Energy Management

Energy can neither be created nor destroyed; that is a basic rule of physics. However, energy can be converted from one type into another. The two main types of energy in physics are kinetic (energy of movement) and potential (stored energy) and these can be subdivided into many more, such as radiant, gravitational, sound, electrical, chemical, and nuclear.

As pilots, we primarily deal with kinetic and potential energy, and, to a lesser extent, heat, which is a form of radiant energy. The engine has the job of converting the potential chemical energy of avgas initially to heat, which creates pressure against the pistons (mechanical energy), which the crankshaft converts to torque (rotational energy), and finally the propeller converts the torque to thrust (kinetic energy). All these conversions are not very efficient, with most of the energy wasted as heat and sound; only about 30% of the potential energy of the avgas goes into thrust. (Less if the prop over-speeds and the tips go trans-sonic, wasting energy in the form of a sonic boom). The airplane uses the thrust to accelerate along the runway, converting the thrust into speed (kinetic energy). When there is adequate speed, the wings deflect air downward, and the equal and opposite reaction pushes the airplane upward. Rate of climb is proportional to the amount of excess thrust the engine can produce beyond that required to maintain level flight.

All airplanes have drag: induced drag caused by the production of lift, and parasite drag, which does not produce lift. Both forms of drag convert kinetic energy into heat.

Why do we try to keep the wings level as we climb? Because the wings are most efficient at producing lift when they are parallel to the ground. Any time we add roll, the downward-deflected aileron creates lift (induced drag), leaving less energy for climb, and the upward-deflected aileron creates parasite drag. In addition, some of the air that the wings were pushing straight down is now being used to create side-thrust, thus reducing rate-of-climb. This is why, when we take off with a cross-wind, we allow the airplane to weathervane into the wind, keeping the wings level. We have the option of side-slipping; rolling the airplane into the wind while using rudder to keep us on runway heading, but that would result in the reducing the wing's ability to create lift while the rudder and ailerons create drag.

Some of you have a well-educated seat-of-the-pants and have no need for a skid ball. Evidently, I am not in that category, because, when I added a skid ball to my very basic panel, I noted that rate-of-climb improved noticeably. It would seem that coordinated flight, even while adding some drag with the rudder to compensate for P-factor, creates less drag than does skidding through the sky.

OK, back to kinetic and potential energy. On the ground, the only potential energy we have is in the fuel tanks, but in the air, altitude provides potential energy; the higher we are, the more energy we have available. This can be good or bad, depending on the circumstances. If we lose engine power, the potential energy of altitude is money in the bank; energy we can use to maintain airspeed (kinetic energy) to land farther away. Slowing to best glide speed reduces drag and stretches that glide. On the other hand, When we want to land, we need to shed the potential energy of altitude, or we will arrive at the runway with too much speed and may run out of runway before we can stop. All too many pilots dive down to the runway and then depend upon having enough runway length to allow them to float until they have expended enough kinetic energy through drag for the airplane to be willing to stop flying. Ground effect makes this worse, as it provides more lift to the wing, which is now pushing air down onto the runway, which pushes back harder than does more yielding open air.

So now we are hopefully thinking in terms of energy management. The most skillful pilots are experts at it; aerobatic pilots and crop dusters come to mind. To perform a hammerhead turn (which is NOT a stall, by the way), the pilot must plan to lose enough kinetic energy to nearly stop climbing before ruddering the plane over onto the downline. Too early, and there is enough energy for the wings to turn the airplane onto its back. Too late, and the airplane tail-slides backwards. Too much kinetic energy on the downline and the turning radius is too large to stay inside the aerobatic box or the pilot has to pull an intolerable amount of G.

Crop dusters perform a ballet of energy management on every flight. Their job entails flying a heavily laden airplane slowly over a field so that the chemical they drop disperses straight down. Reaching the end of the field, they accelerate, increasing kinetic energy, which is abruptly converted into altitude (potential energy) at a speed low enough to allow a very short-radius turn back to the field, then trading potential energy for kinetic energy. The weight of the fuel and chemical are decreasing constantly, and the pilot has to take this decrease in potential energy into account, all while avoiding a stall. Now THAT is energy management!

By now, some of you are thinking: I'm not a crop duster nor an aerobatic pilot, so I don't have to be an expert at energy management. And it's true that, with a forgiving enough airplane and a really long runway, you can get away with a lot of energy mismanagement, but is that the kind of pilot you want to be? So, what should we be doing to better manage energy? The human brain has, at least potentially, the ability to do amazing calculations of height and distance. Let's look again at the two scenarios: loss of power or too much altitude too close to the airfield.

In the first case, you need to be very frugal with the potential energy that your altitude provides. As soon as possible, adjust airspeed to best glide speed (least altitude loss per distance travelled) and look for an attainable landing strip. You were continuously scanning for one during the whole flight, weren't you, so you already had one or two in mind when things suddenly got quiet. Of course, try for a restart while you are doing this, but plan for the worst. If you are too high, you can circle, with steeper turns eating up more altitude than gently ones. Avoid using flaps until you are adjusting your landing glide path. If you are coming up a little short, you can stretch the glide by swooping down into ground effect. Once the wheels are on the ground, use those brakes to convert kinetic energy into heat.

What to do with a working engine but too much altitude? If your engine is susceptible to shock cooling, plan ahead and reduce power farther out to avoid it. Raising the nose will slow you enough to deploy flaps and gear, if those are an option, then lowering it again to maintain airspeed as you descend and gradually reduce power. Add more flaps if needed, but don't just automatically add them if your rate of descent is adequate. If you're still a little high or fast turning base or final, add flaps as needed and use that extra drag to convert kinetic energy to heat. A steeper turn will lose more altitude without increasing speed. Glide slope still too steep? More flaps, weaving back and forth, or a forward slip will eat up more energy. Still too high or fast despite all the above? Go around and practice better energy management this time.

Here's another example of how skillful energy management can save the day. Ever heard of the Canyon Turn? The scenario is that some like to fly into canyons that are wide enough to allow turning around if needed. What sometimes happens is that the pilot flies into the wrong canyon and finds it narrowing and the terrain rising faster than the airplane is able to climb. While there is still some excess airspeed available, the pilot applies full power and pulls up the nose, trading kinetic energy for altitude while slowing. The lower airspeed allows a tighter radius of turn, and the kinetic energy is restored as the airplane flies downslope. Which way to turn? In the direction that doesn't fight P-factor. In other words, if you need right rudder to compensate for P-factor, turn from the right side to the left side of the canyon and stay coordinated. Learning this kind of energy management can save your life.

Of course, no talk about energy management could be complete without mentioning the acknowledged Grand Master, Bob Hoover. He was famous for dazzling his audience with aerobatics, including loops and multi-point rolls, in decidedly not-aerobatic airplanes, such as executive piston twins. That not being enough, he would then shut down and feather one engine and continue the routine. Then restart that engine and shut down and feather the other. Finally, he would shut down and feather the remaining engine and continue the aerobatics with no engine power, trading the potential energy of altitude for the necessary kinetic energy. When it was time to land, the gear would come down, he would do an aileron roll, then land on one main wheel, lift off, and land on the other, lift off, and finally land. It was rumored that he then had precisely the amount of kinetic energy left for him to roll to airshow center, make a 90 degree turn toward the crowd, and roll to a stop without touching the brakes. Wow.

At a much, much lower level of competence, on my last aerobatic lesson with Hal Goddard, I was taught a lesson on energy management on our way back to the airport. He was teaching me to do aileron rolls in a Citabria: diving for 120 MPH airspeed, then pulling up 30 degrees and muscling the airplane over, recovering with the nose slightly low. On this occasion, he told me to leave the throttle at the cruise setting, so that we lost some altitude on each roll, and we did a series of alternating left and right rolls most of the way back. Each time, we lost about the same amount of potential energy (altitude) as we did on the previous roll, until we reached pattern altitude. I was performing aerobatics without ever touching the throttle!

How often do you practice your short-field and soft-field takeoffs and landings? How will you know what the energy management requirements of your airplane are if you don't test them? Instead of doing the same flight over and over, you might see what your specific airplane likes and what it can do with improved energy management.

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