Gliding, Props, and Arithmetic
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I've mentioned a couple of times lately that an airplane with a controllable-pitch propeller will glide farther with the propeller in coarse pitch than in fine pitch.

These terms coarse and fine aren't exactly intuitive, but they are analogous to screw threads of coarse and fine pitch. A screw with fine threads needs more turns to advance a certain distance; likewise, an airplane engine turns faster, at a given forward speed, when the prop is in fine pitch. Fine pitch is also called flat pitch. "Flat" may give a clearer idea of the position of the blade, but unfortunately it does not have a suitable antonym. Tilted pitch? Bumpy pitch? You hear "steep" pitch sometimes, but that's confusing because a more steep pitch gives a less steep climb or descent.

Anyway, the gist of the idea is that a windmilling propeller is driving the engine, it takes a certain amount of power to do this, and the faster the engine turns the more power it takes. This power has to be supplied by the airplane's descent; the more power is required to spin the engine, the greater the rate of descent has to be.

Curious about the magnitude of the effect, I ran a quick test. In the vicinity of 7,000 feet, at 100 kias (which is five knots above my best glide speed, but a convenient number to hold on the ASI), I throttled back to idle. My rate of descent was 1,200 fpm with the prop in fine pitch and 1,000 fpm with it in coarse pitch. This is quite a significant difference -- a 20-percent increase in gliding distance just for moving the prop control back.

This simple experiment stimulated my curiosity further. What would be the rate of descent at zero thrust -- in other words, if the prop weren't there at all? There's no way to identify zero thrust without special equipment: either a thrust meter or, more simply and ingeniously, a microswitch touching the back of the propeller flange and detecting the crankshaft's small fore-and-aft movement as the prop passes from drag to thrust. Maybe one of these days I'll install one of those switches -- just for the fun of it -- but in the meanwhile I resorted to my computer simulation of my airplane, which generally seems to be pretty accurate. It said that the rate of descent at zero thrust should be around 750 fpm.

Is this reasonable?

A tentative answer comes from a 1972 Lycoming paper entitled *Performance Characteristics of the Continental IO-360-D Model Engine*. Lycoming tested Continental's six-cylinder competitor -- which I have -- to its own 360-cubic-inch 200-hp engine in order to "note the significance of the unlikenesses to Lycoming engines." The main conclusions were that the rival engine breathed well at high rpm, had very even mixture distribution among the cylinders, cooled marginally at takeoff power, produced five fewer horsepower than claimed, and achieved a specific fuel consumption "in the range of .40"

(which is very good). Lycoming also noted that the Continental engine had various features that simplified manufacturing and reduced its cost. This will come as news to anybody who has ever bought one.

Anyway, this handy piece of corporate data-gathering (I will not say espionage, since they bought the engine fair and square) includes a plot of engine friction against rpm. I'm not sure whether or not it includes pumping losses -- the work done sucking in air and blowing it out -- but at any rate the range is from around 12 horsepower at 2,000 rpm to 28 at 2,800. The variation is pretty linear -- about two horsepower per 100 rpm.

Horsepower is readily convertible into rate of climb or descent. One horsepower equals 33,000 pounds going one foot per minute. The pounds, feet and minutes can all vary, so long as, when you multiply the pounds times the feet and divide by the minutes, the result is 33,000. A 3,000-pound airplane, for instance, climbing 11 feet per minute in still air is absorbing one horsepower (3,000 x 11 = 33,000). By the same token, a 3,000-pound airplane descending 1,100 feet per minute yields 100 horsepower. It works both ways; the airplane requires horsepower to climb, and returns the investment when descending. Descent is an engine: It is the only engine of a glider.

Taking Lycoming's 12-friction-horsepower figure for 2,000 rpm, and jacking it up to 15 or 16 for prop losses (because the prop does not convert aerodynamic force into work with perfect efficiency; quite a bit is lost to random turbulence), it turns out that a 2,100-pound airplane, which mine was at the time I was doing this test, has to lose around 236 fpm just to keep the engine spinning. This matches the difference between the computer's 750-fpm rate of descent and the observed 1,000 fpm pretty well.

(Did that go by too fast? It's simple: 15 horsepower = 15 x 33,000 or 495,000 pound-feet per minute. Divide this by the weight of the airplane, 2,100 pounds, and you get 236 feet per minute.)

So far, so good. But now you have to wonder about a stopped prop. Suppose the engine seizes up and doesn't windmill. Is the glide better or worse than with a windmilling prop?

For a lot of different reasons, it's hard to guess the drag of a stopped prop. The flow field around the nose of the airplane is distorted, the blades are not exactly flat plates and they get more streamlined toward the hub. The drag may depend on the position in which the prop stops. The prop's wake may affect the drag of the rest of the airplane. But let's stipulate for the sake of this discussion that that my propeller, stopped and in fine pitch (because a constant-speed prop automatically goes to fine pitch when it stops turning), has an equivalent flat plate area of 1.7 square feet.

At 100 kias, every square foot of equivalent flat plate area is subject to a pressure of about 30 pounds from the oncoming air. I was at 7,000 feet, so my true airspeed was 111 knots, or about 11,200 feet per minute. Going back

to the definition of horsepower as 33,000 pound-feet per minute, we multiply 11,200 times 30 and divide the result by 33,000 to find that each square foot of flat plate absorbs around 10 horsepower. So if the flat plate area of the prop is 1.7 square feet, it is absorbing 17 horsepower, which must be supplied by increasing the rate of descent accordingly -- by 267 fpm, to be exact (more exact, actually, than this calculation warrants). And suppose I had a three-bladed prop -- the increase in sink rate would be even worse.

But wait -- that's *more* than I figured the windmilling prop was using in coarse pitch. Weren't we taught that the drag of a stopped prop is less than that of a windmilling one?

This is where the ifs, ands and buts come in.

There's a basic difference in kind between the windmilling drag of an engine and the drag of a stopped prop. The horsepower cost of windmilling increases and decreases more or less in direct proportion to the airspeed; for my engine, remember, the rate is about two horsepower per 100 rpm. If you slow down, the engine turns a little more slowly and needs a little less horsepower to keep it turning. The horsepower cost of the drag of the stopped prop, however, is a function of the *cube* of the speed. Reducing speed by 10% reduces the rate-of-descent penalty of the stopped prop by 27%.

I suspect that the idea that you can glide farther with a stopped prop than with a windmilling one originated with the fixed-pitch propellers and slow gliding speeds of those old trainers. A slow airplane's propeller has flat pitch, and therefore high engine speed and friction while windmilling. Between the high engine friction and the low flying speed, the balance tipped in favor of a stopped propeller.

Cleaner, heavier, faster-gliding airplanes with constant-speed and, in many cases, three-bladed propellers gain little or nothing by stopping the prop. For them, the gain is in pulling back the prop control to coarse pitch, which also has the advantage of being a simple action that can be performed instantly and does not distract the pilot from the most important task at hand: identifying a landing place that the airplane can actually reach without requiring extraordinary airmanship or luck on the part of the pilot.

There's one more control that affects glide angle: the throttle. People usually say that the throttle should be open, believing that a free flow of air reduces windmilling resistance. But pumping more air through the engine should require more work, not less. I hadn’t toyed with the throttle during my first test -- I had left it closed -- so I flew again a couple of days later.

This time I tried shutting down the engine entirely -- mixture at idle cutoff, mags off -- and checked both rpm and descent rate per the vsi. (The vsi is not a very accurate instrument in absolute terms, but it's fine for comparing a series of tests.) I first found that closing the throttle with the prop in fine pitch reduces the windmilling rpm by around 200. I then ran and re-ran a series of glides with throttle open and closed and with the prop in coarse and fine

pitch. There was too much scatter in the results to allow fine discrimination among three of the cases; but one stood out as vastly superior to the others: coarse pitch and open throttle, which bested the others by 30% or more.

I'm puzzled about why closing the throttle seemed to erase the advantage of coarse pitch. Maybe I'm just a lousy test pilot. I'm going to repeat these tests, and I would be grateful to hear from readers who care to try them in other airplanes. The routine is simple. Climb to 8,000 feet or so in smooth air near an airport with a nice long runway. Trim for best glide speed and loiter for a few minutes let the engine cool down. Then throttle back to idle, mixture to idle cutoff, mags off. Stabilize the glide -- this will take at least 15 or 20 seconds -- and note the rate of descent and the rpm. Then open the throttle, stabilize and note. Then pull the prop all the way back to coarse pitch, stabilize and note. Then close the throttle, stabilize and note. It's a good idea to write the procedure down before taking off; without a "test card" you're likely to get mixed up or forget a step.

To restart, crack the throttle, turn the mags on, and enrich the mixture. Restore power gradually, because the engine will have cooled quite a bit. I lost about 3,000 feet during each series.

In addition to collecting some interesting information, this test has the collateral benefit of letting you know how it will feel if you ever run out of gas. It is, whatever you do with throttle and prop, a sinking feeling.