International Helicopter Safety Team

Our Goal is to Reduce the Civil Helicopter Accident Rate by 80% by 2016.

Training Fact Sheet - Energy in Autorotations

Contact: Nick Mayhew
Phone: (321) 567 0386

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 $I\Omega^2$)

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.

	Energy Type		
Phase	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

Thanks to Shawn Coyle for allowing this Energy in Autorotations chapter of his book "The Little Book of Autorotations" to be modified and used by the JHSIT Training Working Group to populate this Fact Sheet

More information about the IHST, its reports, its safety tools, and presentations can be obtained at its web site: (www.IHST.org).