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Low Rotor RPM Threatens Safe Helicopter Flight

Maintaining proper rotating speed of main rotor blades is a basic flying skill which, if allowed to deteriorate, can affect the safety of flight, especially in light piston-powered helicopters.

by

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Advances in flight control systems, avionics and powerplant design are intended to make helicopters more reliable and to reduce pilot work load. While an increase in reliability is always welcome, a reduction in pilot work load, while just as welcome, also means that electromechanical devices accomplish some tasks that previously required the pilot's attention. This, however, can lead to a degeneration of some basic flying skills. When the pilot accustomed to flying a sophisticated rotorcraft returns to flying a light piston-engine helicopter, basic flying skills must be reviewed. This return to basics forces a pilot to be attentive to a variety of different and perhaps forgotten techniques; the most critical is maintenance of rotor rpm. Consider the following example:

On a warm summer day a high-time turbine pilot and a passenger embarked on a long ferry flight in a two-seat, piston-powered light helicopter. With both fuel tanks full, the aircraft was loaded to gross weight. The pilot and his passenger decided to make an off-airport landing to get out and stretch. Having topped off the tanks less then one hour earlier, the aircraft still had approximately 24 gallons of fuel remaining of its original 30 gallons. The pilot chose a vacant area behind a truck stop and started an approach.

On short final, the aircraft's low-rotor rpm horn sounded. The pilot tried to add throttle but found that it was already wide open. Realizing that he had to maintain rotor rpm, he reduced the collective slightly. With the airspeed slow and the aircraft not yet in ground effect, the pilot decided that aborting the landing would require additional power, but none was available. He maintained rotor rpm to keep the aircraft in effective translational lift while he attempted a run-on landing. The aircraft hit hard, slid into a small gully and caused minor damage to one skid.

This example illustrates a leading cause of accidents in light piston helicopters. It occurred because the pilot was not accustomed to flying a helicopter that can easily reach its power limit. He was not attentive to the helicopter's rotor rpm and he did not consider the extent to which high density altitude affects normally aspirated engines. These are skills that are less critical in most corporate twin-engine turbine helicopter operations, particularly when most flights are to and from very familiar areas.

Equipment Complexity Varies, Requires Pilot Awareness

One important difference between turbine helicopters and piston helicopters is the method used to adjust rotor rpm in response to changes in engine power. A turbine engine utilizes an rpm governor while a piston engine employs an rpm correlator. The difference between an rpm governor and an rpm correlator should be understood.

The governor senses the rpm and adjusts the fuel control accordingly. Generally, once a pilot sets the desired rpm, the governor will maintain it, and the pilot need not make adjustments. When a pilot usually flies with a governor maintaining the rpm for him, complacency may dull his attention to this important detail.

An engine correlator is merely a mechanical linkage that adjusts the carburetor throttle as a function of collective pitch control position. Most piston-powered helicopters are equipped with an rpm correlator to help adjust the engine in response to collective movement. But the correlator does not sense rpm and will not take the helicopter's weight or density altitude into consideration. It can be adjusted to respond closely to collective movement at a fixed weight and density altitude (normally about 3,000 feet density altitude). When operating at a much higher density altitude, the pilot must manually add throttle when increasing collective pitch. Failure to do so will result in decay of the main rotor rpm, eventually stalling the main rotor blades.

Failure to correct quickly low rotor rpm during hover can result in another problem — loss of tail rotor effectiveness.

On an approach, especially at high density altitude, allowing the airspeed to decrease and the descent rate to increase (steep approaches) can lead to trouble. Pilots not accustomed to constantly adjusting the throttle may raise the collective to control power and rate of descent. Without adding throttle, this will begin to pull down the rotor rpm and the helicopter will continue to settle.

As the rotor rpm slows, the angle of attack of the main rotor blades must increase to maintain sufficient lift. If the pilot is unaware of the dropping rotor rpm and continues to add collective pitch, the rotor rpm will continue to decay and the helicopter will settle faster. The upward flow of air through the main rotor disc will increase the angle of attack of the main rotor blades where they will begin to stall. When this occurs, the lift will decrease and the drag will increase, causing the helicopter to descend at an accelerated rate. The increase in the descent rate will increase the upward airflow and further increase the blades' angle-of-attack, thus accelerating the stall. Recovery at this point is nearly impossible and can lead to the main rotor blades flexing downward and striking the tail boom.

Basics Essential in Marginal Flight Regimes

In a helicopter, engine power is directly proportional to main rotor rpm. A 10 percent drop in rpm means there is 10 percent less power available. Therefore, whenever rotor rpm begins to decrease, it is essential to recover and maintain it. It is far better to reduce collective and land hard in control, than to stall the main rotor blades at 50 feet above ground level.

If a low rotor rpm condition occurs while hovering near the surface, a technique known as "milking the collective" can be used. When sufficient power is available, the procedure is to momentarily lower the collective to reduce the angle of attack and drag while increasing the throttle to recover the rotor rpm. The collective should not be lowered too abruptly because it increases the likelihood of a hard landing. Then, slowly raise the collective to stop the descent without allowing the rpm to decrease. In certain situations, this procedure may need to be repeated several times to fully recover the rpm.

Failure to quickly correct low rotor rpm during hover can result in another problem — loss of tail rotor effectiveness. Because the tail rotor is directly coupled to the main rotor, any drop in main rotor rpm will result in a proportional drop in tail rotor rpm. This will reduce tail rotor thrust and eventually lead to loss of directional control. If the situation allows it, setting the helicopter down while still under control may be the safest course of action.

A pilot can encounter a low rotor rpm situation quickly. For example, a single-engine turbine helicopter was on a photo mission with two passengers in addition to the photographer and pilot. While hovering at 200 feet above a river channel so that photographs could be taken, the engine failed. Hovering out of ground effect in a heavily loaded helicopter requires a high power setting and the pilot most likely had been operating at 100 percent power. The abrupt stoppage at high power caused an accelerated decay of the rotor rpm. The pilot lowered the nose in an attempt to achieve forward airspeed, but this action pulled the rotor rpm down even further. The helicopter hit the water hard in a nose-low attitude, resulting in the death of the three passengers. The pilot survived with severe back injuries.

Although low rotor rpm was not the primary cause of this accident, the events following the power failure certainly underscore the importance of maintaining rotor rpm in critical situations. In this case, lowering the nose simply exacerbated what had become a critical low rotor rpm condition, and increased the helicopter's rate of descent. This accident shows that at low altitudes, a helicopter may have insufficient potential energy to achieve the airspeed required to arrest the ensuing increase in descent rate.

This accident occurred in a marginal flight regime that is identified by a shaded area of the height-velocity diagram (Figure 1).

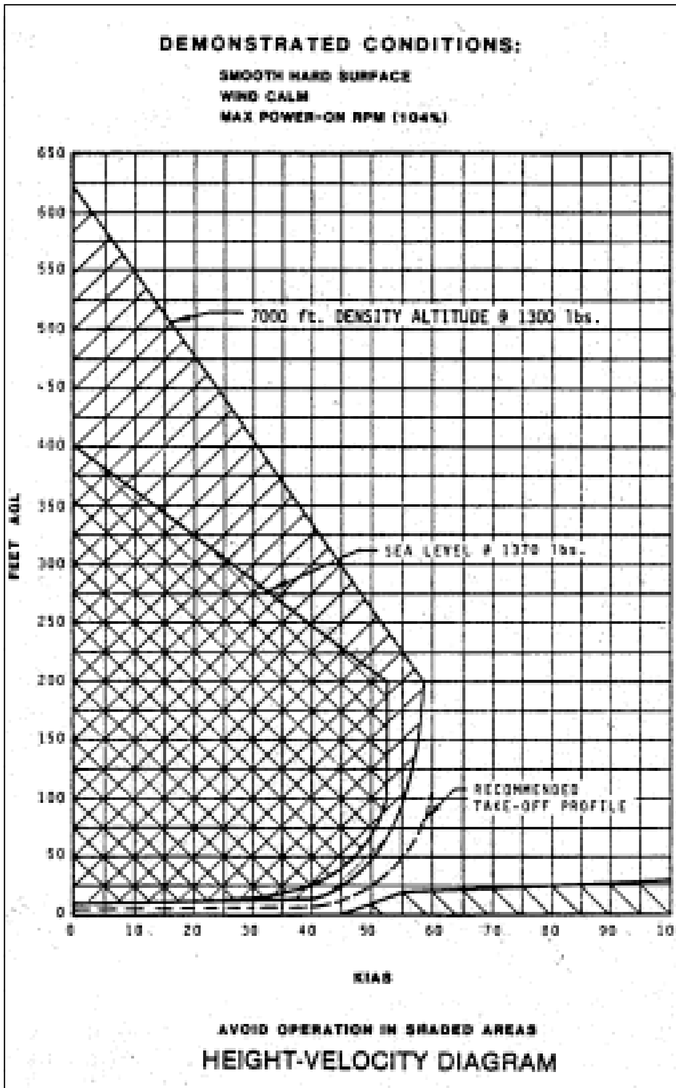

Figure 1

Pilots are cautioned from flying within that airspeed/altitude combination because in that range it is difficult to make successful autorotative landings. But techniques for increasing the likelihood of a safe autorotation while operating in marginal areas of performance are important for sling-load operations, agricultural work and other missions that require steep approaches. These tend to place pilots in low altitude/low airspeed situations where correct recovery procedures often may require extra training.

The pilot of the photo flight might have completed a successful emergency ditching if he had held his position and immediately reduced the collective to the full-down position. This is a good procedure because, in autorotation, lowering the nose to gain airspeed reduces the volume of air acting on the rotor disc and further decreases rotor rpm. Allowing the helicopter to descend vertically results in a greater volume of air moving upward though the rotor disc and regains some rotor rpm. Then the pilot utilizes the additional stored kinetic energy in the rotor rpm to slow the helicopter's rate of descent just prior to contact with the surface. This is accomplished by pulling full collective pitch immediately prior to surface contact to generate a brief burst of lift. Timing is paramount to allow the helicopter to contact the surface with the lowest speed to increase passenger survivability.

During autorotation, the rpm is controlled by three zones in the main rotor disc (Figure 2). The area from the center of the disc to approximately 25 percent of the disc radius is called the "stall region." The area from there to approximately 70 percent is called the "driving region." The outside section to the blade tips is known as the "driven region." The stall region of each main rotor blade operates at or above the stall angle of attack and produces high drag forces that slow the rotation of the rotor system. The driving region produces aerodynamic forces that will try to increase the rotor rpm during autorotation. The driven region adds a small amount of drag that will decrease rotor rpm. The rotor rpm will stabilize when the forces in the stall region plus the driven region equal the forces in the driving region.

When operating at high pitch settings (even with a high-inertia rotor system in a turbine helicopter) rotor rpm will decay rapidly if a pilot fails to lower the collective immediately upon experiencing engine failure. This is especially true in low-inertia rotor systems found on most piston helicopters. In the first example that involved a light, two-seat helicopter, the pilot was experienced enough to know the importance of maintaining

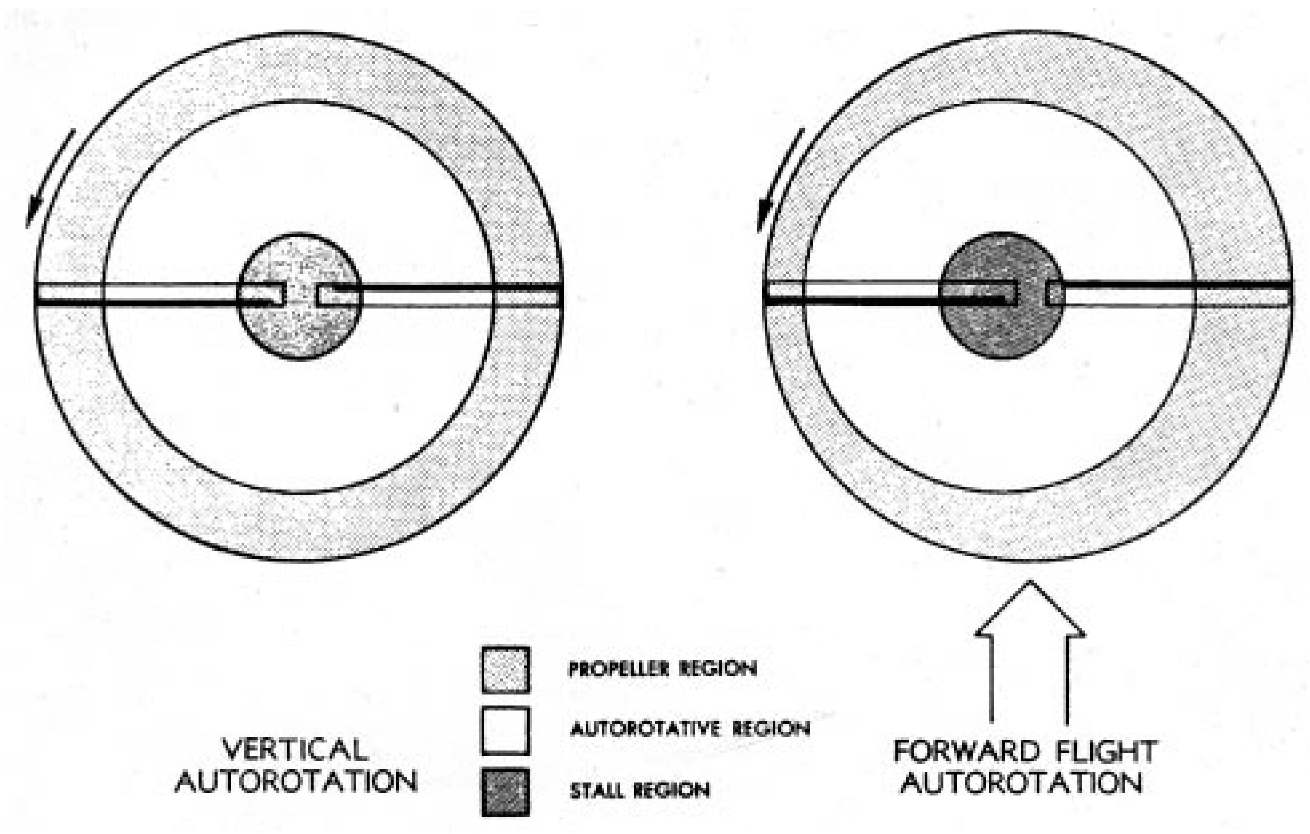

Figure 2

rotor rpm. He was able to correct a situation that could have become extremely dangerous.

Any rotorcraft pilot who expects to fly a light, piston-engine helicopter or, perhaps, to do some instructing, must know the importance of maintaining sufficient rotor rpm.◆

About the Author

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