SIDEBAR

**THE SHOCKING FACTS**

*Engineering For Arrival*

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Let's face it. A pilot’s reputation is too often based on the smoothness of his landings. A 30-year professional may shepherd a million pounds of airplane across a continent, through airspace, weather, and traffic, but let the landing be just a little too firm and even the 6-year old seated in coach calls him a noob.

In one respect, our aversion to hard arrivals makes "normal" landing gear design a little easier. In the case of a certified light airplane, FAR Part 23 says a designer need not assume a vertical component at ground contact of more than 10 feet per second, a descent rate pilots recognize as 600 feet per minute. The regulation assumes no operator would *intentionally* drive the typical Bonanza or Cirrus into a runway surface at more than 600 FPM. A "good" landing is certainly much, much less.

No so for the backwoods pilot. Short landings are all about minimum speed and maximum vertical component, as both reduce the landing roll. The perfect short final is steep and slow, often followed by a "chop and drop". However, drop in from too high, and the result can be a bounce. Every pilot knows it doesn't take much additional drop to magnify the size of a bounce, but they may not know why.

Assume a 1550 lb airplane, with 1500 lbs on the main gear and 50 lbs on the tail wheel. We'll start by driving it into the runway with a vertical velocity of 10 feet per second (fps), the 600 FPM maximum from FAR 23.473. Any moving mass stores kinetic energy; the equation for how much is *k = 0.5 \* mass \* velocity2* . If we convert 1500 lbs to mass and square 10 fps, we find that our main gear must absorb 2344 ft lbs of energy.

Although the FAA doesn't *require* a designer to use more than 10 fps for certification, the steep approach angles typical for STOL aircraft demand much more. A no-flare impact at 15 degrees and 40 mph is over 15 fps, and a chop-and-drop may be higher yet. The design challenge is how to deal with the huge jump in required energy absorption. Remember, kinetic energy is a product of velocity *squared*. If we increase vertical velocity from 600 FPM (10 fps) to 1000 FPM (16.666 fps), energy jumps from 2344 ft lbs to a whopping *6510* ft lbs.

So what can a designer do to manage the increase? The first measure is to store some of that kinetic energy in a controlled manner. A mass can’t be brought to a halt *instantly* without catastrophic results; the equal and opposite reaction would destroy the structure. Instead, the mass must be slowed to zero velocity over a reasonable distance. The familiar term for the resulting reaction is a deceleration we call “g”, expressed as multiples of standard Earth gravity. Here distance equates to landing gear stroke, the total of tire and spring compression. More stroke means less g, and decreased stress for both airframe and occupants.

The second measure is add compression damping, which dissipates some of the energy *before* it can be stored in the springs. A typical hydraulic damper does so by forcing a viscous liquid through a orifice; viscous friction converts energy to heat. The orifice may be fixed, with damping proportional to velocity squared, or valved, so damping can be varied as desired. In reality, it is usually a combination.

At full compression, the former kinetic energy not dissipated by damping is stored as potential energy, and left uncontrolled, it will launch the airframe skyward again by forcefully extending the gear . In the case of a system which has stored a *lot* of energy, rebound damping becomes critical, greatly slowing the velocity at which the suspension extends. Rebound damping operates the same as compression damping, with valves arranged for oil flow in the opposite direction. The use of separate valves means that compression and rebound may have different damping rates.

Traditional light planes with bungee springing have no active damping. The same is true of tapered rod (or leaf) gear legs. Both systems depend on pilot skill to minimize vertical velocity (Vv) immediately before impact, regardless of VV throughout the approach. More advanced aircraft incorporate viscous damping in the form of oleo struts. At the far end of the spectrum, naval aircraft are designed with damped landing gear fully capable of absorbing a no-flare impact with the carrier deck....but even they don't drop in like a really botched STOL arrival full of moose meat.