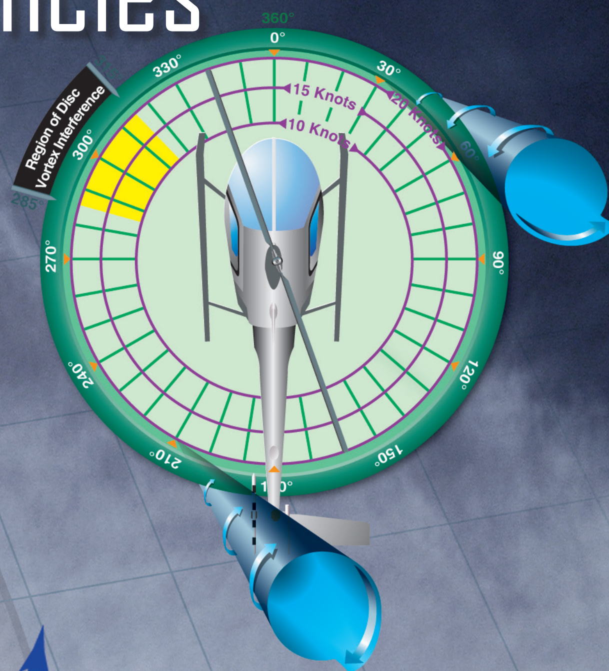
Chapter 11

Helicopter Emergencies and Hazards



Introduction

Today, helicopters are quite reliable. However, emergencies do occur, whether a result of mechanical failure or pilot error, and should be anticipated. Regardless of the cause, the recovery needs to be quick and precise. By having a thorough knowledge of the helicopter and its systems, a pilot is able to handle the situation more readily. Helicopter emergencies and the proper recovery procedures should be discussed and, when possible, practiced in flight. In addition, by knowing the conditions that can lead to an emergency, many potential accidents can be avoided.

Autorotation

In a helicopter, an autorotative descent is a power-off maneuver in which the engine is disengaged from the main rotor system and the rotor blades are driven solely by the upward flow of air through the rotor. *[Figure 11-1]* In other words, the engine is no longer supplying power to the main rotor.

The most common reason for an autorotation is failure of the engine or drive line, but autorotation may also be performed in the event of a complete tail rotor failure, since there is virtually no torque produced in an autorotation. In both areas, maintenance has often been a contributing factor to the failure. Engine failures are also caused by fuel contamination or exhaustion as well resulting in a forced autorotation.

If the engine fails, the freewheeling unit automatically disengages the engine from the main rotor allowing the main rotor to rotate freely. Essentially, the freewheeling unit disengages anytime the engine revolutions per minute (rpm) is less than the rotor rpm.

At the instant of engine failure, the main rotor blades are producing lift and thrust from their angle of attack (AOA) and velocity. By lowering the collective pitch, which must be done immediately in case of an engine failure, lift and drag are reduced, and the helicopter begins an immediate descent, thus producing an upward flow of air through the rotor system. This upward flow of air through the rotor provides sufficient thrust to maintain rotor rpm throughout the descent. Since the tail rotor is driven by the main rotor transmission during autorotation, heading control is maintained with the antitorque pedals as in normal flight.

Several factors affect the rate of descent in autorotation: density altitude, gross weight, rotor rpm, and airspeed. The primary way to control the rate of descent is with airspeed. Higher or lower airspeed is obtained with the cyclic pitch control just as in normal powered flight. In theory, a pilot has a choice in the angle of descent varying from a vertical descent to maximum range, which is the minimum angle of descent. Rate of descent is high at zero airspeed and decreases to a minimum at approximately 50–60 knots, depending upon the particular helicopter and the factors just mentioned. As the airspeed increases beyond that which gives minimum rate of descent, the rate of descent increases again.

When landing from an autorotation, the only energy available to arrest the descent rate and ensure a soft landing is the kinetic energy stored in the rotor blades. Tip weights can greatly increase this stored energy. A greater amount of rotor energy is required to stop a helicopter with a high rate of descent than is required to stop a helicopter that is descending more slowly. Therefore, autorotative descents at very low or very high airspeeds are more critical than those performed at the minimum rate of descent airspeed.

Each type of helicopter has a specific airspeed and rotor rpm at which a power-off glide is most efficient. The specific airspeed is somewhat different for each type of helicopter, but certain factors affect all configurations in the same manner. In general, rotor rpm maintained in the low green area gives more distance in an autorotation. Higher weights may require more collective pitch to control rotor rpm. Some helicopters need slight adjustments to minimum rotor rpm settings for winter versus summer conditions, and high altitude versus sea level flights. For specific autorotation airspeeds and rotor rpm combinations for a particular helicopter, refer to the Federal Aviation Administration (FAA)-approved rotorcraft flight manual (RFM).

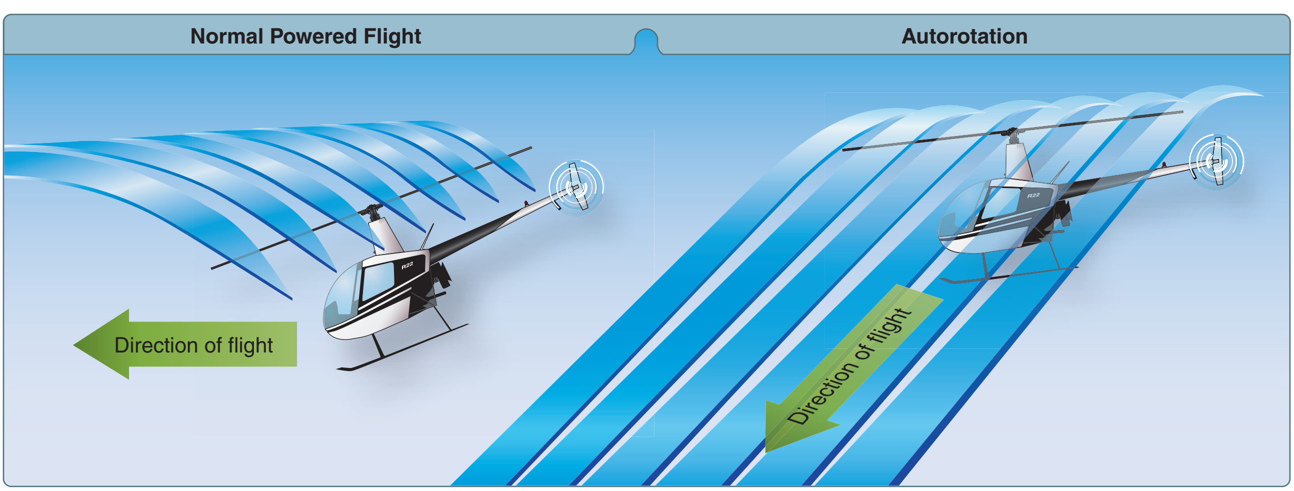


Figure 11-1. *During an autorotation, the upward flow of relative wind permits the main rotor blades to rotate at their normal speed. In effect, the blades are "gliding" in their rotational plane.*

The specific airspeed and rotor rpm for autorotation is established for each type of helicopter on the basis of average weather, wind conditions, and normal loading. When the helicopter is operated with heavy loads in high density altitude or gusty wind conditions, best performance is achieved from a slightly increased airspeed in the descent. For autorotation at low density altitude and light loading, best performance is achieved from a slight decrease in normal airspeed. Following this general procedure of fitting airspeed and rotor rpm to existing conditions, a pilot can achieve approximately the same glide angle in any set of circumstances and estimate the touchdown point.

Pilots should practice autorotations with varying airspeeds between the minimum rate of descent to the maximum glide angle airspeed. The decision to use the appropriate airspeed for the conditions and availability of landing area must be instinctive. The helicopter glide ratio is much less than that of a fixed wing aircraft and takes some getting used to. The flare to land at 55 KIAS will be significantly different than the flare from 80 KIAS. Rotor rpm control is critical at these points to ensure adequate rotor energy for cushioning the landing.

Straight-In Autorotation

A straight-in autorotation implies an autorotation from altitude with no turns. Winds have a great effect on an autorotation. Strong headwinds cause the glide angle to be steeper due to the slower groundspeed. For example, if the helicopter is maintaining 60 knots indicated airspeed and the wind speed is 15 knots, then the groundspeed is 45 knots. The angle of descent will be much steeper, although the rate of descent remains the same. The speed at touchdown and the resulting ground run depend on the groundspeed and amount of deceleration. The greater the degree of deceleration, or flare, and the longer it is held, the slower the touchdown speed and the shorter the ground run. Caution must be exercised at this point as the tail rotor will be the closest component of the helicopter to the ground. If timing is not correct and a landing attitude not set at the appropriate time, the tail rotor may contact the ground causing a forward pitching moment of the nose and possible damage to the helicopter.

A headwind is a contributing factor in accomplishing a slow touchdown from an autorotative descent and reduces the amount of deceleration required. The lower the speed desired at touchdown is, the more accurate the timing and speed of the flare must be, especially in helicopters with low-inertia rotor systems. If too much collective pitch is applied too early during the final stages of the autorotation, the kinetic energy may be depleted, resulting in little or no cushioning effect available. This could result in a hard landing with corresponding damage to the helicopter. It is generally better practice to accept more ground run than a hard landing with minimal groundspeed. As proficiency increases, the amount of ground run may be reduced.

Technique

Refer to *Figure 11-2* (position 1). From level flight at the appropriate airspeed (cruise or the manufacturer's recommended airspeed), 500–700 feet above ground level (AGL), and heading into the wind, smoothly but firmly lower the collective pitch control to the full down position, maintaining rotor rpm in the green arc with collective. If the collective is in the full down position, the rotor rpm is then being controlled by the mechanical pitch stops. During maintenance, the rotor stops must be set to allow minimum autorotational rpm with a light loading. This means that some collective pitch adjustment can be made if the air density or helicopter loading changes. After entering an autorotation, collective pitch must be adjusted to maintain the desired rotor rpm.

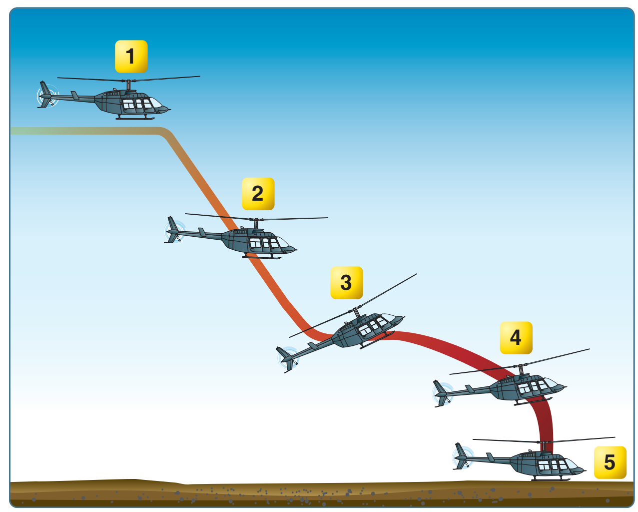


Figure 11-2. *Straight-in autorotation.*

Coordinate the collective movement with proper antitorque pedal for trim, and apply cyclic control to maintain proper airspeed. Once the collective is fully lowered, decrease throttle to ensure a clean split/separation of the needles. This means that the rotor rpm is higher than the engine rpm and a clear indication that the freewheeling unit has allowed the engine to disconnect. After splitting the needles, readjust the throttle to keep engine rpm above normal idling speed, but not high enough to cause rejoining of the needles. The manufacturer often recommends the proper rpm for that particular helicopter.

At position 2, adjust attitude with cyclic control to obtain the manufacturer's recommended autorotation or best gliding speed. Adjust collective pitch control, as necessary, to maintain rotor rpm in the green arc. Aft cyclic movements cause an increase in rotor rpm, which is then controlled by a small increase in collective pitch control. Avoid a large collective pitch increase, which results in a rapid decay of rotor rpm, and leads to "chasing the rpm." Avoid looking straight down in front of the aircraft. Continually crosscheck attitude, trim, rotor rpm, and airspeed.

At the altitude recommended by the manufacturer (position 3), begin the flare with aft cyclic control to reduce forward airspeed and decrease the rate of descent. Maintain heading with the antitorque pedals. During the flare maintain rotor rpm in the green range. Care must be taken in the execution of the flare so that the cyclic control is neither moved rearward so abruptly that it causes the helicopter to climb nor moved so slowly that it does not arrest the descent, which may allow the helicopter to settle so rapidly that the tail rotor strikes the ground. In most helicopters, the proper flare attitude is noticeable by an apparent groundspeed of a slow run. When forward motion decreases to the desired groundspeed, which is usually the lowest possible speed (position 4), move the cyclic control forward to place the helicopter in the proper attitude for landing.

In many light helicopters, the student pilot can sit in the pilot seat while the instructor pulls down on the helicopter's tail until the tail rotor guard or "stinger" touches the surface. This action gives the student an idea of airframe attitude to avoid, because a pilot should never allow ground contact unless the helicopter is more nose low than that attitude. Limiting the flare to that pitch attitude may result in slightly faster touchdown speeds, but will eliminate the possibility of tail rotor impact on level surfaces.

The landing gear height at this time should be approximately 3–15 feet AGL, depending on the altitude recommended by the manufacturer. As the apparent groundspeed and altitude decrease, the helicopter must be returned to a more level attitude for touchdown by applying forward cyclic. Some helicopters can be landed on the heels in a slightly nose high attitude to help decrease the forward groundspeed whereas others must land skids or landing gear level to equally spread the landing loads to all of the landing gear. Extreme caution should be used to avoid an excessive nose high and tail low attitude below 10 feet. The helicopter must be close to the landing attitude to keep the tail rotor from contacting the surface.

At this point, if a full touchdown landing is to be made, allow the helicopter to descend vertically (position 5). Increase collective pitch, as necessary, to arrest the descent and cushion the landing. This collective application uses some of the potential energy in the rotor system to help slow the descent rate of the helicopter. Additional antitorque pedal is required to maintain heading as collective pitch is raised due to the reduction in rotor rpm and the resulting reduced effect of the tail rotor. Touch down in a level flight attitude.

Control response with increased pitch angles will be slightly different than normal. With a decrease in main rotor rpm, the antitorque authority is reduced, requiring larger control inputs to maintain heading at touchdown.

Some helicopters have a canted tail stabilizer like the Schweitzer 300. It is crucial that the student apply the appropriate pedal input at all times during the autorotation. If not the tailboom tends to swing to the right, which allows the canted stabilizer to raise the tail. This can result in a severe nose tuck which is quickly corrected with right pedal application.

A power recovery can be made during training in lieu of a full touchdown landing. Refer to the section on power recovery for the correct technique. After the helicopter has come to a complete stop after touchdown, lower the collective pitch to the full-down position. Do not try to stop the forward ground run with aft cyclic, as the main rotor blades can strike the tail boom. Rather, by lowering the collective slightly during the ground run, more weight is placed on the undercarriage, slowing the helicopter.

One common error is holding the helicopter off the surface versus cushioning the helicopter on to the surface during an autorotation. Holding the helicopter in the air by using all of the rotor rpm potential energy usually causes the helicopter to have a hard landing, which results in the blades flexing down and contacting the tail boom. The rotor rpm should be used to cushion the helicopter on to the surface for a controlled, smooth landing instead of allowing the helicopter to drop the last few inches.

Common Errors

1. Not understanding the importance of an immediate entry into autorotation upon powerplant or driveline failure.
2. Failing to use sufficient antitorque pedal when power is reduced.
3. Lowering the nose too abruptly when power is reduced, thus placing the helicopter in a dive.
4. Failing to maintain proper rotor rpm during the descent.
5. Applying up-collective pitch at an excessive altitude, resulting in a hard landing, loss of heading control, and possible damage to the tail rotor and main rotor blade stops.

6. Failing to level the helicopter or achieve the manufacturers preferred landing attitude.
7. Failure to maintain ground track in the air and keeping the landing gear aligned with the direction of travel during touchdown and ground contact.
8. Failure to minimize or eliminate lateral movement during ground contact.
9. Failure to go around if not within limits and specified criteria for safe autorotation.

Autorotation With Turns

A turn, or a series of turns, can be made during an autorotation in order to land into the wind or avoid obstacles. The turn is usually made early so that the remainder of the autorotation is the same as a straight-in autorotation. Making turns during an autorotation generally uses cyclic control only. Use of antitorque pedals to assist or increase the speed of the turn causes loss of airspeed and downward pitching of the nose. When an autorotation is initiated, sufficient antitorque pedal pressure should be used to maintain the helicopter in trim and prevent yawing. This pressure should not be changed to assist the turn. If the helicopter is flown out of trim in forward flight, the helicopter will be in either a slip or a skid and airframe drag will be greatly increased which in turn increases the rate of descent. Therefore, for the minimum descent vertical speed, the trim ball should remain centered.

Use collective pitch control to manage rotor rpm. If rotor rpm builds too high during an autorotation, raise the collective sufficiently to decrease rpm back to the normal operating range, then reduce the collective to maintain proper rotor rpm. If the collective increase is held too long, the rotor rpm may decay rapidly. The pilot must then lower the collective and begin chasing the rotor rpm. If the rpm begins decreasing, the pilot must again lower the collective. Always keep the rotor rpm within the established range for the helicopter being flown. During a turn, rotor rpm increases due to the increased G loading, which induces a greater airflow through the rotor system. The rpm builds rapidly and can easily exceed the maximum limit if not controlled by use of collective. The tighter the turn is and the heavier the gross weight is, the higher the rpm is.

Cyclic input has a great effect on the rotor rpm. An aft cyclic input loads the rotor, resulting in coning and an increase in rotor rpm. A forward cyclic input unloads the rotor, resulting in a decrease in rotor rpm. Therefore, it is prudent to attain the proper pitch attitude needed to ensure that the desired landing area can be reached as soon as possible, and to make minor adjustments from there.

To initiate an autorotation in other than in a low hover, lower the collective pitch control. This holds true whether performing a practice autorotation or in the event of an in-flight engine failure. This reduces the pitch of the main rotor blades and allows them to continue turning at normal rpm. During practice autorotations, maintain the rpm in the green arc with the throttle while lowering collective. Once the collective is fully lowered, reduce engine rpm by decreasing the throttle. This causes a split of the engine and rotor rpm needles.

Technique

The most common types of autorotation are 90° and 180° autorotations. For a 180° autorotation, establish the aircraft on the downwind at recommended airspeed and 500–700 feet AGL, parallel to the touchdown area. In a no-wind or headwind condition, establish the ground track approximately 200 feet away from the touchdown point. If a strong crosswind exists, it is necessary to move the downwind leg closer or farther out. When abeam the intended touchdown point, smoothly but firmly lower the collective pitch control to the full down position, maintaining rotor rpm in the green arc with collective.

Coordinate the collective movement with proper antitorque pedal for trim, and apply cyclic control to maintain proper attitude. Once the collective is fully lowered, decrease throttle to ensure a clean split/separation of the needles. After splitting the needles, readjust the throttle to keep engine rpm above normal idling speed, but not high enough to cause rejoining of the needles. The manufacturer often recommends the proper rpm for that particular helicopter. Crosscheck attitude, trim, rotor rpm, and airspeed.

After the descent and airspeed are established, roll into the turn. The turn should be approximately 180°, winds may cause the actual turn to be more or less than 180°. For training purposes, initially roll into a bank of a least 30°, but no more than 50°– 60°. Continuously check airspeed, rotor rpm, and trim throughout the turn. It is important to maintain the proper airspeed and to keep the aircraft in trim. Changes in the aircraft's attitude and the angle of bank cause a corresponding change in rotor rpm. Adjust the collective, as necessary, in the turn to maintain rotor rpm in the green arc.

At the 90° point, check the progress of the turn by glancing toward the landing area. Plan the second 90 degrees of turn to roll out on the centerline. If the helicopter is too close, decrease the bank angle; if too far out, increase the bank angle. Adjusting the bank angle will change the G loading, which in turn alters the airflow and results in rotor rpm changes. Keep the helicopter in trim with antitorque pedals.

The turn should be completed and the helicopter aligned with the intended touchdown area prior to passing through 100 feet AGL. If the collective pitch was temporarily increased to control the rpm, it may need to be lowered on rollout to prevent decay in rpm. Make an immediate power recovery if the aircraft is not aligned with the touchdown point, and if the rotor rpm and/or airspeed are not within proper limits. Otherwise, complete the procedure as if it were a straight-in autorotation.

Common Errors

1. Failure to maintain trim during the turn (increases rate of descent).
2. Failure to maintain autorotation airspeed.
3. Failure to hold proper pitch attitude for type helicopter (too high or too low).
4. Failure to have proper alignment with touchdown zone by 100 feet AGL.
5. Failure to maintain rotor rpm within limits during the maneuver.
6. Failure to go around if not within limits and specified criteria for safe autorotation.

Practice Autorotation With a Power Recovery

A power recovery is used to terminate practice autorotations at a point prior to actual touchdown. After the power recovery, a landing can be made or a go-around initiated.

Technique

At approximately 3–15 feet landing gear height AGL, depending upon the helicopter being used, begin to level the helicopter with forward cyclic control. Avoid excessive nose-high, tail-low attitude below 10 feet. Just prior to achieving level attitude, with the nose still slightly up, coordinate upward collective pitch control with an increase in the throttle to join the needles at operating rpm. The throttle and collective pitch must be coordinated properly.

If the throttle is increased too fast or too much, an engine overspeed can occur; if throttle is increased too slowly or too little in proportion to the increase in collective pitch, a loss of rotor rpm results. Use sufficient collective pitch to stop the descent, but keep in mind that the collective pitch application must be gradual to allow for engine response. Coordinate proper antitorque pedal pressure to maintain heading. When a landing is to be made following the power recovery, bring the helicopter to a hover at hovering altitude and then descend to a landing.

When practicing autorotations with power recovery in nearly all helicopters, the throttle or power levers should be at the flight setting at the beginning of the flare. As the rotor system begins to dissipate its energy, the engine is up to speed as the needles join when the rotor decreases into the normal flight rpm.

Helicopters that do not have the throttle control located on the collective require some additional prudence. The autorotation should be initiated with the power levers left in the "flight," or normal, position. If a full touchdown is to be practiced, it is common technique to move the power levers to the idle position once the landing area can safely be reached. In most helicopters, the pilot is fully committed at that point to make a power-off landing. However, it may be possible to make a power recovery prior to passing through 100 feet AGL if the powerplant can recover within that time period and the instructor is very proficient. The pilot should comply with the RFM instructions in all cases.

When practicing autorotations to a power recovery, the differences between reciprocating engines and turbines may be profound. The reciprocating powerplant generally responds very quickly to power changes, especially power increases. Some turbines have delay times depending on the type of fuel control or governing system installed. Any reciprocating engine needing turbocharged boost to develop rated horse power may have significant delays to demands for increased power, such as in the power recovery. Power recovery in those helicopters with slower engine response times must have the engines begin to develop enough power to rejoin the needles by approximately 100 feet AGL.

If a go-around is to be made, the cyclic control should be moved forward to resume forward flight. In transition from a practice autorotation to a go-around, exercise caution to avoid an altitude-airspeed combination that would place the helicopter in an unsafe area of its height-velocity diagram.

This is one of the most difficult maneuvers to perform due to the concentration needed when transitioning from powered flight to autorotation and then back again to powered flight. For helicopters equipped with the power control on the collective, engine power must be brought from flight power to idle power and then back to a flight power setting. A delay during any of these transitions can seriously affect rotor rpm placing the helicopter in a situation that cannot be recovered.

The cyclic must be adjusted to maintain the required airspeed without power, and then used for the deceleration flare, followed by the transition to level hovering flight. Additionally, the cyclic must be adjusted to remove the compensation for translating tendency. The tail rotor is no longer needed to produce antitorque thrust until almost maximum power is applied to the rotor system for hovering flight, when the tail rotor must again compensate for the main rotor torque, which also demands compensation for the tail rotor thrust and translating tendency.

The pedals must be adjusted from a powered flight antitorque trim setting to the opposite trim setting to compensate for transmission drag and any unneeded vertical fin thrust countering the now nonexistent torque and then reset to compensate for the high power required for hovering flight.

All of the above must be accomplished during the 23 seconds of the autorotation and the tedious control inputs must be made in the last 5 seconds of the maneuver.

Common Errors

1. Initiating recovery too late, which requires a rapid application of controls and results in overcontrolling.
2. Failure to obtain and maintain a level attitude near the surface.
3. Failure to coordinate throttle and collective pitch properly, which results in either an engine overspeed or a loss of rotor rpm.
4. Failure to coordinate proper antitorque pedal with the increase in power.
5. Late engine power engagement causing excessive temperatures or torques, or rpm droop.
6. Failure to go around if not within limits and specified criteria for safe autorotation.

Power Failure in a Hover

Power failure in a hover, also called hovering autorotation, is practiced so that a pilot can automatically make the correct response when confronted with engine stoppage or certain other emergencies while hovering. The techniques discussed in this section are for helicopters with a counterclockwise rotor system and an antitorque rotor.

Technique

To practice hovering autorotation, establish a normal hovering altitude (approximately 2–3 feet) for the particular helicopter being used, considering load and atmospheric conditions. Keep the helicopter headed into the wind and hold maximum allowable rpm.

To simulate a power failure, firmly roll the throttle to the engine idle position. This disengages the driving force of the engine from the rotor, thus eliminating torque effect. As the throttle is closed, apply proper antitorque pedal to maintain heading. Usually, a slight amount of right cyclic control is necessary to keep the helicopter from drifting to the left, to compensate for the loss of tail rotor thrust. However, use cyclic control, as required, to ensure a vertical descent and a level attitude. Do not adjust the collective pitch on entry.

Helicopters with low inertia rotor systems settle immediately. Keep a level attitude and ensure a vertical descent with cyclic control while maintaining heading with the pedals. Any lateral movement must be avoided to prevent dynamic rollover. As rotor rpm decays, cyclic response decreases, so compensation for winds will change, requiring more cyclic input. At approximately 1 foot AGL, apply upward collective pitch control, as necessary, to slow the descent and cushion the landing without arresting the rate of descent above the surface. Usually, the full amount of collective pitch is required just as the landing gear touches the surface. As upward collective pitch control is applied, the throttle must be held in the idle detent position to prevent the engine from re-engaging.

Helicopters with high inertia rotor systems settle more slowly after the throttle is closed. When the helicopter has settled to approximately 1 foot AGL, apply upward collective pitch control while holding the throttle in the idle detent position to slow the descent and cushion the landing. The timing of collective pitch control application and the rate at which it is applied depend upon the particular helicopter being used, its gross weight, and the existing atmospheric conditions. Cyclic control is used to maintain a level attitude and to ensure a vertical descent. Maintain heading with antitorque pedals.

When the weight of the helicopter is entirely resting on the landing gear, cease application of upward collective. When the helicopter has come to a complete stop, lower the collective pitch to the full-down position.

The timing of the collective pitch is a most important consideration. If it is applied too soon, the remaining rpm may not be sufficient to make a soft landing. On the other hand, if collective pitch control is applied too late, surface contact may be made before sufficient blade pitch is available to cushion the landing. The collective must not be used to hold the helicopter off the surface, causing a blade stall. Low rotor rpm and ensuing blade stall can result in a total loss of rotor lift allowing the helicopter to fall to the surface and possibly resulting in blade strikes to the tail boom and other airframe damage such as landing gear damage, transmission mount deformation, and fuselage cracking.

Common Errors

1. Failure to use sufficient proper antitorque pedal when power is reduced.

2. Failure to stop all sideward or backward movement prior to touchdown.
3. Failure to apply up-collective pitch properly, resulting in a hard touchdown.
4. Failure to touch down in a level attitude.
5. Failure to roll the throttle completely to idle.
6. Failure to hover at a safe altitude for the helicopter type, atmospheric conditions, and the level of training/proficiency of the pilot.
7. Failure to go around if not within limits and specified criteria for safe autorotation.

Height/Velocity Diagram

The height/velocity diagram or H/V curve is a graph charting the safe/unsafe flight profiles relevant to a specific helicopter. As operation outside the safe area of the chart can be fatal in the event of a power or driveline failure, it is sometimes referred to as the dead man's curve by helicopter pilots. By carefully studying the height/velocity diagram, a pilot is able to avoid the combinations of altitude and airspeed that may not allow sufficient time or altitude to enter a stabilized autorotative descent. A pilot may want to refer to this diagram during the remainder of the discussion on the height/velocity diagram. *[Figure 11-3]*

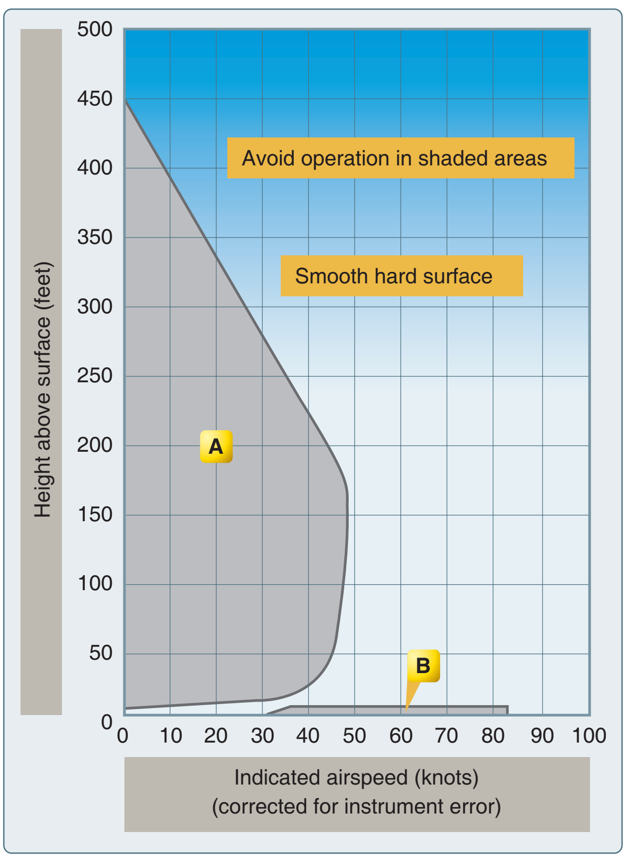


Figure 11-3. *Height/velocity diagram.*

In the simplest explanation, the H/V curve is a diagram in which the shaded areas should be avoided, as the pilot may be unable to complete an autorotation landing without damage. The H/V curve usually contains a takeoff profile, where the diagram can be traversed from 0 height and 0 speed to cruise, without entering the shaded areas or with minimum exposure to shaded areas.

The portion in the upper left of this diagram demonstrates a flight profile that probably does not allow the pilot to complete an autorotation successfully, primarily due to having insufficient airspeed to enter an autorotative profile in time to avoid a crash. The shaded area on the lower right is dangerous due to the airspeed and proximity to the ground resulting in dramatically reduced reaction time for the pilot in the case of mechanical failure, or other in-flight emergencies. This shaded area at the lower right is not portrayed in H/V curves for multi-engine helicopters capable of safely hovering and flying with a single engine failure.

The following examples further illustrate the relevance of the H/V curve to a single-engine helicopter.

At low heights with low airspeed, such as a hover taxi, the pilot can simply use the potential energy from the rotor system to cushion the landing with collective, converting rotational inertia to lift. The aircraft is in a safe part of the H/V curve. At the extreme end of the scale (e.g., a three-foot hover taxi at walking pace) even a complete failure to recognize the power loss resulting in an uncushioned landing would probably be survivable.

As the airspeed increases without an increase in height, there comes a point at which the pilot's reaction time would be insufficient to react with a flare in time to prevent a high speed, and thus probably fatal, ground impact. Another thing to consider is the length of the tailboom and the response time of the helicopter flight controls at slow airspeeds and low altitudes. Even small increases in height give the pilot much greater time to react; therefore, the bottom right part of the H/V curve is usually a shallow gradient. If airspeed is above ideal autorotation speed, the pilot's instinct is usually to flare to convert speed to height and increase rotor rpm through coning, which also immediately gets them out of the dead man's curve.

Conversely, an increase in height without a corresponding increase in airspeed puts the aircraft above a survivable uncushioned impact height, and eventually above a height where rotor inertia can be converted to sufficient lift to enable a survivable landing. This occurs abruptly with airspeeds much below the ideal autorotative speed (typically 40–80 knots). The pilot must have enough time to accelerate to autorotation speed in order to autorotate successfully; this directly relates to a requirement for height. Above a certain height the pilot can achieve autorotation speed even from a 0 knot start, thus putting high OGE hovers outside the curve.

The typical safe takeoff profile involves initiation of forward flight from a 2–3 feet landing gear height, only gaining altitude as the helicopter accelerates through translational lift and airspeed approaches a safe autorotative speed. At this point, some of the increased thrust available may be used to attain safe climb airspeed and will keep the helicopter out of the shaded or hatched areas of the H/V diagram. Although helicopters are not restricted from conducting maneuvers that will place them in the shaded area of the H/V chart, it is important for pilots to understand that operation in those shaded areas exposes pilot, aircraft, and passengers to a certain hazard should the engine or driveline malfunction. The pilot should always evaluate the risk of the maneuver versus the operational value.

The Effect of Weight Versus Density Altitude

The height/velocity diagram *[Figure 11-3]* depicts altitude and airspeed situations from which a successful autorotation can be made. The time required, and therefore, altitude necessary to attain a steady state autorotative descent, is dependent on the weight of the helicopter and the density altitude. For this reason, the H/V diagram is valid only when the helicopter is operated in accordance with the gross weight versus density altitude chart. If published, this chart is found in the RFM for the particular helicopter. *[Figure 11-4]* The gross weight versus density altitude chart is not intended to provide a restriction to gross weight, but to be an advisory of the autorotative capability of the helicopter during takeoff and climb. A pilot must realize, however, that at gross weights above those recommended by the gross weight versus density altitude chart, the values are unknown.

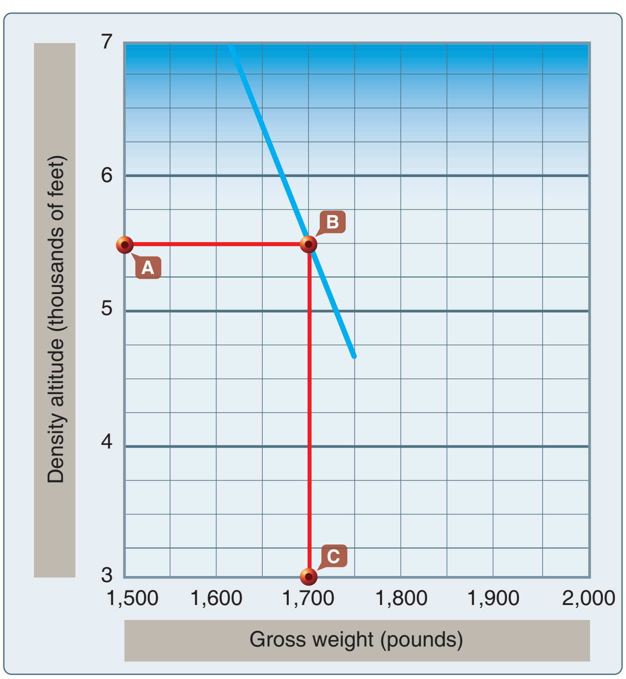


Figure 11-4. *Gross weight versus density altitude.*

Assuming a density altitude of 5,500 feet, the height/velocity diagram in *Figure 11-3* would be valid up to a gross weight of approximately 1,700 pounds. This is found by entering the graph in *Figure 11-4* at a density altitude of 5,500 feet (point A), then moving horizontally to the solid line (point B). Moving vertically to the bottom of the graph (point C), with the existing density altitude, the maximum gross weight under which the height/velocity diagram is applicable is 1,700 pounds.

Charts and diagrams for helicopters set out in Title 14 of the Code of Federal Regulations (14 CFR) Part 27, Airworthiness Standards: Normal Category Rotorcraft, are advisory in nature and not regulatory. However, these charts do establish the safe parameters for operation. It is important to remember these guidelines establish the tested capabilities of the helicopter. Unless the pilot in command (PIC) is a certificated test pilot, operating a helicopter beyond its established capabilities can be considered careless and reckless operation, especially if this action results is death or injury.

Common Errors

1. Performing hovers higher than performed during training for hovering autorotations and practiced proficiency.
2. Excessively nose-low takeoffs. The forward landing gear would impact before the pilot could assume a landing attitude.
3. Adding too much power for takeoff.
4. Not maintaining landing gear aligned with takeoff path until transitioning to a crab heading to account for winds.

Settling With Power (Vortex Ring State)

Vortex ring state describes an aerodynamic condition in which a helicopter may be in a vertical descent with 20 percent up to maximum power applied, and little or no climb performance. The term "settling with power" comes from the fact that the helicopter keeps settling even though full engine power is applied.

In a normal out-of-ground-effect (OGE) hover, the helicopter is able to remain stationary by propelling a large mass of air down through the main rotor. Some of the air is recirculated near the tips of the blades, curling up from the bottom of the rotor system and rejoining the air entering the rotor from the top. This phenomenon is common to all airfoils and is known as tip vortices. Tip vortices generate drag and degrade airfoil efficiency. As long as the tip vortices are small, their only effect is a small loss in rotor efficiency. However, when the helicopter begins to descend vertically, it settles into its own downwash, which greatly enlarges the tip vortices. In this vortex ring state, most of the power developed by the engine is wasted in circulating the air in a doughnut pattern around the rotor.

In addition, the helicopter may descend at a rate that exceeds the normal downward induced-flow rate of the inner blade sections. As a result, the airflow of the inner blade sections is upward relative to the disk. This produces a secondary vortex ring in addition to the normal tip vortices. The secondary vortex ring is generated about the point on the blade where the airflow changes from up to down. The result is an unsteady turbulent flow over a large area of the disk. Rotor efficiency is lost even though power is still being supplied from the engine. *[Figure 11-5]*

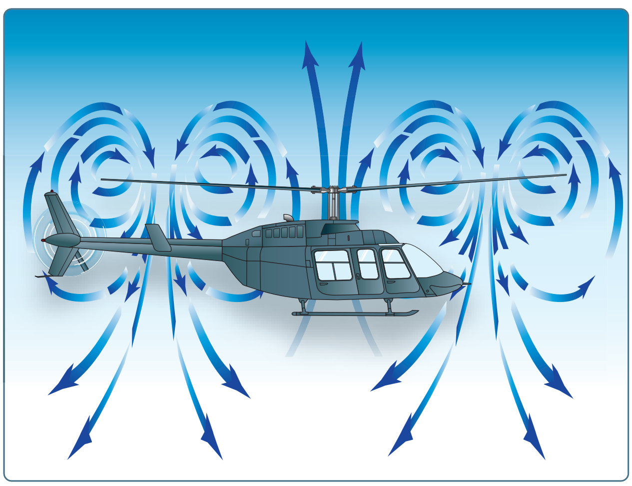


Figure 11-5. *Vortex ring state.*

A fully developed vortex ring state is characterized by an unstable condition in which the helicopter experiences uncommanded pitch and roll oscillations, has little or no collective authority, and achieves a descent rate that may approach 6,000 feet per minute (fpm) if allowed to develop.

A vortex ring state may be entered during any maneuver that places the main rotor in a condition of descending in a column of disturbed air and low forward airspeed. Airspeeds that are below translational lift airspeeds are within this region of susceptibility to settling with power aerodynamics. This condition is sometimes seen during quick-stop type maneuvers or during recovery from autorotation.

The following combination of conditions is likely to cause settling in a vortex ring state in any helicopter:

1. A vertical or nearly vertical descent of at least 300 fpm. (Actual critical rate depends on the gross weight, rpm, density altitude, and other pertinent factors.)
2. The rotor system must be using some of the available engine power (20–100 percent).
3. The horizontal velocity must be slower than effective translational lift.

Some of the situations that are conducive to a settling with power condition are: any hover above ground effect altitude, specifically attempting to hover OGE at altitudes above the hovering ceiling of the helicopter, attempting to hover OGE without maintaining precise altitude control, pinnacle or rooftop helipads when the wind is not aligned with the landing direction, and downwind and steep power approaches in which airspeed is permitted to drop below 10 knots depending on the type of helicopter.

When recovering from a settling with power condition, the pilot tends first to try to stop the descent by increasing collective pitch. However, this only results in increasing the stalled area of the rotor, thereby increasing the rate of descent. Since inboard portions of the blades are stalled, cyclic control may be limited. Recovery is accomplished by increasing airspeed, and/or partially lowering collective pitch. In many helicopters, lateral cyclic combined with lateral tailrotor thrust will produce the quickest exit from the hazard assuming that there are no barriers in that direction. In a fully developed vortex ring state, the only recovery may be to enter autorotation to break the vortex ring state.

Tandem rotor helicopters should maneuver laterally to achieve clean air in both rotors at the same time.

For settling with power demonstrations and training in recognition of vortex ring state conditions, all maneuvers should be performed at an altitude of 2000–3000 feet AGL to allow sufficient altitude for entry and recovery.

To enter the maneuver, come to an OGE hover, maintaining little or no airspeed (any direction), decrease collective to begin a vertical descent, and as the turbulence begins, increase collective. Then allow the sink rate to increase to 300 fpm or more as the attitude is adjusted to obtain airspeed of less than 10 knots. When the aircraft begins to shudder, the application of additional up collective increases the vibration and sink rate. As the power is increased, the rate of sink of the aircraft in the column of air will increase.

If altitude is sufficient, some time can be spent in the vortices, to enable the pilot to develop a healthy knowledge of the maneuver. However, helicopter pilots would normally initiate recovery at the first indication of settling with power. Recovery should be initiated at the first sign of vortex ring state by applying forward cyclic to increase airspeed and/ or simultaneously reducing collective. The recovery is complete when the aircraft passes through effective translational lift and a normal climb is established.

Common Errors

1. Too much lateral speed for entry into settling with power.
2. Excessive decrease of collective pitch.

Retreating Blade Stall

In forward flight, the relative airflow through the main rotor disk is different on the advancing and retreating side. The relative airflow over the advancing side is higher due to the forward speed of the helicopter, while the relative airflow on the retreating side is lower. This dissymmetry of lift increases as forward speed increases.

To generate the same amount of lift across the rotor disk, the advancing blade flaps up while the retreating blade flaps down. This causes the AOA to decrease on the advancing blade, which reduces lift, and increase on the retreating blade, which increases lift. At some point as the forward speed increases, the low blade speed on the retreating blade, and its high AOA cause a stall and loss of lift.

Retreating blade stall is a major factor in limiting a helicopter's never-exceed speed (V_{NE}) and its development can be felt by a low frequency vibration, pitching up of the nose, and a roll in the direction of the retreating blade. High weight, low rotor rpm, high density altitude, turbulence and/ or steep, abrupt turns are all conducive to retreating blade stall at high forward airspeeds. As altitude is increased, higher blade angles are required to maintain lift at a given airspeed. Thus, retreating blade stall is encountered at a lower forward airspeed at altitude. Most manufacturers publish charts and graphs showing a V_{NE} decrease with altitude.

When recovering from a retreating blade stall condition, moving the cyclic aft only worsens the stall as aft cyclic produces a flare effect, thus increasing the AOA. Pushing forward on the cyclic also deepens the stall as the AOA on the retreating blade is increased. Correct recovery from retreating blade stall requires the collective to be lowered first, which reduces blade angles and thus AOA. Aft cyclic can then be used to slow the helicopter.

Common Errors

1. Failure to recognize the combination of contributing factors leading to retreating blade stall.
2. Failure to compute V_{NE} limits for altitudes to be flown.

Ground Resonance

Helicopters with articulating rotors (usually designs with three or more main rotor blades) are subject to ground resonance, a destructive vibration phenomenon that occurs at certain rotor speeds when the helicopter is on the ground. Ground resonance is a mechanical design issue that results from the helicopter's airframe having a natural frequency that can be intensified by an out-of-balance rotor. The unbalanced rotor system vibrates at the same frequency or multiple of the airframe's resonant frequency and the harmonic oscillation increases because the engine is adding power to the system, increasing the magnitude (or amplitude) of the vibrations until the structure or structures fail. This condition can cause a helicopter to self-destruct in a matter of seconds.

Hard contact with the ground on one corner (and usually with wheel-type landing gear) can send a shockwave to the main rotor head, resulting in the blades of a three-blade rotor system moving from their normal 120° relationship to each other. This movement occurs along the drag hinge and could result in something like 122°, 122°, and 116° between blades. *[Figure 11-6]* When one of the other landing gear strikes the surface, the unbalanced condition could be further aggravated. If the rpm is low, the only corrective action to stop ground resonance is to close the throttle immediately and fully lower the collective to place the blades in low pitch. If the rpm is in the normal operating range, fly the helicopter off the ground,

Figure 11-6. *Ground resonance.*

and allow the blades to rephase themselves automatically. Then, make a normal touchdown. If a pilot lifts off and allows the helicopter to firmly re-contact the surface before the blades are realigned, a second shock could move the blades again and aggravate the already unbalanced condition. This could lead to a violent, uncontrollable oscillation.

This situation does not occur in rigid or semi-rigid rotor systems because there is no drag hinge. In addition, skid-type landing gear is not as prone to ground resonance as wheel-type landing gear since the rubber tires are not present and change the rebound characteristics.

Dynamic Rollover

A helicopter is susceptible to a lateral rolling tendency, called dynamic rollover, when the helicopter is in contact with the surface during takeoffs or landings. For dynamic rollover to occur, some factor must first cause the helicopter to roll or pivot around a skid or landing gear wheel, until its critical rollover angle is reached. (5–8° depending on helicopter, winds, and loading) Then, beyond this point, main rotor thrust continues the roll and recovery is impossible. After this angle is achieved, the cyclic does not have sufficient range of control to eliminate the thrust component and convert it to lift. If the critical rollover angle is exceeded, the helicopter rolls on its side regardless of the cyclic corrections made.

Dynamic rollover begins when the helicopter starts to pivot laterally around its skid or wheel. This can occur for a variety of reasons, including the failure to remove a tie down or skid-securing device, or if the skid or wheel contacts a fixed object while hovering sideward, or if the gear is stuck in ice, soft asphalt, or mud. Dynamic rollover may also occur if you use an improper landing or takeoff technique or while performing slope operations. Whatever the cause, if the gear or skid becomes a pivot point, dynamic rollover is possible if not using the proper corrective technique.

Once started, dynamic rollover cannot be stopped by application of opposite cyclic control alone. For example, the right skid contacts an object and becomes the pivot point while the helicopter starts rolling to the right. Even with full left cyclic applied, the main rotor thrust vector and its moment follows the aircraft as it continues rolling to the right. Quickly reducing collective pitch is the most effective way to stop dynamic rollover from developing. Dynamic rollover can occur with any type of landing gear and all types of rotor systems.

It is important to remember rotor blades have a limited range of movement. If the tilt or roll of the helicopter exceeds that range (5–8°), the controls (cyclic) can no longer command a vertical lift component and the thrust or lift becomes a lateral force that rolls the helicopter over. When limited rotor blade movement is coupled with the fact that most of a helicopter's weight is high in the airframe, another element of risk is added to an already slightly unstable center of gravity. Pilots must remember that in order to remove thrust, the collective must be lowered as this is the only recovery technique available.

Critical Conditions

Certain conditions reduce the critical rollover angle, thus increasing the possibility for dynamic rollover and reducing the chance for recovery. The rate of rolling motion is also a consideration because, as the roll rate increases, there is a reduction of the critical rollover angle at which recovery is still possible. Other critical conditions include operating at high gross weights with thrust (lift) approximately equal to the weight.

Refer to *Figure 11-7*. The following conditions are most critical for helicopters with counterclockwise rotor rotation:

1. Right side skid or landing wheel down, since translating tendency adds to the rollover force.
2. Right lateral center of gravity (CG).
3. Crosswinds from the left.
4. Left yaw inputs.

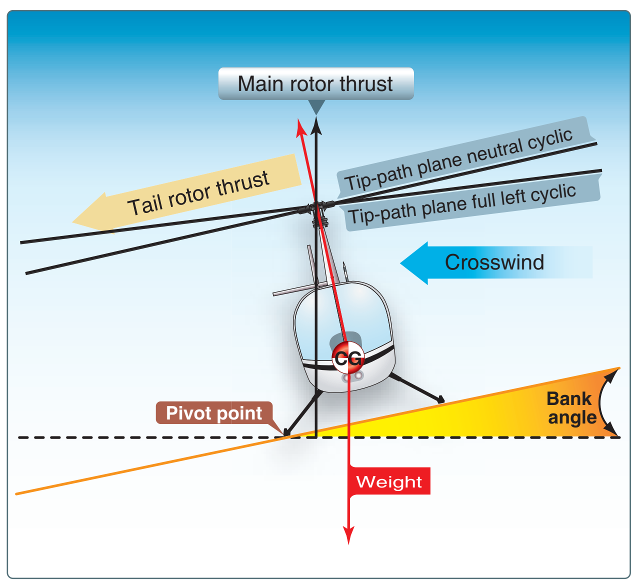


Figure 11-7. *Forces acting on a helicopter with right skid on the ground.*

For helicopters with clockwise rotor rotation, the opposite conditions would be true.

Cyclic Trim

When maneuvering with one skid or wheel on the ground, care must be taken to keep the helicopter cyclic control carefully adjusted. For example, if a slow takeoff is attempted and the cyclic is not positioned and adjusted to account for translating tendency, the critical recovery angle may be exceeded in less than two seconds. Control can be maintained if the pilot maintains proper cyclic position, and does not allow the helicopter's roll and pitch rates to become too great. Fly the helicopter into the air smoothly while keeping movements of pitch, roll, and yaw small; do not allow any abrupt cyclic pressures.

Normal Takeoffs and Landings

Dynamic rollover is possible even during normal takeoffs and landings on relatively level ground, if one wheel or skid is on the ground and thrust (lift) is approximately equal to the weight of the helicopter. If the takeoff or landing is not performed properly, a roll rate could develop around the wheel or skid that is on the ground. When taking off or landing, perform the maneuver smoothly and carefully adjust the cyclic so that no pitch or roll movement rates build up, especially the roll rate. If the bank angle starts to increase to an angle of approximately 5–8°, and full corrective cyclic does not reduce the angle, the collective should be reduced to diminish the unstable rolling condition. Excessive bank angles can also be caused by landing gear caught in a tie down strap, or a tie down strap still attached to one side of the helicopter. Lateral loading imbalance (usually outside published limits) is another contributing factor.

Slope Takeoffs and Landings

During slope operations, excessive application of cyclic control into the slope, together with excessive collective pitch control, can result in the downslope skid or landing wheel rising sufficiently to exceed lateral cyclic control limits, and an upslope rolling motion can occur. *[Figure 11-8]*

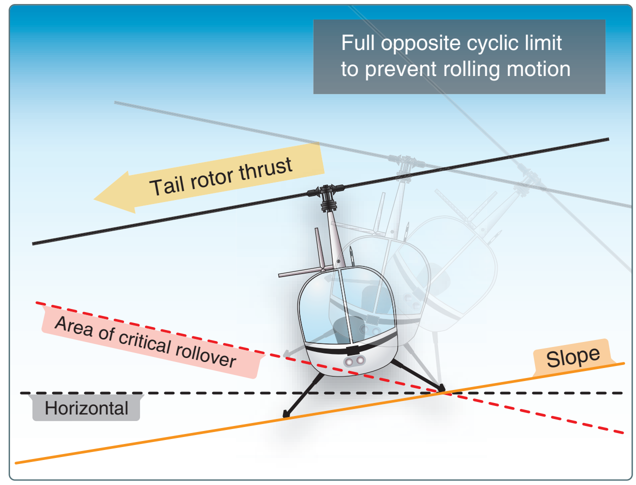


Figure 11-8. *Upslope rolling motion.*

When performing slope takeoff and landing maneuvers, follow the published procedures and keep the roll rates small. Slowly raise the downslope skid or wheel to bring the helicopter level, and then lift off. During landing, first touch down on the upslope skid or wheel, then slowly lower the downslope skid or wheel using combined movements of cyclic and collective. If the helicopter rolls approximately 5–8° to the upslope side, decrease collective to correct the bank angle and return to level attitude, then start the landing procedure again.

Use of Collective

The collective is more effective in controlling the rolling motion than lateral cyclic, because it reduces the main rotor thrust (lift). A smooth, moderate collective reduction, at a rate of less than approximately full up to full down in two seconds, may be adequate to stop the rolling motion. Take care, however, not to dump collective at an excessively high rate, as this may cause a main rotor blade to strike the fuselage. Additionally, if the helicopter is on a slope and the roll starts toward the upslope side, reducing collective too fast may create a high roll rate in the opposite direction. When the upslope skid or wheel hits the ground, the dynamics of the motion can cause the helicopter to bounce off the upslope skid or wheel, and the inertia can cause the helicopter to roll about the downslope ground contact point and over on its side. *[Figure 11-9]*

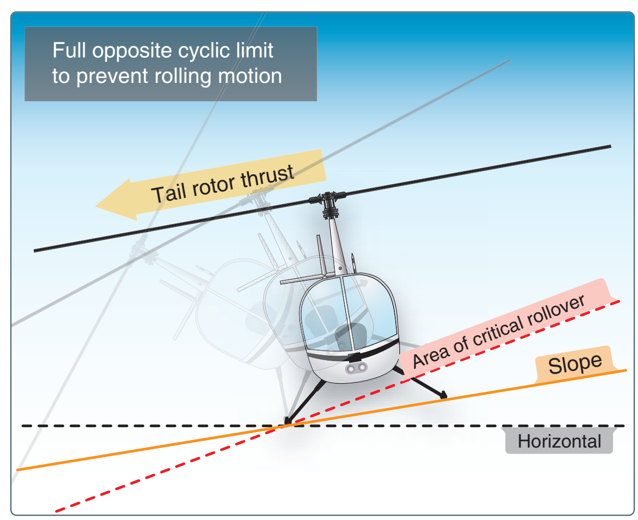


Figure 11-9. *Downslope rolling motion.*

Under normal conditions, the collective should not be pulled suddenly to get airborne because a large and abrupt rolling moment in the opposite direction could occur. Excessive application of collective can result in the upslope skid or wheel rising sufficiently to exceed lateral cyclic control limits. This movement may be uncontrollable. If the helicopter develops a roll rate with one skid or wheel on the ground, the helicopter can roll over on its side.

Precautions

To help avoid dynamic rollover:

1. Always practice hovering autorotations into the wind, and be wary when the wind is gusty or greater than 10 knots.
2. Use extreme caution when hovering close to fences, sprinklers, bushes, runway/taxi lights, tiedown cables, deck nets, or other obstacles that could catch a skid or wheel. Aircraft parked on hot asphalt over night might find the landing gear sunk in and stuck as the ramp cooled during the evening.
3. Always use a two-step lift-off. Pull in just enough collective pitch control to be light on the skids or landing wheels and feel for equilibrium, then gently lift the helicopter into the air.
4. Hover high enough to have adequate skid or landing wheel clearance with any obstacles when practicing hovering maneuvers close to the ground, especially when practicing sideways or rearward flight.
5. Remember that when the wind is coming from the upslope direction, less lateral cyclic control is available.
6. Avoid tailwind conditions when conducting slope operations.
7. Remember that less lateral cyclic control is available due to the translating tendency of the tail rotor when the left skid or landing wheel is upslope. (This is true for counterclockwise rotor systems.)
8. Keep in mind that the lateral cyclic requirement changes when passengers or cargo are loaded or unloaded.
9. Be aware that if the helicopter utilizes interconnecting fuel lines that allow fuel to automatically transfer from one side of the helicopter to the other, the gravitational flow of fuel to the downslope tank could change the CG, resulting in a different amount of cyclic control application to obtain the same lateral result.
10. Do not allow the cyclic limits to be reached. If the cyclic control limit is reached, further lowering of the collective may cause mast bumping. If this occurs, return to a hover and select a landing point with a lesser degree of slope.
11. During a takeoff from a slope, begin by leveling the main rotor disk with the horizon or very slightly into the slope to ensure vertical lift and only enough lateral thrust to prevent sliding on the slope. If the upslope skid or wheel starts to leave the ground before the downslope skid or wheel, smoothly and gently lower the collective and check to see if the downslope skid or wheel is caught on something. Under these conditions, vertical ascent is the only acceptable method of lift-off.
12. Be aware that dynamic rollover can be experienced during flight operations on a floating platform if the platform is pitching/rolling while attempting to land or takeoff. Generally, the pilot operating on floating platforms (barges, ships, etc.) observes a cycle of seven during which the waves increase and then decrease to a minimum. It is that time of minimum wave motion that the pilot needs to use for the moment of landing or takeoff on floating platforms. Pilots operating from floating platforms should also exercise great caution concerning cranes, masts, nearby boats (tugs) and nets.

Low-G Conditions and Mast Bumping

Low acceleration of gravity (low-G or weightless) maneuvers create specific hazards for helicopters, especially those with semirigid main rotor systems because helicopters are primarily designed to be suspended from the main rotor in normal flight with only small variations for positive G load maneuvers. Since a helicopter low-G maneuver departs from normal flight conditions, it may allow the airframe to exceed the manufacturer's design criteria. A low-G condition could have disastrous results, the best way to prevent it from happening is to avoid the conditions in which it might occur.

Low-G conditions are not about the loss of thrust, rather the imbalance of forces. Helicopters are mostly designed to have weight (gravity pulling down to the earth) and lift opposing that force of gravity. Low-G maneuvers occur when this balance is disturbed. An example of this would be placing the helicopter into a very steep dive. At the moment of pushover, the lift and thrust of the rotor is forward, whereas gravity is now vertical or straight down. Since the lift vector is no longer vertical and opposing the gravity (or weight) vector, the fuselage is now affected by the tail rotor thrust below the plane of the main rotor. This tail rotor thrust moment tends to make the helicopter fuselage tilt to the left. Pilots then apply right cyclic inputs to try to correct for the left. Since the main rotor system does not fully support the fuselage at this point, the fuselage continues to roll and the pilot applies more right cyclic until the rotor system strikes the mast (mast bumping), often ending with unnecessary fatal results. In mast bumping, the rotor blade exceeds its flapping limits, causing the main rotor hub to "bump" into the rotor shaft. *[Figure 11-10]* The main rotor hub's contact with the mast usually becomes more violent with each successive flapping motion. This creates a greater flapping displacement and leads to structural failure of

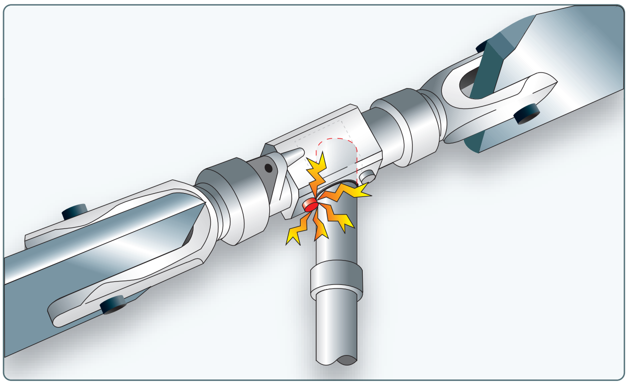


Figure 11-10. *Result of improper corrective action in a low-G condition.*

the rotor shaft. Since the mast is hollow, the structural failure manifests itself either as shaft failure with complete separation of the main rotor system from the helicopter or a severely damaged rotor mast.

In situations like the one described above, the helicopter pilot should first apply aft cyclic to bring the vectors into balance, with lift up and gravity down. Since helicopter blades carry the helicopter and have limited motion attachment, care must be given to those attachment limits. Helicopter pilots should always adhere to the maneuvering limitations stated in the RFM. There may be more than one reason or design criteria which limits the helicopters flight envelope. Heed all of the manufacturer's limitations and advisory data. Failure to do so could lead to dire, unintended consequences.

Low Rotor RPM and Blade Stall

As mentioned earlier, low rotor rpm during an autorotation might result in a less than successful maneuver. However, if rotor rpm decays to the point at which all the rotor blades stall, the result is usually fatal, especially when it occurs at altitude. It can occur in a number of ways, such as simply rolling the throttle the wrong way, pulling more collective pitch than power available, or when operating at a high density altitude.

When the rotor rpm decreases, the blades produce less lift so the pilot feels it necessary to increase collective pitch to stop the descent or increase the climb. As the pitch increases, drag increases, which requires more power to keep the blades turning at the proper rpm. When power is no longer available to maintain rpm and, therefore, lift, the helicopter begins to descend. This changes the relative wind and further increases the AOA. At some point, the blades stall unless rpm is restored. As main rotor RPM decays, centrifugal force continues to lessen until the lift force overcomes the centrifugal forces and folds or breaks the blades. At this point, airflow will provide no any lift or driving force for the system, and the result is disastrous.

Even though there is a safety factor built into most helicopters, any time rotor rpm falls below the green arc and there is power, simultaneously add throttle and lower the collective. If in forward flight, gently applying aft cyclic causes more air flow through the rotor system and helps increase rotor rpm. If without power, immediately lower the collective and apply aft cyclic.

Recovery From Low Rotor RPM

Under certain conditions of high weight, high temperature, or high density altitude, a pilot may get into a low rotor rpm situation. Although the pilot is using maximum throttle, the rotor rpm is low and the lifting power of the main rotor blades is greatly diminished. In this situation, the main rotor blades have an AOA that has created so much drag that engine power is not sufficient to maintain or attain normal operating rpm. When rotor rpm begins to decrease, it is essential to recover and maintain it.

As soon as a low rotor rpm condition is detected, apply additional throttle if it is available. If there is no throttle available, lower the collective. The amount the collective can be lowered depends on altitude. Rotor rpm is life! If the engine rpm is too low, it cannot produce its rated power for the conditions because power generation is defined at a qualified rpm value. An rpm that is too low equals low power. Main rotor rpm must be maintained.

When operating at altitude, the collective may need to be lowered only once to regain rotor speed. If power is available, throttle can be added and the collective raised. Once helicopter rotor blades cone excessively due to low rotor rpm, return the helicopter to the surface to allow the main rotor rpm to recover. Maintain precise landing gear alignment with the direction of travel in case a landing is necessary. Low inertia rotor systems can become unrecoverable in 2 seconds or less if the rpm is not regained immediately.

Since the tail rotor is geared to the main rotor, low main rotor rpm may prevent the tail rotor from producing enough thrust to maintain directional control. If pedal control is lost and the altitude is low enough that a landing can be accomplished before the turning rate increases dangerously, slowly decrease collective pitch, maintain a level attitude with cyclic control, and land.

System Malfunctions

The reliability and dependability record of modern helicopters is very impressive. By following the manufacturer's recommendations regarding operating limits and procedures and periodic maintenance and inspections, most systems and equipment failures can be eliminated. Most malfunctions or failures can be traced to some error on the part of the pilot; therefore, most emergencies can be averted before they happen. An actual emergency is a rare occurrence.

Antitorque System Failure

Antitorque failure usually falls into one of two categories. One is failure of the power drive portion of the tail rotor system resulting in a complete loss of antitorque. The other category covers mechanical control failures prohibiting the pilot from changing or controlling tail rotor thrust even though the tail rotor may still be providing antitorque thrust.

Tail rotor drive system failures include driveshaft failures, tail rotor gearbox failures, or a complete loss of the tail rotor itself. In any of these cases, the loss of antitorque normally results in an immediate spinning of the helicopter's nose. The helicopter spins to the right in a counterclockwise rotor system and to the left in a clockwise system. This discussion is for a helicopter with a counterclockwise rotor system. The severity of the spin is proportionate to the amount of power being used and the airspeed. An antitorque failure with a high power setting at a low airspeed results in a severe spinning to the right. At low power settings and high airspeeds, the spin is less severe. High airspeeds tend to streamline the helicopter and keep it from spinning.

If a tail rotor failure occurs, power must be reduced in order to reduce main rotor torque. The techniques differ depending on whether the helicopter is in flight or in a hover, but ultimately require an autorotation. If a complete tail rotor failure occurs while hovering, enter a hovering autorotation by rolling off the throttle. If the failure occurs in forward flight, enter a normal autorotation by lowering the collective and rolling off the throttle. If the helicopter has enough forward airspeed (close to cruising speed) when the failure occurs, and depending on the helicopter design, the vertical stabilizer may provide enough directional control to allow the pilot to maneuver the helicopter to a more desirable landing sight. Applying slight cyclic control opposite the direction of yaw compensates for some of the yaw. This helps in directional control, but also increases drag. Care must be taken not to lose too much forward airspeed because the streamlining effect diminishes as airspeed is reduced. Also, more altitude is required to accelerate to the correct airspeed if an autorotation is entered at a low airspeed.

The throttle or power lever on some helicopters is not located on the collective and readily available. Faced with the loss of antitorque, the pilot of these models may need to achieve forward flight and let the vertical fin stop the yawing rotation. With speed and altitude the pilot will have the time to set up for an autorotative approach and set the power control to idle or off as the situation dictates. At low altitudes, the pilot may not be able to reduce the power setting and enter the autorotation before impact.

A mechanical control failure limits or prevents control of tail rotor thrust and is usually caused by a stuck or broken control rod or cable. While the tail rotor is still producing antitorque thrust, it cannot be controlled by the pilot. The amount of antitorque depends on the position at which the controls jam or fail. Once again, the techniques differ depending on the amount of tail rotor thrust, but an autorotation is generally not required.

The specific manufacturer's procedures should always be followed. The following is a generalized description of procedures when more specific procedures are not provided.

Landing—Stuck Left Pedal

A stuck left pedal (high power setting), which might be experienced during takeoff or climb conditions, results in the left yaw of the helicopter nose when power is reduced. Rolling off the throttle and entering an autorotation only makes matters worse. The landing profile for a stuck left pedal is best described as a normal to steep approach angle to arrive approximately 2–3 feet landing gear height above the intended landing area as translational lift is lost. The steeper angle allows for a lower power setting during the approach and ensures that the nose remains to the left.

Upon reaching the intended touchdown area and at the appropriate landing gear height, increase the collective smoothly to align the nose with the landing direction and cushion the landing. A small amount of forward cyclic is helpful to stop the nose from continuing to the right and directs the aircraft forward and down to the surface. In certain wind conditions, the nose of the helicopter may remain to the left with zero to near zero groundspeed above the intended touchdown point. If the helicopter is not turning, simply lower the helicopter to the surface. If the nose of the helicopter is turning to the right and continues beyond the landing heading, roll the throttle toward flight idle the amount necessary to stop the turn while landing. If the helicopter is beginning to turn left, the pilot should be able to make the landing prior to the turn rate becoming excessive. However, if the turn rate begins to increase prior to the landing, simply add power to make a go-around and return for another landing.

Landing—Stuck Neutral or Right Pedal

The landing profile for a stuck neutral or a stuck right pedal is a low-power approach terminating with a running or roll-on landing. The approach profile can best be described as a shallow to normal approach angle to arrive approximately 2–3 feet landing gear height above the intended landing area with a minimum airspeed for directional control. The minimum airspeed is one that keeps the nose from continuing to yaw to the right.

Upon reaching the intended touchdown area and at the appropriate landing gear height, reduce the throttle as necessary to overcome the yaw effect if the nose of the helicopter remains to the right of the landing heading. The amount of throttle reduction will vary based on power applied and winds. The higher the power setting used to cushion the landing, the more the throttle reduction will be. A coordinated throttle reduction and increased collective will result in a very smooth touchdown with some forward ground speed. If the nose of the helicopter is to the left of the landing heading, a slight increase in collective or aft cyclic may be used to align the nose for touchdown. The decision to land or go around has to be made prior to any throttle reduction. Using airspeeds slightly above translational lift may be helpful to ensure that the nose does not continue yawing to the right. If a go-around is required, increasing the collective too much or too rapidly with airspeeds below translational lift may cause a rapid spinning to the right.

Once the helicopter has landed and is sliding/rolling to a stop, the heading can be controlled with a combination of collective, cyclic and throttle. To turn the nose to the right, raise the collective or apply aft cyclic. The throttle may be increased as well if it is not in the full open position. To turn the nose to the left, lower the collective or apply forward cyclic. The throttle may be decreased as well if it is not already at flight idle.

Loss of Tail Rotor Effectiveness (LTE)

Loss of tail rotor effectiveness (LTE) or an unanticipated yaw is defined as an uncommanded, rapid yaw towards the advancing blade which does not subside of its own accord. It can result in the loss of the aircraft if left unchecked. It is very important for pilots to understand that LTE is caused by an aerodynamic interaction between the main rotor and tail rotor and not caused from a mechanical failure. Some helicopter types are more likely to encounter LTE due to the normal certification thrust produced by having a tail rotor that, although meeting certification standards, is not always able to produce the additional thrust demanded by the pilot.

A helicopter is a collection of compromises. Compare the size of an airplane propeller to that of a tail rotor. Then, consider the horsepower required to run the propeller. For example, a Cessna 172P is equipped with a 160-horsepower (HP) engine. A Robinson R-44 with a comparably sized tail rotor is rated for a maximum of 245 HP. If you assume the tail rotor consumes 50 HP, only 195 HP remains to drive the main rotor. If the pilot were to apply enough collective to require 215 HP from the engine, and enough left pedal to require 50 HP for the tail rotor, the resulting engine overload would lead to one of two outcomes: slow down (reduction in rpm) or premature failure. In either outcome, antitorque would be insufficient and total lift might be less than needed to remain airborne.

Every helicopter design requires some type of antitorque system to counteract main rotor torque and prevent spinning once the helicopter lifts off the ground. A helicopter is heavy, and the powerplant places a high demand on fuel. Weight penalizes performance, but all helicopters must have an antitorque system, which adds weight. Therefore, the tail rotor is certified for normal flight conditions. Environmental forces can overwhelm any aircraft, rendering the inherently unstable helicopter especially vulnerable.

As with any aerodynamic condition, it is very important for pilots to not only understand the definition of terms but more importantly how and why they happen, how to avoid the situation and lastly, how to correct the condition once it is encountered. We must first understand the capabilities of the aircraft or even better what it is not capable of doing. For example, if you were flying a helicopter with a maximum gross weight of 5,200 lbs, would a pilot knowingly try to take on fuel, baggage and passengers causing the weight to be 5,500 lbs? A wise professional pilot should not ever exceed the certificated maximum gross weight or performance flight weight for any aircraft. The manuals are written for safety and reliability. The limitations and emergency procedures are stressed because lapses in procedures or exceeding limitations can result in aircraft damage or human fatalities. At the very least, exceeding limitations will increase the costs of maintenance and ownership of any aircraft and especially helicopters.

Overloaded parts will fail before their designed lifetime. There are no extra parts in helicopters. The respect and discipline pilots exercise for following flight manuals should also be applied to understanding aerodynamic conditions. If flight envelopes are exceeded, the end results can be catastrophic.

LTE is an aerodynamic condition and is the result of a control margin deficiency in the tail rotor. It can affect all single rotor helicopters that utilize a tail rotor of some design. The design of main and tail rotor blades and the tail boom assembly can affect the characteristics and susceptibility of LTE but will not nullify the phenomenon entirely. Translational lift is obtained by any amount of clean air through the main rotor system. Chapter 3 discusses translational lift with respect to the main rotor blade, explaining that the more clean air there is going through the rotor system, the more efficient it becomes. The same holds true for the tail rotor. As the tail rotor works in less turbulent air, it reaches a point of translational thrust. At this point, the tail rotor becomes aerodynamically efficient and the improved efficiency produces more antitorque thrust. The pilot can determine when the tail rotor has reached translational thrust. As more antitorque thrust is produced, the nose of the helicopter yaws to the left (opposite direction of the tail rotor thrust), forcing the pilot to correct with right pedal application (actually decreasing the left pedal). This, in turn, decreases the AOA in the tail rotor blades. Pilots should be aware of the characteristics of the helicopter they fly and be particularly aware of the amount of tail rotor pedal typically required for different flight conditions.

LTE is a condition that occurs when the flow of air through a tail rotor is altered in some way, either by altering the angle or speed at which the air passes through the rotating blades of the tail rotor system. An effective tail rotor relies on a stable and relatively undisturbed airflow in order to provide a steady and constant antitorque reaction as discussed in the previous paragraph. The pitch and angle of attack of the individual blades will determine the thrust output of the tail rotor. A change to any of these alters the amount of thrust generated. A pilot's yaw pedal input affects a thrust reaction from the tail rotor. Altering the amount of thrust delivered for the same yaw input creates an imbalance. Taking this imbalance to the extreme will result in the loss of effective control in the yawing plane, and LTE will occur.

This alteration of tail rotor thrust can be affected by numerous external factors. The main factors contributing to LTE are:

1. Airflow and downdraft generated by the main rotor blades interfering with the airflow entering the tail rotor assembly.
2. Main blade vortices developed at the main blade tips entering the tail rotor.
3. Turbulence and other natural phenomena affecting the airflow surrounding the tail rotor.
4. A high power setting, hence large main rotor pitch angle, induces considerable main rotor blade downwash and hence more turbulence than when the helicopter is in a low power condition.
5. A slow forward airspeed, typically at speeds where translational lift and translational thrust are in the process of change and airflow around the tail rotor will vary in direction and speed.
6. The airflow relative to the helicopter;
    a. Worst case—relative wind within ±15° of the 10 o'clock position, generating vortices that can blow directly into the tail rotor. This is dictated by the characteristics of the helicopters aerodynamics of tailboom position, tailrotor size and position relative to the main rotor and vertical stabilizer, size and shape. *[Figure 11-11]*
    b. Weathercock stability—tailwinds from 120° to 240° *[Figure 11 -12]*, such as left crosswinds, causing high pilot workload.
    c. Tail rotor vortex ring state (210° to 330°). *[Figure 11-13]* Winds within this region will result in the development of the vortex ring state of the tail rotor.

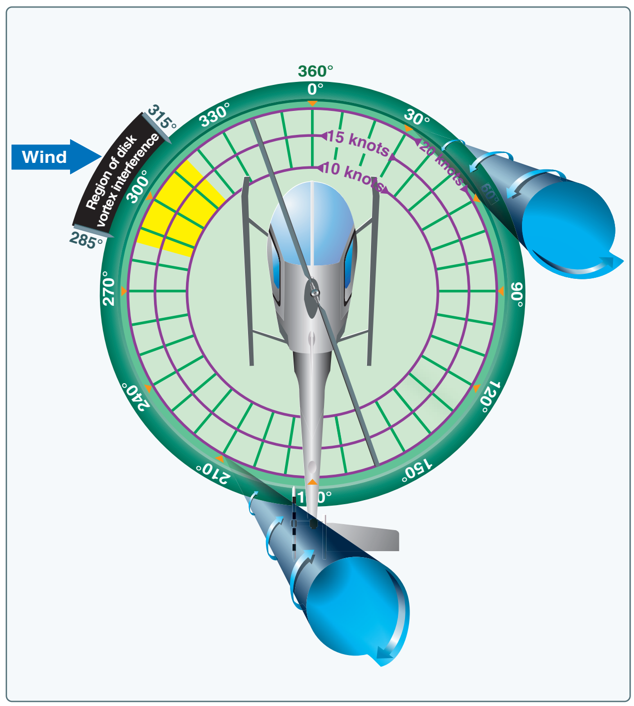


Figure 11-11. *Main rotor disk vortex interference.*

7. Combinations (a, b, c) of these factors in a particular situation can easily require more anti-torque than the helicopter can generate and in a particular environment LTE can be the result.

Certain flight activities lend themselves to being more at high risk to LTE than others. For example, power line and pipeline patrol sectors, low speed aerial filming/photography as well as in the Police and Helicopter Emergency Medical Services (EMS) environments can find themselves in low and slow situations over geographical areas where the exact wind speed and direction are hard to determine.

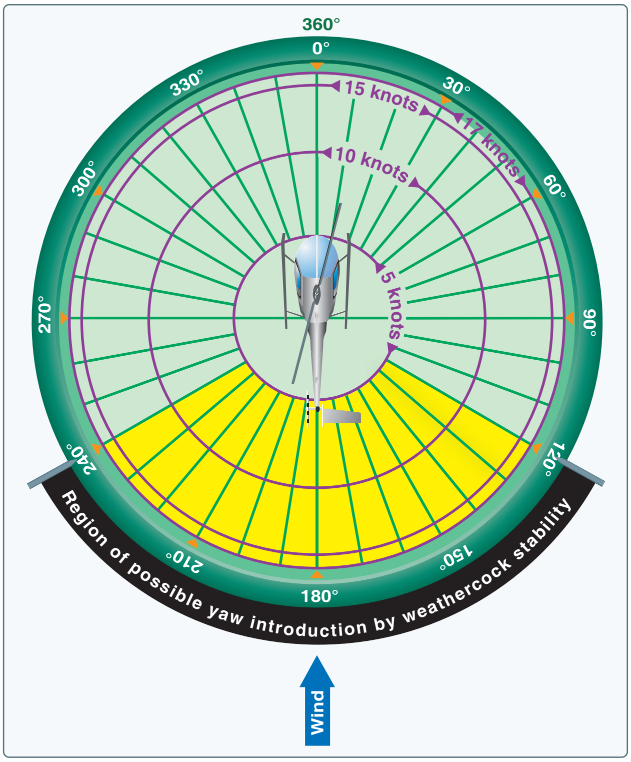


Figure 11-12. *Weathercock stability.*

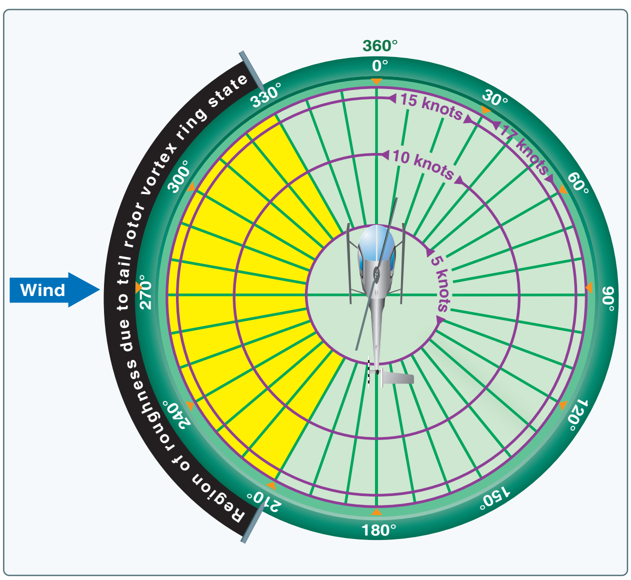


Figure 11-13. *Tail rotor vortex ring state.*

Unfortunately, the aerodynamic conditions that a helicopter is susceptible to are not explainable in black and white terms. LTE is no exception. There are a number of contributing factors but what is more important to understanding LTE are taking the contributing factors and couple them with situations that should be avoided. Whenever possible, pilots should learn to avoid the following combinations:

1. Low and slow flight outside of ground effect.
2. Winds from ±15° of the 10 o'clock position and probably on around to 5 o'clock position *[Figure 11-11]*
3. Tailwinds that may alter the onset of translational lift and translational thrust hence induce high power demands and demand more anti-torque (left pedal) than the tail rotor can produce.
4. Low speed downwind turns.
5. Large changes of power at low airspeeds.
6. Low speed flight in the proximity of physical obstructions that may alter a smooth airflow to both the main rotor and tail rotor.

Pilots who put themselves in situations where the combinations above occur should know that they are likely to encounter LTE. The key is to not put the helicopter in a compromising condition but if it does happen being educated enough to recognize the onset of LTE and be prepared to quickly react to it before the helicopter cannot be controlled.

Early detection of LTE followed by the immediate flight control application of corrective action; applying forward cyclic to regain airspeed, applying right pedal not left as necessary to maintain rotor RPM and reducing the collective thus reducing the high power demand on the tail rotor is the key to a safe recovery. Pilots should always set themselves up when conducting any maneuver to have enough height and space available to recover in the event they encounter an aerodynamic situation such as LTE.

Understanding the aerodynamic phenomenon of LTE is by far the most important factor, and the ability and option to either go around if making an approach or pull out of a maneuver safely and re-plan, is always the safe option. Having the ability to fly away from a situation and re-think the possible options should always be part of a pilot's planning process in all phases of flight. Unfortunately, there have been many pilots who have idled a good engine and fully functioning tail rotor system and autorotated a perfectly airworthy helicopter to the crash site because they misunderstood or misperceived both the limitations of the helicopter and the aerodynamic situation.

Main Rotor Disk Interference (285–315°)

Refer to *Figure 11-11.* Winds at velocities of 10–30 knots from the left front cause the main rotor vortex to be blown into the tail rotor by the relative wind. This main rotor disk vortex causes the tail rotor to operate in an extremely turbulent environment. During a right turn, the tail rotor experiences a reduction of thrust as it comes into the area of the main rotor disk vortex. The reduction in tail rotor thrust comes from the airflow changes experienced at the tail rotor as the main rotor disk vortex moves across the tail rotor disk.

The effect of the main rotor disk vortex initially increases the AOA of the tail rotor blades, thus increasing tail rotor thrust. The increase in the AOA requires that right pedal pressure be added to reduce tail rotor thrust in order to maintain the same rate of turn. As the main rotor vortex passes the tail rotor, the tail rotor AOA is reduced. The reduction in the AOA causes a reduction in thrust and right yaw acceleration begins. This acceleration can be surprising, since previously adding right pedal to maintain the right turn rate. This thrust reduction occurs suddenly, and if uncorrected, develops into an uncontrollable rapid rotation about the mast. When operating within this region, be aware that the reduction in tail rotor thrust can happen quite suddenly, and be prepared to react quickly to counter this reduction with additional left pedal input.

Weathercock Stability (120–240°)

In this region, the helicopter attempts to weathervane, or weathercock, its nose into the relative wind. *[Figure 11-12]* Unless a resisting pedal input is made, the helicopter starts a slow, uncommanded turn either to the right or left, depending upon the wind direction. If the pilot allows a right yaw rate to develop and the tail of the helicopter moves into this region, the yaw rate can accelerate rapidly. In order to avoid the onset of LTE in this downwind condition, it is imperative to maintain positive control of the yaw rate and devote full attention to flying the helicopter.

Tail Rotor Vortex Ring State (210–330°)

Winds within this region cause a tail rotor vortex ring state to develop. *[Figure 11-13]* The result is a nonuniform, unsteady flow into the tail rotor. The vortex ring state causes tail rotor thrust variations, which result in yaw deviations. The net effect of the unsteady flow is an oscillation of tail rotor thrust. Rapid and continuous pedal movements are necessary to compensate for the rapid changes in tail rotor thrust when hovering in a left crosswind. Maintaining a precise heading in this region is difficult, but this characteristic presents no significant problem unless corrective action is delayed. However, high pedal workload, lack of concentration, and overcontrolling can lead to LTE.

When the tail rotor thrust being generated is less than the thrust required, the helicopter yaws to the right. When hovering in left crosswinds, concentrate on smooth pedal coordination and do not allow an uncommanded right yaw to develop. If a right yaw rate is allowed to build, the helicopter can rotate into the wind azimuth region where weathercock stability then accelerates the right turn rate. Pilot workload during a tail rotor vortex ring state is high. Do not allow a right yaw rate to increase.

LTE at Altitude

At higher altitudes where the air is thinner, tail rotor thrust and efficiency are reduced. Because of the high density altitude, powerplants may be much slower to respond to power changes. When operating at high altitudes and high gross weights, especially while hovering, the tail rotor thrust may not be sufficient to maintain directional control, and LTE can occur. In this case, the hovering ceiling is limited by tail rotor thrust and not necessarily power available. In these conditions, gross weights need to be reduced and/or operations need to be limited to lower density altitudes. This may not be noted as criteria on the performance charts.

Reducing the Onset of LTE

To help reduce the onset of LTE, follow these steps:

1. Maintain maximum power-on rotor rpm. If the main rotor rpm is allowed to decrease, the antitorque thrust available is decreased proportionally.
2. Avoid tailwinds below airspeeds of 30 knots. If loss of translational lift occurs, it results in an increased power demand and additional antitorque pressures.
3. Avoid OGE operations and high power demand situations below airspeeds of 30 knots at low altitudes.
4. Be especially aware of wind direction and velocity when hovering in winds of about 8–12 knots. A loss of translational lift results in an unexpected high power demand and an increased antitorque requirement.
5. Be aware that if a considerable amount of left pedal is being maintained, a sufficient amount of left pedal may not be available to counteract an unanticipated right yaw.
6. Be alert to changing wind conditions, which may be experienced when flying along ridge lines and around buildings.
7. Execute slow turns to the right which would limit the effects of rotating inertia, and the loading on the tailrotor to control yawing would be decreased.

Recovery Technique

If a sudden unanticipated right yaw occurs, the following recovery technique should be performed. Apply forward cyclic control to increase speed. If altitude permits, reduce power. As recovery is affected, adjust controls for normal forward flight. A recovery path must always be planned, especially when terminating to an OGE hover and executed immediately if an uncommanded yaw is evident.

Collective pitch reduction aids in arresting the yaw rate but may cause an excessive rate of descent. Any large, rapid increase in collective to prevent ground or obstacle contact may further increase the yaw rate and decrease rotor rpm. The decision to reduce collective must be based on the pilot's assessment of the altitude available for recovery.

If the rotation cannot be stopped and ground contact is imminent, an autorotation may be the best course of action. Maintain full left pedal until the rotation stops, then adjust to maintain heading. For more information on LTE, see Advisory Circular (AC) 90-95, Unanticipated Right Yaw in Helicopters.

Main Drive Shaft or Clutch Failure

The main drive shaft, located between the engine and the main rotor gearbox, transmits engine power to the main rotor gearbox. In some helicopters, particularly those with piston engines, a drive belt is used instead of a drive shaft. A failure of the drive shaft clutch or belt has the same effect as an engine failure because power is no longer provided to the main rotor and an autorotation must be initiated. There are a few differences, however, that need to be taken into consideration. If the drive shaft or belt breaks, the lack of any load on the engine results in an overspeed. In this case, the throttle must be closed in order to prevent any further damage. In some helicopters, the tail rotor drive system continues to be powered by the engine even if the main drive shaft breaks. In this case, when the engine unloads, a tail rotor overspeed can result. If this happens, close the throttle immediately and enter an autorotation. The pilot must be knowledgeable of the specific helicopter's system and failure modes.

Pilots should keep in mind that when there is any suspected mechanical malfunction, first and foremost they should always attempt to maintain rotor RPM. If the rotor RPM is at the normal indication with normal power settings, an instrument failure might be occurring and it would be best to fly the helicopter to a safe landing area. If the rotor RPM is in fact decreasing or low, then there is a drive line failure.

Hydraulic Failure

Many helicopters incorporate the use of hydraulic actuators to overcome high control forces. A hydraulic system consists of actuators, also called servos, on each flight control; a pump, which is usually driven by the main rotor gearbox; and a reservoir to store the hydraulic fluid. A switch in the cockpit can turn the system off, although it is left on during normal conditions. A pressure indicator in the cockpit may be installed to monitor the system.

An impending hydraulic failure can be recognized by a grinding or howling noise from the pump or actuators, increased control forces and feedback, and limited control movement. The required corrective action is stated in detail in the appropriate RFM. However, in most cases, airspeed needs to be reduced in order to reduce control forces. The hydraulic switch and circuit breaker should be checked and recycled. If hydraulic power is not restored, make a shallow approach to a running or roll-on landing. This technique is used because it requires less control force and pilot workload. Additionally, the hydraulic system should be disabled by placing the switch in the off position. The reason for this is to prevent an inadvertent restoration of hydraulic power, which may lead to overcontrolling near the ground.

In those helicopters in which the control forces are so high that they cannot be moved without hydraulic assistance, two or more independent hydraulic systems are installed. Some helicopters use hydraulic accumulators to store pressure that can be used for a short time while in an emergency if the hydraulic pump fails. This gives enough time to land the helicopter with normal control.

Governor or Fuel Control Failure

Governors and fuel control units automatically adjust engine power to maintain rotor rpm when the collective pitch is changed. If the governor or fuel control unit fails, any change in collective pitch requires manual adjustment of the throttle to maintain correct rpm. In the event of a high side failure, the engine and rotor rpm tend to increase above the normal range. If the rpm cannot be reduced and controlled with the throttle, close the throttle and enter an autorotation. If the failure is on the low side, normal rpm may not be attainable, even if the throttle is manually controlled. In this case, the collective has to be lowered to maintain rotor rpm. A running or roll-on landing may be performed if the engine can maintain sufficient rotor rpm. If there is insufficient power, enter an autorotation. As stated previously in this chapter, before responding to any type of mechanical failure, pilots should confirm that rotor rpm is not responding to flight control inputs. If the rotor rpm can be maintained in the green operating range, the failure is in the instrument, and not mechanical.

Abnormal Vibration

With the many rotating parts found in helicopters, some vibration is inherent. A pilot needs to understand the cause and effect of helicopter vibrations because abnormal vibrations cause premature component wear and may even result in structural failure. With experience, a pilot learns what vibrations are normal and those that are abnormal, and can then decide whether continued flight is safe or not. Helicopter vibrations are categorized into low, medium, or high frequency.

Low-Frequency Vibrations

Low-frequency vibrations (100–500 cycles per minute) usually originate from the main rotor system. The main rotor operational range, depending on the helicopter, is usually between 320 and 500 rpm. A rotor blade that is out of track or balance will cause a cycle to occur with every rotation. The vibration may be felt through the controls, the airframe, or a combination of both. The vibration may also have a definite direction of push or thrust. It may be vertical, lateral, horizontal, or even a combination of these. Normally, the direction of the vibration can be determined by concentrating on the feel of the vibration, which may push a pilot up and down, backwards and forwards, or in the case of a blade being out of phase, from side to side. The direction of the vibration and whether it is felt in the controls or the airframe is important information for the mechanic when he or she troubleshoots the source. Out-of-track or out-of-balance main rotor blades, damaged blades, worn bearings, dampers out of adjustment, or worn parts are possible causes of low frequency vibrations.

Medium- and High-Frequency Vibrations

Medium-frequency vibrations (1,000–2,000 cycles per minute) range between the low frequencies of the main rotor (100–500 cycles per minute) and the high frequencies (2,100 cycles per minute or higher) of the engine and tail rotor. Depending on the helicopter, medium-frequency vibration sources may be engine and transmission cooling fans, and accessories such as air conditioner compressors, or driveline components. Medium-frequency vibrations are felt through the entire airframe, and prolonged exposure to the vibrations will result in greater pilot fatigue.

Most tail rotor vibrations fall into the high-frequency range (2,100 cycles per minute or higher) and can be felt through the tail rotor pedals as long as there are no hydraulic actuators to dampen out the vibration. This vibration is felt by the pilot through his or her feet, which are usually "put to sleep" by the vibration. The tail rotor operates at approximately a 6:1 ratio with the main rotor, meaning for every one rotation of the main rotor the tail rotor rotates 6 times. A main rotor operating rpm of 350 means the tail rotor rpm would be 2,100 rpm. Any imbalance in the tail rotor system is very harmful as it can cause cracks to develop and rivets to work loose. Piston engines usually produce a normal amount of high-frequency vibration, which is aggravated by engine malfunctions, such as spark plug fouling, incorrect magneto timing, carburetor icing and/or incorrect fuel/air mixture. Vibrations in turbine engines are often difficult to detect as these engines operate at a very high rpm. Turbine engine vibration can be at 30,000 rpm internally, but common gearbox speeds are in the 1,000 to 3,000 rpm range for the output shaft. The vibrations in turbine engines may be short lived as the engine disintegrates rapidly when damaged due to high rpm and the forces present.

Tracking and Balance

Modern equipment used for tracking and balancing the main and tail rotor blades can also be used to detect other vibrations in the helicopter. These systems use accelerometers mounted around the helicopter to detect the direction, frequency, and intensity of the vibration. The built-in software can then analyze the information, pinpoint the origin of the vibration, and suggest the corrective action.

The use of a system such as a health and usage monitoring system (HUMS) provides the operator the ability to record engine and gearbox performance and provide rotor track and balance. This system has been around for over 30 years and is now becoming more affordable, more capable, and more commonplace in the rotorcraft industry.

Multiengine Emergency Operations

Single-Engine Failure

When one engine has failed, the helicopter can often maintain altitude and airspeed until a suitable landing site can be selected. Whether or not this is possible becomes a function of such combined variables as aircraft weight, density altitude, height above ground, airspeed, phase of flight, single-engine capability, and environmental response time and control technique may be additional factors. Caution must be exercised to correctly identify the malfunctioning engine since there is no telltale yawing as occurs in most multiengine airplanes. Shutting down the wrong engine could be disastrous!

Even when flying multiengine powered helicopters, rotor rpm must be maintained at all costs, because fuel contamination has been documented as the cause for both engines failing in flight.

Dual-Engine Failure

The flight characteristics and the required crew member control responses after a dual-engine failure are similar to those during a normal power-on descent. Full control of the helicopter can be maintained during autorotational descent. In autorotation, as airspeed increases above 70–80 knots indicated airspeed (KIAS), the rate of descent and glide distance increase significantly. As airspeed decreases below approximately 60 KIAS, the rate of descent increases and glide distance decreases.

Lost Procedures

Pilots become lost while flying for a variety of reasons, such as disorientation, flying over unfamiliar territory, or visibility that is low enough to render familiar terrain unfamiliar. When a pilot becomes lost, the first order of business is to fly the aircraft; the second is to implement lost procedures. Keep in mind that the pilot workload will be high and increased concentration is necessary. If lost, always remember to look for the practically invisible hazards such as wires by searching for their support structures, such as poles or towers, which are almost always near roads.

If lost, follow common sense procedures.

- Try to locate any large landmarks, such as lakes, rivers, towers, railroad tracks, or Interstate highways. If a landmark is recognized, use it to find the helicopter's location on the sectional chart. If flying near a town or city, a pilot may be able to read the name of the town on a water tower or even land to ask for directions.
- If no town or city is nearby, the first thing a pilot should do is climb. An increase in altitude increases radio and navigation reception range as well as radar coverage.
- Navigation aids, dead reckoning, and pilotage are skills that can be used as well.
- Do not forget air traffic control—controllers assist pilots in many ways, including finding a lost helicopter. Once communication with ATC has been established, follow their instructions.

These common sense procedures can be easily remembered by using the four Cs: Climb, Communicate, Confess, and Comply.

- Climb for a better view, improved communication and navigation reception, and terrain avoidance.
- Communicate by calling the nearest flight service station (FSS)/automated flight service station (AFSS) on 122.2 MHz. If the FSS/AFSS does not respond, call the nearest control tower, center, or approach control. For frequencies, check the chart in the vicinity of the last known position. If that fails, switch to the emergency radio frequency (121.5 MHz) and transponder code (7700).
- Report the lost situation to air traffic control and request help.
- Comply with controller instructions.

Pilots should understand the services provided by ATC and the resources and options available. These services enable pilots to focus on aircraft control and help them make better decisions in a time of stress.

When contacting ATC, pilots should provide as much information as possible because ATC uses the information to determine what kind of assistance it can provide with available assets and capabilities. Information requirements vary depending on the existing situation, but at a minimum a pilot should provide the following information:

- Aircraft identification and type
- Nature of the emergency
- Aviator's desires

To reduce the chances of getting lost in the first place, use flight following when it is available, monitor checkpoints no more than 25 miles apart, keep navigation aids such as VORs tuned in, and maintain good situational awareness.

Getting lost is a potentially dangerous situation for any aircraft, especially when low on fuel. Due to the helicopter's unique ability to land almost anywhere, pilots have more flexibility than other aircraft as to landing site. An inherent risk associated with being lost is waiting too long to land in a safe area. Helicopter pilots should land before fuel exhaustion occurs because maneuvering with low fuel levels could cause the engine to stop due to fuel starvation as fuel sloshes or flows away from the pickup port in the tank.

If lost and low on fuel, ALWAYS land with fuel on board to enable a safe landing. Preferably, land near a road or in an area allowing plenty of room for another helicopter to land in the same area safely. Having fuel delivered is a minor inconvenience when compared to a crash. Fuel on board after landing allows use of the radios as well as heat in colder climates.

Emergency Equipment and Survival Gear

Both Canada and Alaska require pilots to carry survival gear. Always carry survival gear when flying over rugged and desolate terrain. The items suggested in *Figure 11-14* are both weather and terrain dependent. The pilot also needs to consider how much storage space the helicopter has and how the equipment being carried affects the overall weight and balance of the helicopter.

Chapter Summary

Emergencies should always be anticipated. Knowledge of the helicopter, possible malfunctions and failures, and methods of recovery can help the pilot avoid accidents and be a safer pilot. Helicopter pilots should always expect the worse hazards and possible aerodynamic effects and plan for a safe exit path or procedure to compensate for the hazard.

EMERGENCY EQUIPMENT AND SURVIVAL GEAR
Food cannot be subject to deterioration due to heat or cold. There should be at least 10,000 calories for each person on board, and it should be stored in a sealed waterproof container. It should have been inspected by the pilot or his representative within the previous 6 months, and bear a label verifying the amount and satisfactory condition of the contents.
A supply of water
Cooking utensils
Matches in a waterproof container
A portable compass
An ax weighing at least 2.5 pounds with a handle not less than 28 inches in length
A flexible saw blade or equivalent cutting tool
30 feet of snare wire and instructions for use
Fishing equipment, including still-fishing bait and gill net with not more than a two-inch mesh
Mosquito nets or netting and insect repellent sufficient to meet the needs of all persons aboard, when operating in areas where insects are likely to be hazardous
A signaling mirror
At least three pyrotechnic distress signals
A sharp, quality jackknife or hunting knife
A suitable survival instruction manual
Flashlight with spare bulbs and batteries
Portable emergency locator transmitter (ELT) with spare batteries
Stove with fuel or a self-contained means of providing heat for cooking
Tent(s) to accommodate everyone on board
Additional items for winter operations: • Winter sleeping bags for all persons when the temperature is expected to be below 7 °C • Two pairs of snow shoes • Spare ax handle • Ice chisel • Snow knife or saw knife

Figure 11-14. *Emergency equipment and survival gear.*