind, when observing a large aircraft above you and on the same ground track.

These guidelines are not all inclusive and are offered only as assistance for the ever-increasing "pilot judgment" responsibility.

Realize the Dangers of Downwash

When a helicopter is at a hover, the rotor tip vortex reduces the effectiveness of the outer portions of the rotor blades. The vortices of preceding blades also severely affect the lift of following blades. If the vortex made by one passing blade remains a vicious swirl for several seconds, the continuous creation of new vortices and ingestion of existing vortices creates a situation that is the primary cause of high-power requirements during hover.

During hover, the rotor blades also move large volumes of air in a downward direction. This "pumping process" requires a lot of power and accelerates air to relatively high velocities. Air velocity under a helicopter may read 60 to 100 knots, depending upon the size and gross weight of the helicopter.

Caution should be exercised while hovering in an area congested by other aircraft or crowded with nearby equipment. If you hover near another helicopter that is at very low rotor speed, typical of initial engine start or shutdown, your downwash could easily cause the other helicopter's rotor blades to flex sufficiently to cause a tailboom strike. Thinking about the large surface area of "fixed wings," an obvious target for helicopter downwash is an unwary student pilot's unsecured fixed-wing aircraft. More than one light, fixed-wing aircraft has been flipped over by a helicopter.

Dust, loose snow and assorted foreign objects also contribute to making downwash awareness a continuous requirement:

• During landing approach to a field site, rotorwash created a dust cloud that caused the pilot to lose visual contact with the ground. While attempting to get the helicopter on the ground, a tree was struck. The aircraft came to rest inverted and was destroyed.

• While hovering prior to landing, the pilot of a light helicopter observed a canvas cover blow off a nearby piece of machinery. The cover contacted the main rotor blades, causing a massive rotor imbalance and subsequent breakup of the helicopter and minor injuries to the two persons on board.

Settling with power is a condition of powered flight where the helicopter settles in its own downwash. This condition is also referred to as "vortex ring state." Conditions conducive to settling with power are:

• Vertical or near-vertical descent of at least 300 feet per minute.

• Low forward speed.

• Rotor system using only part of the engine's available power.

• Insufficient power remaining to retard sink rate.

These conditions typically occur during approaches with a tailwind and during formation approaches when one aircraft is flying in turbulence from another aircraft.

Under the above conditions, a helicopter may descend at a rate that exceeds the normal downward induced flow rate of the inner blade sections and causes the airflow of the inner blade sections to be upward relative to the rotor disk. This change in normal airflow produces a secondary vortex ring in addition to the normal tip vortex.

Handling a Secondary Vortex Ring

The secondary vortex ring is generated about the inner blade at the point where airflow changes direction. The result is an unsteady turbulent flow over a large area of the disk which causes loss of rotor efficiency even though additional power is applied. During the vortex ring state, roughness and loss of control is experienced, because of the turbulent rotational flow on the blades and the unsteady shifting of the flow along the blade span.

Settling with power is an unstable condition. Normal pilot tendency is to recover by application of collective pitch and power. If insufficient power is available for recovery, this action may aggravate the situation, resulting in more turbulence and a higher rate of descent.

Recovery can be accomplished by lowering collective pitch and increasing forward speed. It is quite obvious then that both of these methods of recovery require altitude to be successful.

Wake turbulence, downwash and settling with power are just three more of the areas that must be mastered and always on the mind of the safe and efficient helicopter pilot. ♦

Should You Put it Down or Continue to Fly?

Why a rotorcraft pilot should consider landing at the first sign of mechanical trouble rather than trying to make it the extra mile to an airport.

While on approach to a runway about a mile-and-a-half away, a CH-47 pilot saw the transmission chip detector light flicker. Rather than continue the approach, he immediately made a precautionary landing. As the helicopter touched down, the transmission exploded and the aircraft caught fire, causing major damage. At the time of the emergency, six persons were on board the aircraft. If the pilot had ignored the warning light and continued his approach, all six could have been killed.

Sooner or later any pilot who flies long enough is going to have an opportunityto demonstrate whether or not his training and flying hours have been well spent. As rotary wing pilots know, a helicopter is a mass of push-pull rods, chains, gear-boxes, linkages, servos, and other items which generally work smoothly, but occasionally hang up and once in a while go “snap, crackle, and pop.” When this happens, the pilot must have the good sense to put the aircraft down at once.

But this is not always the case. Many accidents occur when pilots don’t make precautionary landings. Why don’t they? Let’s look at a few of the reasons some have given:

- “It’s probably just a fouled plug. We can make it.”

- “The boss doesn’t like to fill out all the paperwork that’s required if we put the aircraft down out here.”

- “That light comes on all the time; ignore it.”

- “I just brushed that tree. There’s no real damage.

Excuses such as these can have catastrophic results.

A UH-1 (Army version of the Bell 204B) pilot entered autorotation when the engine dropped to 5,200. The rpm then increased and the pilot made a power approach to the ground. Once on the gound, he decided that since the engine was still running, he could make it one more mile to an airfield. Complete engine failure occurred en route and the aircraft crashed.

Quit While You're Ahead

In another case, an OH-6 (a version of the Hughes 500) was not developing full power, so the pilot landed to see what was wrong. He then made a hover check and decided the engine was performing normally. Instead of having maintenance inspect the helicopter, he tried to continue his flight. During takeoff, the engine failed at 100 feet, the helicopter crashed, and all on board were killed.

Another OH-6 pilot radioed he was having trouble controlling excessive engine rpm. The problem continued for 10 minutes when the pilot said, “I think I just lost everything.” Witnesses said they heard the engine and rotor rev up, then there was relative silence. The main rotor severed the tail boom and the aircraft fell from about1,500 feet. The aircraft was destroyed and the pilot killed all because he failed to land after numerous indications of a malfunction.

Ignored Warning Light

Ten minutes after takeoff, another helicopter pilot reported his engine chip detector light was on and he was returning to home base. The last radio transmission heard was that the turbine outlet temperature was “out of sight,” that the aircraft was vibrating severely, and that the pilot intended to land at the closest helipad. A witness stated he saw flames coming from the rear of the helicopter and then the engine quit. The aircraft hit a 60-foot tree and sank in about eight feet of water. All three occupants were killed.

It’s hard to say why these aviators continued to fly rater that land, but no reason could justify their decisions to continue flight and jeopardize lives and aircraft.

Maintenance personnel aren’t immune to accidents, and are no more qualified than any other aviator to fly a substandard aircraft even when there may be only a “suspected” malfunction.

In one case, a pilot decided his aircraft was unflyable due to an increase in EGT when power was applied. Black smoke had been seen pouring from the tailpipe, oil vents, and particle separator. His mechanic made a 15-minute run-up with the same signs of a malfunction, but then decided to fly the aircraft to the maintenance area. As he made a downwind, near-maximum performance takeoff, the engine failed. The aircraft rolled and slid 280 feet down a railroad track.

A decision to tow or slingload the helicopter to the maintenance area would have prevented this accident.

Regardless of any excuse, whether it be pride, his job to do, or coercion by supervisory or maintenance personnel, it’s safer to put that aircraft down — and leave it down — at the first sign of trouble. ♦

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