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Preventing Dynamic Rollover

Before describing how to prevent dynamic rollover, the author , a U.S. Naval aviator, explains how a helicopter can be maneuvered into attitudes that can induce rollover.

by

Maj. Joseph H. Schmid

Before a pilot can understand what dynamic rollover is, it is helpful to know what it is not. There exists for every object a static rollover angle. This is the angle to which you must tilt an object to bring the center of gravity directly over the roll point. If the object is tilted beyond this angle, it will fall over. It is this angle that the drunk defies.

For most fleet helicopters, the static rollover angle is between 30 and 35 degrees. Every helicopter also has a critical rollover angle. This is the maximum hillside angle on which you can land the helicopter and still be able to have the rotor system horizontal.

Another way of thinking about the critical rollover angle is that it is the maximum blade flapping angle. For most fleet helicopters, the critical rollover angle is approximately 13-17 degrees. The important concept is that you can be committed to dynamic rollover at a roll angle much less than the static or critical rollover angles.

Occurrence of a Dynamic Rollover Depends on Four Conditions

Four general conditions must exist for a pilot to get into dynamic rollover.

- The helicopter must be on or restrained to the deck. A wheel or skid could be in contact with the ground or an object on the ground such as an external load. It may be a tiedown chain that restrains the helicopter, even though the skids or wheels are off the ground. In a recent mishap, dynamic rollover was suggested, even though the witnesses stated that the wheel was either on the ground or close to it. If the wheel was not on the ground, it could not have been dynamic rollover.

- The helicopter must pivot about the ground contact point instead of the center of gravity. There are many common flight regimes in which the helicopter will pivot about the ground contact point. During vertical takeoffs from hillsides, the helicopter pivots about the uphill skid or wheel until the gear is level. Operators of skid-equipped helicopters often shake the rudder pedals before takeoff in arctic conditions to prevent the possibility of pivoting about one skid frozen to the deck.

Lateral cyclic during takeoff has been the cause of numerous dynamic rollovers (or pivots about the ground contact point). Taking off with tiedowns attached provides a pivot at the ground attachment point.

The most common occurrence is ground contact in lateral translation. A classic case is the instructor who was demonstrating a night hover with the position lights on flashing dim. He developed just a bit of a drift. The aircraft caught a skid 650 feet from the initial hover point. The helicopter then flipped smartly onto its back.

- The helicopter must have some angular velocity about the pivot point. That is to say, you must have some roll rate about the pivot point.

- The helicopter is usually at liftoff thrust or light on the skids.

Examine the Cause of Rollover

With an understanding of when dynamic rollover occurs, the next step is to study why it occurs. The basic cause of dynamic rollover is **excessive angular momentum**. Isaac Newton said that an unbalanced force equals the time rate of change of momentum . . . F = ma. That is true for objects moving in straight lines. However, for rotational motion, Newton's law changes slightly — an unbalanced moment equals the time rate of change of angular momentum.

Angular momentum is defined as the moment of inertia (I) multiplied by the angular velocity (ω). Newton's law really does make sense in relation to helicopters. In a hover, there is no roll rate or angular velocity. However, when the cyclic is displaced, the rotor system is tilted. The thrust of the rotor system then creates a moment about the center of gravity, and the helicopter develops a roll.

Remember, the moment of inertia is a body's resistance to rotation and is defined for rolls about the center of gravity as the sum of all the bits of mass of the body (m) multiplied by the square of the radius of each of those bits from the center of rotation. Algebraically, the moment of inertia is $I = \sum mr^2$. This is the old spinning figure skater trick. When the skater is on the ice, there is little friction, so there is little change in the angular momentum $I\omega$ of the skater. As she brings her arms in, the mass does not change, but the radius of where that mass is located does decrease. Therefore, as the skater's moment of inertia and resistance to rotation decreases, her spin rate, or angular velocity, increases.

For every helicopter, the manufacturer must determine the maximum control moment. Each helicopter must, by U.S. military specifications and U.S. Federal Aviation Regulations, achieve a particular roll rate. The manufacturer knows the mass of the helicopter and how that mass is distributed. Therefore he knows the moment of inertia. The manufacturer produces the helicopter so that, with full cyclic displacement, the rotor system produces a sufficient moment about the center of gravity to change the angular momentum of the helicopter and achieve the desired roll rate.

This is acceptable for rolls about the center of gravity, but dynamic rollover occurs when the pilot rolls about a pivot point. For rolls about some point other than the center of gravity, the moment of inertia changes to become $I=mr^2 + md^2$, where d is the distance between the center of gravity and the point of rotation.

Clearly, the moment of inertia must be greater for rolls not about the CG. The helicopter still has the same maximum control moment. Therefore, with a greater moment of inertia, full opposite stick displacement will not produce as large a roll rate. More important, the helicopter cannot arrest as large a roll rate. That is the insidious part of dynamic rollover. What is a normal roll rate about the center of gravity may well be an excessive roll rate when pivoting about a wheel or skid. The bottom line remains: The basic cause of dynamic rollover is **excessive angular momentum**.

There are several contributing factors that can make conditions worse. Any shift of the center of gravity toward the roll point makes the helicopter more likely to statically roll over. This CG shift could be caused by a cargo shift or by personnel changing positions in the aircraft. For American-made helicopters, the thrust of the tail rotor is directed toward the right. For rollovers to the right, the tail rotor thrust would be an aggravating condition. Winds can also make conditions worse. If the winds are strong enough, the side force on the fuselage may be sufficient to roll the helicopter. Winds from the left will increase the tail rotor angle of attack, increasing the tail rotor thrust. Finally, winds in the direction of the rollover will cause "blowback" of the main rotor, tilting it in the direction of roll.

Tips to Prevent Rollover

The conditions for occurrence are present for nearly every helicopter takeoff. How, then does a pilot recognize and prevent dynamic rollover? Earlier, it was discussed that, for rolls not about the CG, the moment of inertia increased . . . It becomes insensitive to cyclic control. If the conditions for occurrence are present and the helicopter does not respond to cyclic inputs, there is a distinct possibility that dynamic rollover is imminent. What should a pilot do now? **Lower the collective**.

Look at all the forces acting on the helicopter and see how they contribute to the rollover. The thrust of the main rotor multiplied by its moment arm about the pivot points is in the pro-rollover direction. The thrust of the main rotor multiplied by its moment arm is also pro-rollover. The combined effects of the wind are also pro-rollover. Only the weight of the aircraft multiplied by its moment arm opposes the rollover.

Countering the roll with cyclic-only reduces the main rotor thrust moment arm. Lowering the collective reduces the magnitude of the main rotor thrust. Clearly, there is far greater control authority with collective than with cyclic. **Lower the collective**. The pilot who tries to snatch the helicopter off the deck with the collective in the armpit may get the helicopter airborne. But he has just made a tremendous increase to the pro-rollover moments and, at an altitude of about three feet, will probably have the rotor blades strike the ground. **Lower the collective**.

Collective pitch reduction must be immediate but not a panic reduction. The pilot who is ham-fisted and slams the collective down runs the risk of blade-to-fuselage contact or a rollover in the opposite direction, either of which can ruin a pilot's whole day.

Prevention of dynamic rollover is simple. **Control the roll rate**. Prevent the roll rates from becoming excessive by judicious use of collective. **Control the roll rate**. And, if control seems marginal, **lower the collective**. ♦

Insidious Rotor Ice

Pilots should be particularly aware of blade icing. With barely any warning, ice can form quickly on the rotor with no sign of it on the fuselage.

by

Aage Roed

During the analysis of a helicopter accident, an investigative team speculated that rotor ice, which accumulated while the helicopter was hovering immediately below a cloud base, may have been a contributing factor. In the post-accident report it was also stated that ice may have accumulated on the rotor blades, although no ice could be detected on the wind screens or the fuselage structure.

In response to the analysis, operators have noted that ice will always show on the wind screens and fuselage structure at the same time that it accumulates on the rotor.

This Is Wrong.

Several published reports show that ice can accumulate on the main rotor without any detectable ice on the fuselage. The following is one example:

Two helicopters flew below clouds for a short time. The lead helicopter had a two-man crew and, for this reason, could maintain lower altitude than the second (the non-flying crew member kept a sharp lookout for wires). However, the altitude difference was only a few meters, with the second helicopter following closely behind and above the lead aircraft. The flight proceeded close to the cloud base.

At one point, when the pilot of the lead helicopter had to slow down, the second pilot found that he did not have sufficient power to maintain altitude and made an emergency landing. The same maneuver had been made a moment earlier without any problem. No vibrations were felt during the flight. Two to three minutes after the second helicopter had landed, the lead aircraft had to make an emergency landing because of a rapidly increasing demand for additional power to remain at level flight.

Both crews found that the main and tail rotor blades of their helicopters had glass-clear layers of ice varying in thickness from about one to 10 millimeters on the outboard two thirds of the main rotor blades. No ice was found on the fuselages or the landing gears.

Helicopter pilots cannot be sure that they will be warned of blade icing by ice formations on the fuselage. They also should be aware that ice may accumulate very rapidly on the blades. ♦

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