COPING WITH A POWER FAILURE

STRETCHING THE GLIDE

An engine will seldom pick the most convenient time and place to quit. For this reason, it is sometimes valuable to know how to milk the last drop out of the autorotative procedure--to either provide the most time for restarting the engine or to stretch the glide to that distant landing spot. The pilot has two parameters to work with, indicated forward speed and rotor speed.

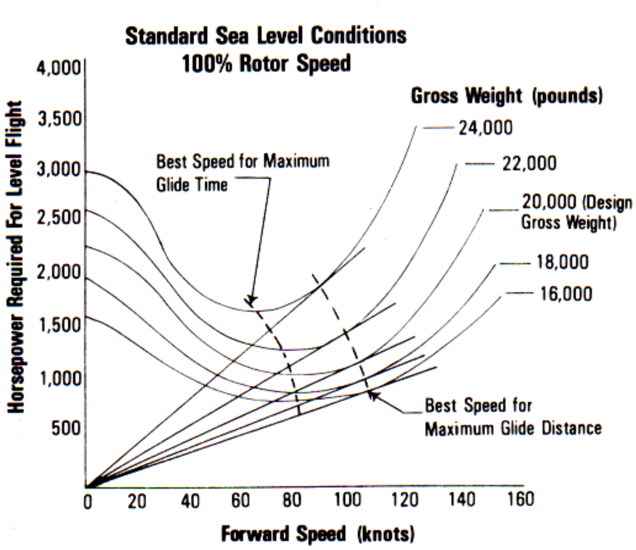
The right forward speed

For a given helicopter, the best forward speed can be determined from the curves of power required to maintain level flight. To illustrate this, let’s look at the results of some calculations made for a typical--but hypothetical--helicopter. The figure below shows the power required at several gross weights in level flight.

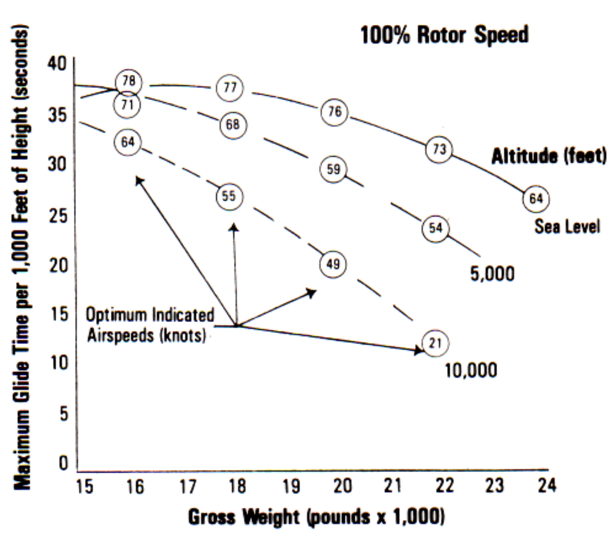
The power required for autorotation is almost the same as in level flight (a little less because the tail rotor is not working quite so hard and because autorotation gives a slightly more efficient distribution of local angles of attack) but instead of coming from the engine, the power must come from the rate of decrease in potential energy as the helicopter loses altitude. The approximate rate of descent in feet per minute required to provide this power can be found by multiplying the horsepower for level flight by 33,000 and then dividing by the gross weight. The figure above shows the results of the calculation as the maximum glide time available per thousand feet of height above the terrain before the terrain comes up to meet the helicopter. Curves are plotted for sea level and two higher altitudes.

It is sometimes said that gross weight and altitude have no effect on the rate of descent. This is approximately true for the example helicopter in the weight range between 15,000 and 18,000 pounds at sea level and at 5,000 feet but the generality breaks down for other conditions. The sea-level curve from 15,000 to 17,000 pounds illustrates a trend that has been verified in flight-test programs of several helicopters: within a certain range, the rate of descent is decreased as the weight is increased because the potential energy goes up faster that

Power Required For Typical Helicopter



Maximum Time Available To Restart Engine



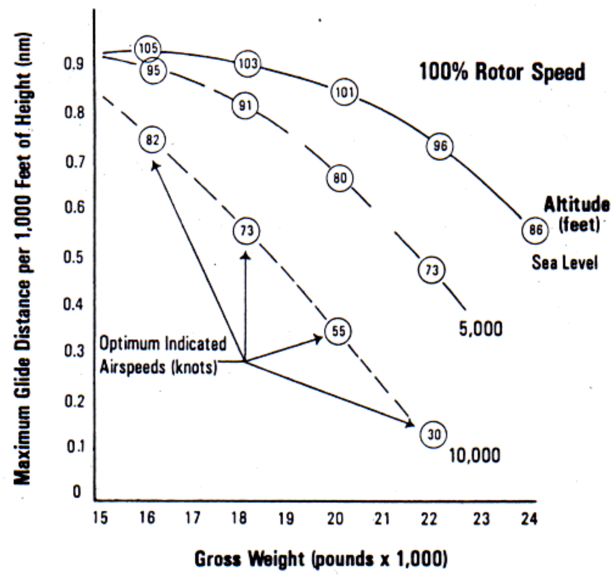
the power required increases. At higher gross weights, however, because the induced power is proportional to the square of the weight, the trend reverses--so the maximum glide time starts to go down again. At altitude, the rate of descent at low gross weights is about the same as it is at sea level--but at higher gross weights, this equality no longer holds. The figure shows that the optimum indicated airspeeds decrease drastically as both altitude and gross weight are increased.

Stretching the glide

The speed for maximum glide *distance* is higher than for the maximum glide *time* as shown on the first figure. It is where the ratio of forward speed to power is a maximum and where a line from the origin is tangent to the power-required curve. This best-distance speed also defines the conditions for the maximum lift-to-drag ratio (which airplane aerodynamicists are always interested in) and is approximately the optimum cruise speed for both helicopters and airplanes.

The maximum glide distance in terms of nautical miles per thousand feet of altitude can be determined from the parameters of the first figure by dividing the product of gross weight and optimum speed by 1,980 times the horsepower. The next figure shows the results of this process at sea level and for two higher altitudes. For each point, the optimum indicated airspeed is noted.

The results of the figures are somewhat low because the calculations have been based on the power required in level flight rather than the slightly lower power required for autorotation. A check using measured flight-test data on a Bell AH-1G indicates that this approximation introduced an error of about 20%. This is a conservative error and if the pilot relies on the approximate calculation, he has a little margin to do the wrong thing during this exciting period of his career.



The right rpm

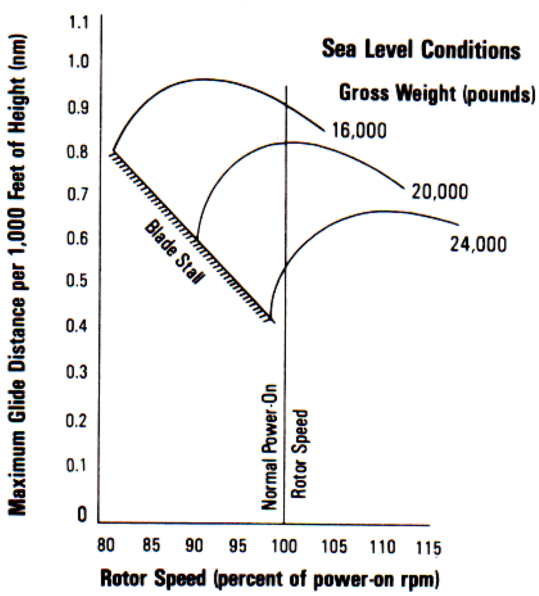
Besides the optimum indicated forward airspeed, there is also an optimum autorotative rotor speed that can be used to stretch the glide. This is the speed resulting in the most blade elements working at the best angles of attack for producing maximum local lift-to-drag ratios. As an average on a typical rotor in autorotation, this is about 5^{o}. Many helicopters are designed to operate at lower angles under normal conditions so that they have adequate capability to go to abnormal conditions such as high weights, high speeds, high altitudes, and high maneuvering load factors. This means that in gentle flight conditions such as steady autorotation--especially at low weight and altitude--the rotor efficiency can be increased somewhat by lowering the rpm until the rotor is operating at the desired 5^{o} of average blade element angles of attack.

The average angle of attack is related to the non-dimensional blade-loading coefficient, C_T/σ, just as the average angle of attack on an airplane wing is related to the lift coefficient, C_L.

For both the airplane and the helicopter aerodynamicists, their coefficient tells them how close the wing or rotor is to stall. A wing without flaps or slats can usually be counted on up to a lift coefficient of about 1.3 and a rotor in forward flight can operate comfortably up to a blade-loading coefficient of about 0.1. In each case, the optimum coefficient for best performance is 15% to 25% lower than these values. To be specific, most rotors are at the peak of their efficiency in forward flight when C_T/σ is about 0.08. If the normal value is less than this, slowing the rotor will give better autorotative performance, and if the coefficient is already above the optimum, rotor speed should be increased.

The next figure shows the trend for this example helicopter. Note that decreasing rotor speed too much can reverse the trend by inviting blade stall and a violent end to autorotation.

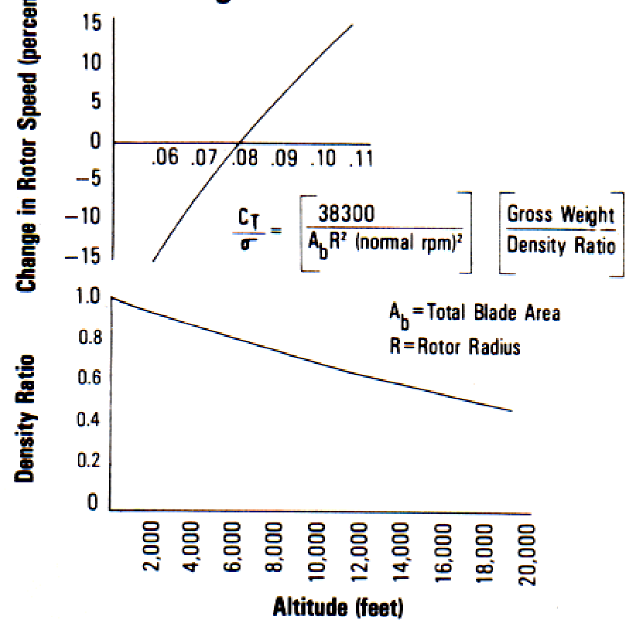
Effect of Rotor Speed on Stretching the Glide



At altitude, the lower air density makes the helicopter seem heavier. For instance, at 5,000 feet, the example helicopter at its design gross weight of 20,000 pounds would act like it was loaded to 23,000 pounds at sea level.

Whether to increase or decrease rotor speed to stretch the glide depends on the initial value of that parameter, C_T/σ. The final figure shows the recommended action based on rotor blade area, radius, normal rpm, gross weight, and the ratio of density at altitude to that at sea level.

Recommended Rotor Speed Change To Stretch Glide



If a pilot has chosen a low rotor speed to stretch the glide, he will probably want to get the rpm back up as he nears the ground to enhance his ability to carry out a good flare.

In principle, each power-on flight condition also has a unique optimum rotor speed, but designers are reluctant to give the pilot too much choice in the matter, primarily because of the trouble they have taken to insure an absence of resonance conditions at the design rpm. Continued operation outside the range specified in the operator's handbook could lead to high vibration and shortened component fatigue lives. Autorotation is such a brief and infrequent flight condition, however, that some relaxation can be allowed if it would mean the difference between a vibrating landing in that distant clearing or a jet-smooth ride into the trees.

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