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Helicopter Dynamic Rollover

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Irrespective of the environment, dynamic rollover can happen to any helicopter pilot. The U. S. Navy SH-60B NATOPS (Naval Air Training and Operating Procedures Standardization) manual states, "The insidious aspect of dynamic rollover is that the roll rates which precipitate it are within the range the pilot would normally allow in flight." Put another way, this statement says that a helicopter could be placed in a rollover situation well before the pilot recognizes it. The goal of this article is to provide a better understanding of the causes of dynamic rollover and how to correct for it.

Dynamic rollover typically occurs when a critical rollover angle is exceeded. This angle--often referred to as the dynamic rollover angle--is considered that angle-of-bank beyond which the pilot's control authority can't arrest the angular velocity that develops laterally about a pivot point such as a skid or tire. This angle can be as little as seven degrees and varies with a helicopter's roll rate, gross weight, and main rotor thrust. In addition, there is yet another angle that is nearly as important and provides us with some hope for recovery, it is the static rollover angle. This angle results when the helicopter's lateral center-of-gravity (c.g.) is directly over the skid or tire. In other words, if we could balance a helicopter on its side by lifting one skid or tire until the c.g. is directly over the opposite skid or tire, this would be the static rollover angle.

Let's now look at the helicopter's roll response to cyclic inputs when airborne. In level flight for example, the thrust vector that is perpendicular to the tip-path-plane of the main rotor acts about the lateral c.g. to provide roll rates as shown in Figure 1. Now, the speed at which the aircraft rolls about the pivot point is determined by the helicopter's roll acceleration or *control power* and is dependent on couple of things: the control moment which acts about the c.g. and the roll axis moment of inertia. The control moment again is a function of main rotor thrust acting about the aircraft's lateral c.g. The moment of inertia, however, is not quite as simple. It relates the mass of a component to the point about which it acts and in this case, it's the lateral c.g. Incidentally, all aircraft have specific moments of inertia about each of the helicopter's three rotating degrees of freedom – pitch, roll, and yaw.

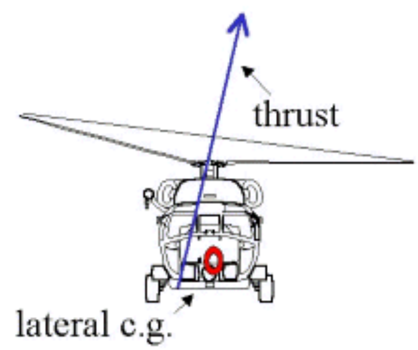

Figure 1

In flight, we are perfectly comfortable with maneuvering about the c.g. A potential problem develops, however, when the helicopter comes in contact with the ground (a lateral drift for example) and a new pivot point is established (e.g. the skid or tire). In this situation, the moment of inertia about the roll axis increases nearly five-fold due to this displaced pivot point and the control power decreases with opposite cyclic as shown in Figure 2. To make things worse, if the pilot applies opposite cyclic too late, the control moment will not act *outside* the new pivot point and will not provide the necessary control power to arrest the rolling motion.

At this point, an important question to ask is, "How do helicopters get into a dynamic rollover situation?" Well, just imagine hovering in a brownout or whiteout situation and attempting to land. In the process, due to loss of visual cues, you establish a lateral drift and contact the ground with one wheel or skid. Unfortunately, the aircraft's c.g. now rotates about the wheel or skid causing the undesirable rolling motion and to make things worse, because the collective is not all the way down, the main rotor thrust is accelerating the motion exacerbating the situation causing the aircraft to rollover.

Identifying the hazards, taking the proper preventive measures, and ensuring that others don't get into the situation are the tenets of risk management; but what if we are unfortunate enough to get into it, how do we stop rolling over? First of all, getting rid of the control moment should be the goal of every pilot because we may not be sure if the main rotor thrust is accelerating or decelerating the roll motion -- we do this by lowering the collective. Fundamentally, this action allows the weight of the aircraft to act against the rolling motion and is beneficial until the helicopter reaches the static rollover angle or the main rotor strikes the ground as shown in Figure 3.

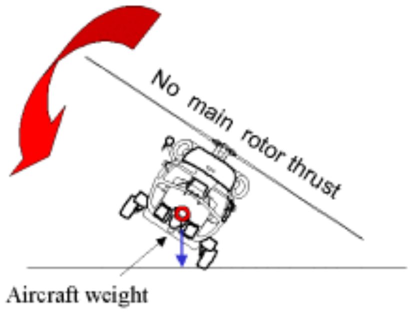

Figure 3

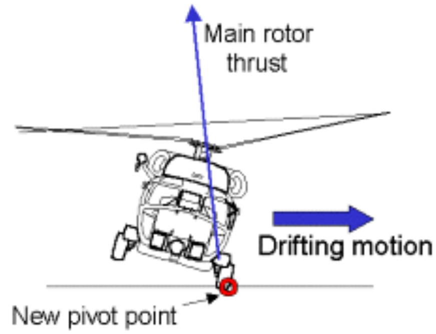

Figure 2

There is yet another important question that should be asked, "What could possibly make this bad situation worse?" Well, what follows are a few points to consider. The tail rotor, for one, can provide a rolling moment about the lateral c.g. Considering only U.S. made helicopters, a rolling motion to the right (when sitting in the helicopter) will be made worse by the thrust produced by the tail rotor as it also acts about the tire or skid. Conversely, a rolling motion to the left will decrease as the tail rotor thrust acts to provide deceleration. The wind can cause the same advantage or disadvantage depending on direction as it provides a force that acts about the pivot point, as well. Additionally, the rolling motions associated with shipboard operations in high sea states can also result in a rollover situation as demonstrated recently by a U.S. Navy SH-60B. The aircraft's main rotor was turning at 100% rpm, *collective full down* and unrestrained when the ship was hit by a rogue wave resulting in 20 to 25 degrees of deck roll. The aircraft rolled to its left side and the main rotor was driven into the deck of the ship. Luckily, the aircraft remained aboard the ship and the aircrew escaped uninjured.

This same discussion on dynamic rollover has direct application to another area of helicopter flight that we are asked to perform as part of our mission – sloped landings. In the case of sloped landings, we actually *want* to pivot about the skid or tire. Normally, a sloped landing is performed by gently lowering the collective from a hover to contact the ground at a single point as shown in Figure 4. Cyclic is usually displaced upslope to provide the greatest control moment possible while preventing the aircraft from sliding. The pilot then gently lowers the collective to make full contact and rest firmly on the terrain as depicted in Figure 5. Two critical things to be aware of during this evolution are rotor clearance (personnel running into your rotor arc from the higher ground) and running out of control authority where the cyclic contacts the stops.

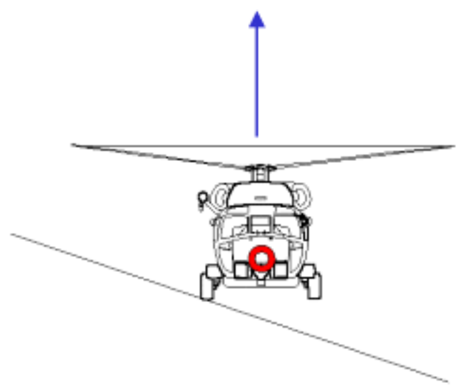
Figure 4

Quite often, a more dangerous aspect of this evolution is lifting off the slope. A common technique used when lifting into a hover from a slope is to displace the cyclic laterally toward the higher ground as up-collective is applied. This is performed delicately as the pilot searches for a level attitude before breaking contact with the ground; however, a problem can arise when the proper technique is not utilized. For example, if an arm full of collective is pulled too quickly before breaking contact with the ground, excessive momentum occur. In other words, if the aircraft is not stabilized prior to breaking contact with the ground, a "whipping" effect can occur as the pivot point quickly moves from the tire back to the c.g. This change in pivot point, thus inertia, can lead to a five-fold increase in control power rendering the aircraft uncontrollable. The end result can be catastrophic.

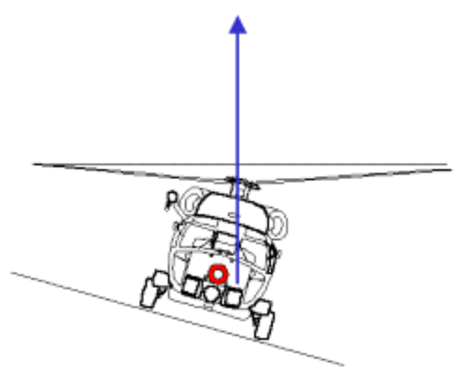
Figure 5

In summary, the brevity of this discussion on dynamic rollover should by no means reflect the importance of the topic. Over the years, several Naval helicopter pilots have experienced a dynamic rollover mishap and many more came close. The one thing that they would all likely agree on is that a firm understanding of this issue would have proved beneficial and perhaps prevented the occurrence. Don't be caught unaware, be knowledgeable and fly safely.

- Major Lobik was the Helicopter Aerodynamics instructor at the School of Aviation Safety, Naval Postgraduate School in Monterey, CA, from May 1995 - May 1998.

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