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Implications of the Power Curve on Single-engine Flight in a Twin-engine Helicopter

Flight with one engine inoperative in most two-engine civil rotorcraft is possible only within a narrow airspeed range. Knowledge of those limits prepare the pilot for an unexpected engine failure.

by
Joel Harris
Helicopter Instructor

When a twin-engine helicopter is suddenly forced to be operated with one engine inoperative (OEI), the pilot is expected to know and complete the appropriate emergency procedures described in the rotorcraft flight manual (RFM). Often, however, pilots are less knowledgeable about the "power required curve" and its implications in this situation than they are of procedures to shut down a defective engine and retain aircraft control.

The power required curve is a graph that illustrates maximum available engine power with all engines operating and plots the amount of engine power necessary to sustain level flight at various airspeeds. In a multi-engine helicopter, the graph may also include maximum power available OEI. The chart may be plotted from actual in-flight observations.

Parasite, Profile and Induced Drag Affect the Curve

The power required curve is the sum of the power required to overcome parasite, profile and induced drag during flight at various airspeeds.

Parasite drag is incurred by any part of the aircraft that does not contribute to the production of lift or thrust. Cowlings, landing gear, pitot tubes and other accessories produce parasite drag. Figure 1 illustrates the curving relationship between parasite drag and the engine power required to overcome it at various airspeeds. At zero airspeed, there is no parasite drag and hence no requirement to expend energy, or "parasite power." However, as the helicopter increases airspeed, the power required to overcome parasite drag increases rapidly. The more aerodynamically clean the helicopter is, the less it is affected by parasite drag.

Profile drag and induced drag, however, are peculiar to lift- or thrust-producing airfoils, such as the helicopter's rotor system. Profile drag is defined as the frictional resistance incurred when an object is moved through a viscous fluid. Air, in this case, may be considered such a fluid that tends to cling to an object passing through it and resists its passage.

Figure 2 shows that the power required to overcome profile drag remains nearly constant at all but the highest airspeeds. A substantial amount of available engine power is required to turn the rotor through the air against the friction of aerodynamic forces. Since rotor speed remains relatively constant, the power required to overcome profile drag increases only slightly as forward airspeed is increased. It is only at very high airspeeds, as retreating blade stall is approached, that profile drag increases rapidly.

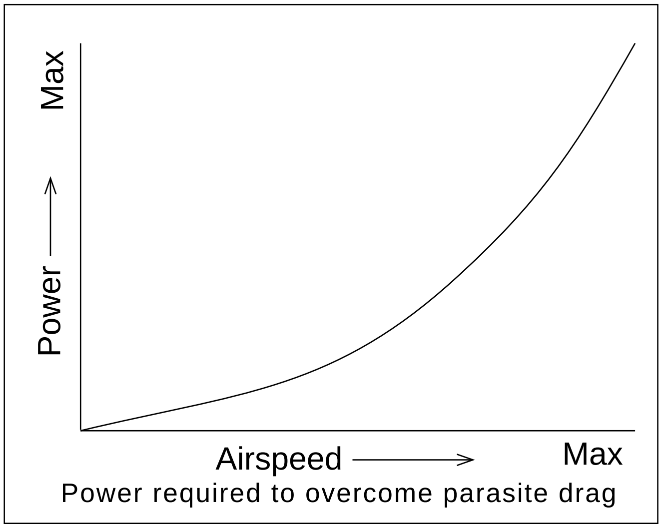

Figure 1

Induced drag is the drag incurred in the actual production of lift. When an airfoil is flown at a positive angle of attack, air is displaced in directions, at pressures and at velocities which are not normal to its free and undisturbed state. Its resistance to these changes, which are necessary to produce lift, forms induced drag.

Figure 3 illustrates the relationship of power required to overcome induced drag vs. airspeed. Note that of the three types of drag, only induced drag decreases as airspeed is increased. The reason for this is that induced drag is very high at zero airspeed because the rotor must use considerable energy to produce enough airflow to result in thrust. The power required to overcome induced drag decreases as the helicopter reaches higher airspeeds. As the rotor moves forward through the air at higher airspeeds, it meets an increasingly larger mass of air per unit of time and does not have to impart as much additional velocity to this mass of air to generate the desired amount of thrust.

Of the amount of available power delivered to the rotor system and required to overcome induced and profile drag, a general estimate for the normal hovering helicopter might be that approximately 65 percent of the total power is needed to overcome induced drag and approximately 35 percent for profile drag. If the rotor receives more power than is required to overcome profile and induced drag, the helicopter will climb.

Power Required Curve Relates to Total Drag

The sum of the amounts of power required to overcome parasite, profile and induced drag equals the power required to sustain level flight at all given airspeeds for a particular helicopter. As previously stated, the power required curve can be produced by simply plotting the power required to maintain level flight at various airspeeds while operating at a given weight and altitude. Figure 4 illustrates a plotted power required curve for a generic helicopter with two engines. (None of the illustrations should be taken as the performance criteria for a particular aircraft; they are provided only as a method of showing the levels of induced, parasite and profile drag, and the power required to overcome them.)

The aircraft whose power required curve is reflected in Figure 4 requires approximately 85 percent of its available dual engine power to sustain hovering flight in calm wind at the test altitude and out of ground effect. As airspeed increases, the power required to maintain level flight begins to dramatically decrease. For example, the graph shows that it takes only approximately 65 percent of available power to maintain level flight when airspeed is increased to 30 knots. This is a reduction in power demand by a full 20 percent. At 50 knots, the power required for level flight has further decreased to only about 50 percent of that available from the two engines. This downward curve of required power continues to its bottom, which occurs at the aircraft's best rate of climb speed (V_{BROC}). In most helicopters, the best rate of climb speed occurs between 60 and 75 knots at sea level and

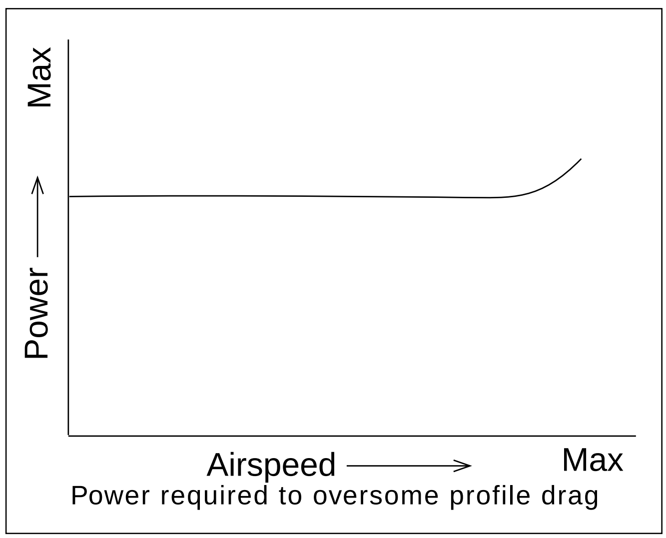

Figure 2

decreases with altitude at a rate of approximately one knot per thousand feet.

V_{BROC} then, is the speed at which the helicopter has the greatest excess of power over that required to maintain level flight. It is the speed at which the helicopter is capable of maintaining the greatest steady rate of climb. This speed is very significant to single-engine flight.

At speeds above V_{BROC}, the power required to sustain level flight begins to gradually increase. In Figure 4, 100 knots of airspeed requires the same amount of engine power to sustain level flight as 50 knots airspeed. Therefore, every airspeed, except V_{BROC} and those airspeeds in the very high range, have a corresponding airspeed on the opposite side of the power curve that requires an equal amount of power to maintain level flight.

OEI Flight and the Power Required Curve Related

The 100 percent value at the top of the graph in Figure 4 marks the maximum power available with both engines operating. The power required curve crosses this maximum power available line at an airspeed of approximately 155 knots in the generic twin-engine helicopter. This airspeed is the point at which the helicopter's powerplants are capable of producing enough power to sustain level flight, and no more. At speeds above 155 knots, the helicopter has insufficient power to maintain level flight and must begin to descend.

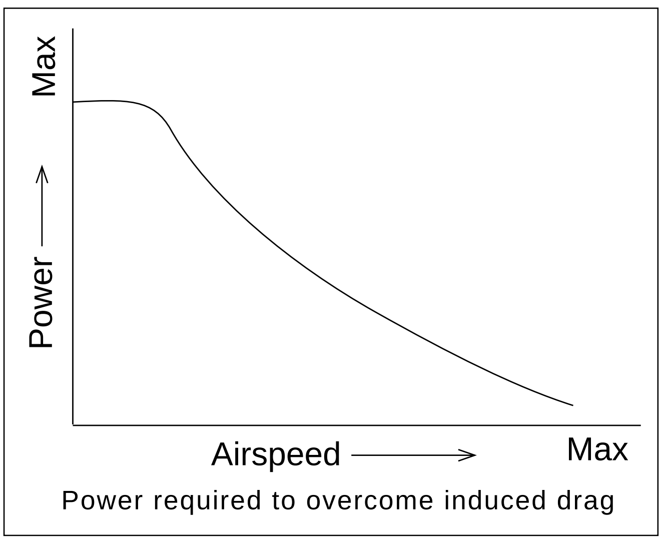

Figure 3

The horizontal dashed line labeled "Maximum OEI" indicates the maximum power available to the aircraft when one of the engines becomes inoperative. This line is more than 50 percent of the power available with both engines because of the higher power limitations allowed for the operating engine during OEI flight. This line intersects with the power required curve at about 30 knots and again at about 120 knots. In other words, while operating under the given conditions, the helicopter is only capable of sustaining level flight with one engine inoperative when flying in the range between 30 and 120 knots airspeed. At speeds outside of this range, this helicopter cannot sustain flight OEI.

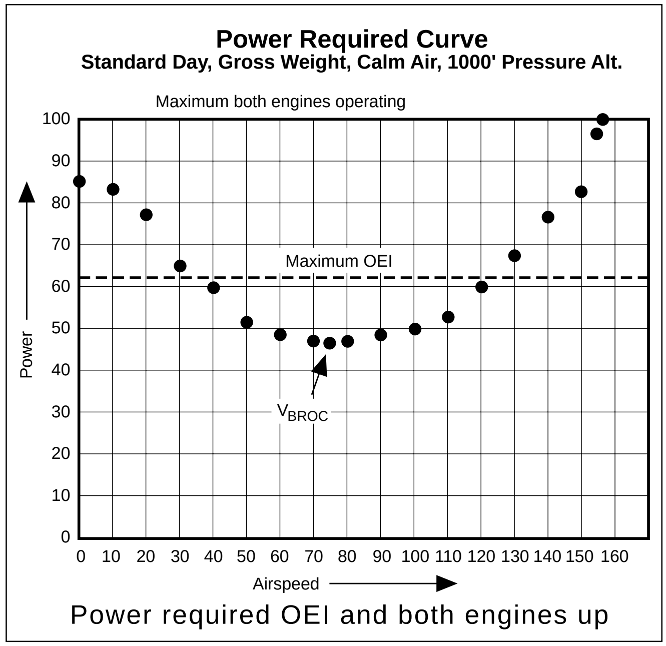

Figure 4

Stay-up Speed Demands Consideration

The point where the power required curve first crosses the maximum power available OEI line — 30 knots in this particular case — is sometimes called "stay-up" speed. Stay-up speed is the airspeed the helicopter must achieve on takeoff before being assured of flying capability should one engine suddenly become inoperative. The more rapidly the helicopter accelerates to stay-up speed, the shorter the time that it is exposed to a forced land-back situation in the event an engine becomes inoperative. In Figure 4, all speeds are plotted out of ground effect — stay-up speed in ground effect could be somewhat lower.

Even if stay-up speed is not achieved on takeoff prior to an engine failure, it may still be achieved if sufficient height exists beneath the helicopter. This height may be traded for the required airspeed by quickly descending. An example would be a helicopter leaving an elevated heliport and suffering an engine loss shortly after clearing the platform. Depending on the elevation of the platform, the pilot may be able to trade height for airspeed and thus achieve stay-up speed or climb capability while operating on one engine.

The following scenario illustrates how the power required curve can be used by the pilot of the generic helicopter. The helicopter is departing an elevated heliport and its departure path is over flat and unobstructed terrain. Should it experience an engine failure on takeoff prior to the stay-up speed of 30 knots, the pilot could anticipate a forced landing, unless there was sufficient height beneath the helicopter to convert that to the required stay-up speed by descending. This equation, however, does not take into account the effect of momentum. An aircraft that is rapidly accelerating when it suffers an engine failure could reasonably be expected to continue the acceleration somewhat beyond the speed at which the engine failed, by virtue of momentum. Although stay-up speed only guarantees sustained level flight OEI, but not a rate of climb, the momentum of acceleration could possibly carry the airspeed beyond mere stay-up airspeed.

As is illustrated in Figure 4, each knot beyond 30 knots increases the excess power available margin. This excess may be either converted into a sustainable rate of climb, or it may be used to continue accelerating in level flight toward the best rate of climb speed. The greatest excess of power, which can be converted to a rate of climb if necessary, is available at V_{BROC}.

Some military flight crews, who operate large, twin-engine helicopters compute stay-up speed for every takeoff. This speed then becomes a part of the checklist call-outs and is enunciated by a non-flying crew member when it is achieved. This practice takes the guesswork out of single-engine flight capability in an emergency. An engine failure prior to the stay-up call means a land-back must be accomplished (assuming excess altitude is not available). An engine failure after stay-up assures the option of continued flight.

Unfortunately, charts for computing stay-up speeds OEI are not usually available in rotorcraft flight manuals. Such charts could be developed, and would need to incorporate density altitude, ground effect and aircraft gross weight. Such charts could serve in much the same way as V_1 speeds do in fixed-wing aircraft. An engine failure prior to the computed V_1 speed requires an abort; after V_1, the pilot is committed to continue the takeoff.

It is important for the pilot of any twin-engine helicopter to be prepared to operate in an emergency OEI condition. One part of preparing for such an emergency is a sound knowledge of the aircraft's performance capability with one engine inoperative. At a minimum, the pilot should know his aircraft's best rate of climb speed and have a general knowledge of the effect of the power required curve upon single-engine flight capability. It is important to remember that in most civilian twin-engine helicopters, OEI flight is possibly only within a limited airspeed range.♦

About the Author

Joel Harris is an instructor and supervisor at the FlightSafety S-76 Learning Center in West Palm Beach, Florida, U.S. He is a contributing editor for the IFR Refresher *newsletter and has taught safety seminars for the emergency medical service (EMS) helicopter industry.*

Harris began flying helicopters with the U.S. Army in 1967. After a tour in Vietnam, he left the Army and earned fixed-wing and instructor pilot ratings. He has been a helicopter instructor since 1980.

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