Training Fact Sheet - Energy in Autorotations

Contact: Nick Mayhew
Phone: (321) 567 0386

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Using Energy for Our Benefit

The secret to extracting the maximum flexibility from an autorotation is to understand the various
energies at your disposal. Energy is the ability to do work, and the ones available in an autorotation
are: **potential, kinetic, and rotational**. There is a subtle, but powerful interplay between these
energies that we can use to our benefit – but only if we know and understand them.

The process of getting from the time/place of the engine failure to safely on the ground can be
thought of as an exercise in energy management. That leaves us with 3 types of energy:

• **Potential** - energy due to height above a surface = *mass x gravity x height* (shorthand version - *mgh*)

• **Kinetic** - energy (of the whole helicopter) due to motion with respect to a point on the ground

= *½ mass x velocity^2* (shorthand version -*½ mv^2*)

• **Rotational** - energy of a rotating mass (the rotors)

= *½ Inertia blade x RPM^2* (shorthand version- *½ IΩ^2*)

By way of further deciphering this, I = moment of inertia (an engineering definition of the inertia of the blades) – don't
worry about it as for any one helicopter, it won't change. Ω = (Omega) the rotational speed of the rotor (I had to put in
at least one Greek symbol). From high school physics,

these energies cannot be created or destroyed, just transferred from one place to another.

Relative Sizes of the Energy

There are many ways that these energies inter-relate. Potential energy can be viewed as a source
of kinetic (and rotational) energy. It's interesting to note the relative sizes of these. It's not easy
to compare kinetic and potential energy, as they can be traded for one another. But the relatively
small size of the rotational energy is surprising. One DVD on the subject showed that the rotational
energy was a very small fraction of the combined kinetic and potential energy even at the start of
a typical flare.

What makes this relative size difference important is that the rotor RPM, while the smallest energy,
is far and away the most important energy – without the rotor RPM, it is not possible to control
the helicopter and all the other energies are of no use!

We've already identified 3 different stages to the autorotation – the descent, the flare and
landing. At each stage, energy is being converted from one type to another, until hopefully, we've
wisely used all of them up. The following table describes the different sources and destinations for
the energy in each phase.

Phase	Energy Type		
	Potential	Kinetic	Rotational
Descent	To Kinetic and Rotational until it's nearly zero	Maintained by Kinetic	Maintained by Kinetic
Flare	Nearly zero, kept constant by Kinetic	To Potential and Rotational until it's nearly zero	Maintained by Kinetic
Touchdown	Zero	Zero (or very low)	Transferred to lift for cushioning touchdown

Since energy can be neither created nor destroyed - where did it all go? Into overcoming the drag
of the rotor blades and the drag of the airframe in the descent.

The reason for discussing the transfer of energy from one type to another is that if we're going to be
playing with getting more kinetic energy (energy of speed) by sacrificing height, we'd better know
what the various benefits and penalties are. As you'll see, it becomes quite interesting!!

The Power of the Squared (2)Term

If you remember high school mathematics, squaring a number means multiplying it by itself. Since the square term shows up in both rotational and kinetic energy terms, it's important to recognize
this.

What it means is that if you've got a higher speed, you've got a lot more energy. Increasing the
speed from 60 to 70 knots for example, means you don't have 10 more units of kinetic energy you
have $(70^2)-(60^2)$ or 4900-3600 =1300 more units of energy to play with.

Similarly, slowing from 60 to 50 knots means you've got 3600-2500 = 900 less units of energy to play with. The effect can be quite dramatic for a 10 knot difference in speed from what would be considered 'normal'.

The energy concept will be used a lot when talking about autorotation performance.

An Example of Energy

Let's take a helicopter and put it in a variety of different heights and speeds and see how much
energy it has. Then let's see what can be done with that energy to get to a couple of different
conditions at the flare

The equation for potential energy is = *mass x gravity x height or mgh.*

We'll assume the mass remains constant, so we can assign it a value of 1 in our equations, and g =
32 feet per second^2

We won't worry about the units, just the overall numbers.

Conditions at Start of Flare

We will ignore the possibility of possible trade-offs for now; if we look at just the height above ground at the end of the descent / start of the flare using different speeds, the real picture becomes very clear.

Let's look at the difference in energy at 50' AGL (the start of the flare) with different speeds. The
potential energy at 50' is 50'x 32 = 1,600 units.
What's really interesting is how much a difference in airspeed (10 knots) from 60 knots makes in
the overall energy situation. At 70 knots, the energy is 1300 units greater than at 60 knots, but at
50 knots it's 900 units less. The difference between the two is nearly 50% (1300-900 = 400 units,
which is about 50% of 900).

If we use 100 knots (let's say that's the maximum airspeed in autorotation) instead of 60 knots,
the difference in energy at the start of the flare is 6400 units greater, and if we go 40 knots slower
than 60, down to the ludicrously low speed of 20 knots, we have 3200 units less energy. We can do
a lot with more energy, but not a lot with very little.

Summary of Energy in Autos

Understanding the types of energy that may be available to the pilot following an engine failure is
essential to understanding what options you have available following the loss of the engine or if you are conducting training autorotations.

Acknowledgement

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