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Helicopters and Turbulence

Downdrafts and microbursts can pose a greater threat to helicopters than to high speed, fixed-wing aircraft, says the author, who describes the two alternatives available to rotary wing pilots who face these hazardous weather phenomena.

by

Joe Mashman

As a result of a series of widely publicized commercial air transport accidents and near accidents that have been attributed to wind shear and downburst atmospheric conditions, it is timely to examine their effect on the rapidly increasing numbers of rotary wing aircraft.

Historically, fixed wing pilots upon transitioning into helicopters, have been impressed with the noticeably lesser effect of turbulence on the aircraft. While this is true, wind shear and downbursts are a different matter, and in some respects can more greatly affect the helicopter than high-speed fixed-wing aircraft.

Before discussing the manner in which this happens, let us examine some of the conditions that produce turbulence and the atmospheric phenomenon known as horizontal and vertical wind shear. The most common causes experienced by helicopter pilots are irregular terrain when combined with strong surface winds, gradient winds, temperature inversions, or thermal convection movements that, in some instances, can occur in close proximity to snow-covered or glacier slopes. All these conditions can be cause for concern. However, research shows that the most dangerous conditions can prevail in the vicinity of warm and cold fronts, thunderstorms, and other rain-producing clouds some of which may not have necessarily grown to thunderstorm intensity.

Frontal passages are often accompanied by wind velocity changes as well as directional changes. These shifts can occur along the entire frontal surface that separates warm and cold air, and pose a particular threat to aircraft flying within 1,000 feet or less from the ground, which is the most common regime of flight for helicopters.

Records show that wind shear hazards can exist for up to an hour or more after passage of a cold front. The potential for a hazardous shear increases with the magnitude of temperature difference across the front. A rule of thumb is to be on the alert if the temperature difference exceeds 15°F and its movement is 25 knots or more. In the case of a warm front, the most critical period can exist up to six hours prior to frontal passage. Typical warm fronts produce significant changes in wind velocity with little change in direction. Warm fronts can produce more dangerous wind shears than cold fronts. Both cold and warm fronts, even when dry with little or no associated weather, can produce violent shears.

Now let us examine the anatomy of some of these most dangerous forms of wind shear involving severe down drafts that meteorological terminology refer to as downbursts and microbursts. The principal difference is that downbursts affect a surface area of up to 15 miles in diameter, whereas microbursts are smaller and affect a surface area of approximately one to two miles. The hazardous elements produced by both of these phenomenon become a concern to low-flying helicopter pilots when one realizes that 1,000 feet per minute downward movement of air, and in some instances vertical velocities of 2,000 to 3,000 fpm, can be encountered within 200 feet of the terrain, thereby posing the potential for forcing the helicopter into the ground.

For the loaded helicopter, downward velocities approaching 1,000 fpm can be a serious threat to safety when in close proximity to the ground. In addition, an accompanying wind shear of 30 knots or more could cause the aircraft to exceed its placarded red-line speed. This could impose structural strains on the airframe and rotor system. But of even greater importance is the possible effect on controllability in two areas. Exceeding V_{NE} by 20 to 30 knots even for a short duration could produce severe retreating blade stall with accompanying severe pitch up and roll. On some types of helicopter, a light gross weight can result in an aft CG, and there could be insufficient forward cyclic to offset the severe pitch-up.

In order to avoid flight into hazardous conditions, we must examine the most common cause of downdrafts. When a column of rain is seen falling from a cumulus cloud, it is quickly cooling the surrounding air, increasing its density. If sufficiently dense, this column of cool air can become an intense local downdraft.

If the helicopter pilot cannot find a place to land and avoid this hazard but elects to fly "special VFR" through this local heavy rain downpour, he may not encounter a severe downdraft, but another hazard that a study by the U.S. National Aeronautics and Space Administration (NASA) indicates could affect rotor lift and drag, thereby adding to wind shear problems. This condition results from a build-up of rain on an airfoil that could result in up to a 30 percent loss of lift and up to 20 percent increase in drag. So for you special VFR pilots, avoid flight into these visually recognizable hazardous conditions.

What can we expect if one inadvertently flies into a low level downburst or microburst condition? In addition to the controllability problems, upon entering the severe downdraft, the helicopter will sink with startling suddenness that most likely will result in one being thrown upward against the seat restraints. Unless you can outclimb the downdraft or quickly fly through it, you can expect to be forced into the ground with dire consequences.

The most severe burst conditions are produced by intense thunderstorm activity. However, dangerous conditions can be produced by cumulus and towering cumulus clouds. Devastating downdrafts can be encountered when flying through seemingly innocent rain showers emanating from these clouds. Another form of violent downdraft can be produced by the phenomenon known as virga. This condition is most commonly encountered in arid regions when rain originating from high-based clouds evaporates before reaching the ground. You can expect such occurrences when surface winds are light, with temperatures above 80°F and the spread between the dew point and temperature exceeds 35°F.

What can we do to minimize the adverse affects of dangerous wind shears? The most important rules govern airspeed and power employment. If flying at an aft CG, fly well below red-line placard speed allowing a 20- to 30-knot margin for encountering headwind shear that could result in placard excedence. If a severe downdraft is encountered, employ maximum power and establish a best rate of climb speed. Do not allow your speed to drop any further even if you continue to experience a sink rate. If ground contact cannot be avoided, maintaining your best rate of climb speed will provide you with the capability of initiating an effective flare to lessen ground impact.

Remember, a helicopter pilot has only two alternatives to counter hazardous wind shear — avoidance and excess power. Since most helicopters do not have excess power to counteract high sink rate downdrafts, the only real alternative is avoidance. ♦

About the Author

Joe Mashman (ATP/CFR, commercial examiner Rotary/Fixed) is a pioneer in the rotorcraft world. After joining Bell as a test pilot in 1943, he made the change to rotary wing in 1945 after the company constructed its first experimental helicopter.

Before retiring in 1983 as vice president of special projects, Mashman had accumulated approximately 21,000 flight hours, 16,000 of them in rotorcraft. His rotary time includes experience in helicopters manufactured by several countries, including the Soviet Union. He has flown the heads-of-state of several nations and U.S. cabinet members. He served as personal pilot and special advisor to U.S. President Lyndon B. Johnson.

Vortex Ring State
. . . Can Ruin Your Whole Day

The author offers tips on avoiding — or coping with — the phenomenon of settling with power.

by

Capt. Michael J. Iltis, USAF

To the untrained eye, helicopters might appear to have all the aerodynamic characteristics of a brick. Those of us who have flown these machines know better. Yet, even the most seasoned helicopter veteran should pause every now and then to examine the aerodynamic forces at work, particularly when the mission requires operations into unprepared takeoff and landing areas.

One aerodynamic characteristic stands out as particularly confusing and potentially deadly: vortex ring state (more commonly known as settling with power). A thorough understanding of this phenomenon will help you avoid its possible disastrous results.

Settling with power

Before we discuss the causes and solutions of this problem, we must first establish proper terminology for the subject. Many publications use the phrases "settling with power" and "power settling" interchangeably. Though both conditions may have the same result — broken bodies and bent sheet metal — the causes are significantly different. So to avoid further confusion, we'll refer to "settling with power" by its more correct, technical term, "vortex ring state."

What is Vortex Ring State?

A helicopter in powered flight produces a downflow of air through the rotor system. This is the thrust that keeps the aircraft flying. As a helicopter begins to descend, an upflow of air through the rotor system begins. In forward flight (above about 35 knots), the effect of rotor tip vortices is negligible.

However, as the helicopter descends and slows below 35 KIAS, the angle of the upflow increases. As descent rate increases, so does air upflow through the rotor system. When the upflow rate exceeds the downflow created by the rotor system thrust, vortices begin to form at the rotor hub and blade tips. These vortices reduce the effectiveness of the rotor system by creating a disturbed column of air for the rotor blades to fly through. The net result of this action is a loss of lift.

Increasing collective pitch to compensate for this loss of lift only aggravates the situation by creating even larger vortices. If the condition persists, the rate of descent will increase and the aircraft will probably hit the ground with G forces in excess of those planned for. The potential for encountering vortex ring state increases with high gross weights, high density altitudes and high rates of descent, combined with slow forward airspeeds.

What to do?

Obviously, the best method of eliminating the effects of vortex ring state is to avoid it entirely. A few simple steps will help:

• **Plan your approach.** During the site evaluation, take time to select a final approach course that permits you to fly, as much as possible, a normal approach glide path (apparent 30o angle). A normal approach allows you to keep airspeed up during early stages of the approach and permits visual contact with the landing zone through most, if not all, of the landing sequence.

Steep approaches, on the other hand, require slower airspeeds throughout the approach and leave the helicopter more vulnerable to the effects of downdrafts. Also, in most helicopters a steep approach is synonymous with losing visual contact with the landing zone on short final. If you must fly a steeper than normal approach, make it as shallow as possible and take care to closely monitor your rate of descent. Do not attempt to salvage a poor approach. It's better to go around and make another attempt.

Make sure you avoid tail wind conditions, particularly during the final portion of the approach where wind direction and velocity may change dramatically. If you maintain a head wind component thorughout the approach, you diminish the possibility of premature loss of effective translational lift (ETL). An early, unplanned loss of ETL will result in a loss of altitude, an instinctive increase in collective pitch and a decrease in airspeed. These conditions favor the formation of vortex ring state.

• **Control the rate of descent.** By definition, vortex ring state exists when upflow exceeds downflow. Reducing the rate of descent will reduce upflow of air through the rotor system. It follows that reducing the rate of descent will necessarily inhibit the formation of rotor blade vortices. In some helicopters a rate of descent as low as 300 feet per minute at airspeeds below ETL may create the upflow necessary to induce vortex ring state. Under no circumstances should you allow the rate of descent to exceed 800 feet-per-minute at airspeeds below ETL and outside of ground effect. Consult your aircraft's flight manual for additional rate of descent restrictions.

• **Reduce airspeed gradually during the approach.** Remember, forward airspeed reduces the angle of upflow and permits rotor blades to fly through undisturbed air. Avoid decelerating below ETL airspeed until the aircraft is in ground effect, with rate of descent no more than 300 feet-per-minute, and in a position where a safe landing is assured. This becomes difficult when you must fly a steep approach. In this case, riding the "burble" of translational lift down the glide path may be a good technique.

• **Ensure that power (collective pitch) required to hover does not exceed power available based on landing zone terrain restrictions.** Make sure you take into account the additional power necessary to arrest the inertia of the descending helicopter. During the initial portions of the approach, keep collective setting changes to a minimum. The same control and performance techniques used during instrument flight can help here. As you continue the approach, carefully increase collective to slow your rate of descent. Excessively high collective settings produce significant downflow.

• **Reducing gross weight reduces collective power demand, which subsequently reduces downflow.** Some military aircraft let you jettison fuel and tip tanks, which allows the air crew to adjust gross weight in flight if necessary. Thorough preflight planning can also ensure that excess fuel isn't on board. Other ways of adjusting gross weight include reducing crew and equipment complements.

• **You must have effective crew coordination in order to recognize symptoms of vortex ring state.** With few exceptions, we [in the military] don't operate single-pilot. Aircraft commanders who use their crews wisely will make their own jobs a lot easier. Let the copilot monitor the gauges while the pilot focuses his attention outside. The copilot should keep the crew informed regarding rates of descent, power settings and airspeeds. It's also critical that he inform the pilot of any deviations from the planned course of action. This sounds painfully obvious, but all too often minor deviations from prebriefed descent angles turn into major problems at the bottom of the approach. There's no harm done by telling the pilot that the approach angle looks steep.

The other crew members also play a major part in the crew coordination process. If inexperienced, don't let this inhibit your inputs. From your vantage point elsewhere in the helicopter you very possibly have the best perception of wind direction and speed on-site, not to mention excellent visibility of objects on the approach route. Keep intercom comments brief and pertinent, but if you detect a deviation, let the pilot know.

• **Maintain your wave-off option.** This is not unique to vortex ring state conditions; it applies when flying any approach. Once you lose this option, you're committed to land — one way or the other.

OK, so messed up and found myself in vortex ring state — what now? In the words of one wise old aviator, "If you don't do something quick, you're gonna die!" In order to avoid this, we recommend:

• **Enter autorotation.** Entering autorotation automatically eliminates the downflow necessary to sustain vortex ring state. This option presupposes sufficient altitude and airspeed to recover. Given the low altitudes and airspeeds normally associated with this phenomenon, autorotation may not be possible.

• **Increase forward airspeed.** The increase permits the helicopter to fly out of the disturbed column of air within which it is settling. This action also requires sufficient altitude in order to compensate for the altitude loss encountered when you lower the nose to gain airspeed, although it requires less altitude than autorotation.

• **Reduce collective pitch.** Like autorotation, reducing collective pitch reduces downflow through the rotor system. If altitude and airspeed preclude autorotation, this option may be best. Minor reductions in collective pitch option may be best. Minor reductions in collective pitch may reduce vortices but probably won't eliminate them.

Keep in mind that all of the above options require an altitude/airspeed trade off. ♦

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