Why "Over Square" Is Good

By Mike Busch , This article originally appeared in THE AVIATION CONSUMER and is reprinted here by permission. July 30, 1995

You should cruise at high MP and low RPM for the same reason you drive the Interstate in high gear. If pilots flew their airplanes the same way that they drive their cars, Continentals and Lycomings might last a lot longer. Here's why.

Almost thirty years ago, my primary CFI gave me my first checkout in an airplane with a constant-speed propeller...a Cessna 182. He repeatedly drilled me on the routine: always retard the throttle before you pull back the prop control; always push in the prop before you advance the throttle; and never NEVER allow the manifold pressure exceed the RPM/100. Operating "over square" will damage the engine, possibly severely.

Well, I guess I'm a fast learner and a slow un-learner, because it took me close to 20 years and several thousand hours to finally figure out that my CFI's "over square rule" was dead wrong. Not only is it okay to operate most engines at high MP and low RPM ("over square"), but for cruise

About the Author ...

Mike Busch is editor-in-chief of AVweb, a member of the technical staff at Cessna Pilots Association, and in a prior lifetime was a contributing editor for The Aviation Consumer and IFR Magazine. A 6,000-hour commercial pilot and CFI with airplane, instrument and multiengine ratings, Mike has been flying for 36 years and an aircraft owner for 33. For the past 14 of those years, he's owned and flown a Cessna

operation it is also the best way to operate them!

T310R turbocharged twin, which he maintains himself. In his never-ending quest to become a true renaissance man of aviation, Mike's on the verge of earning his A&P mechanic certificate. Mike and his wife Jan reside on the central coast of California in a semi-rural area where he can't get DSL or cable TV.

For the past 8 years, I've owned a Cessna Turbo 310 powered by a pair of Continental TSIO-520 engines. My normal cruise power settings in this airplane are 30 inches of MP at 2100 RPM, producing about 65% power. My old CFI would probably roll over in his wheelchair if he saw that his former student was operating 9 inches "over square". Nevertheless, using this technique (plus very aggressive leaning), I took those engines to 500 hours beyond their published 1400-hour TBO without ever having pulled a single cylinder, and at teardown we found that all twelve cylinders were still within factory new limits, and the bottom ends of both engines were in superb shape. If all those hours of over-square operation damaged my engines, it sure wasn't obvious!

Following manufacturers recommendations, turbocharged engines routinely are allowed to operate at 8, 12, even 15 inches "over square" depending on model. (Think of it: a foot over square!) Normally aspirated engines don't have sufficient manifold pressure to do this, but most of them are permitted to operate 1 to 4 inches "over square". (Check the cruise performance charts in your POH.)

There are a lot of technical reasons why high MP/low RPM operation is the optimal way to operate your engine in cruise. But before I discuss them, let me offer an automotive analogy.

Suppose I toss you the keys to a new Nissan 300ZX or Porsche 911 and asked you to take it for a spin on the interstate. As you drive to the on-ramp, you note that the car has a five-speed gearbox and a tachometer with green and yellow arcs and a redline. As you accelerate onto the highway to your desired

cruse speed (perhaps 70 MPH after checking your mirrors carefully), you see that the tach is still in the green arc at 70 MPH even though you're still in third gear. Upshifting to fourth, the tach needle drops to a lower figure. In fifth gear, the tach reads even lower RPM (still in the green). So you find that you can cruise at 70 MPH in third, fourth, or fifth gear and still be within the approved operating envelope.

Okay, so what gear would you use? Fifth, right? Of course! You instinctively cruise in the highest gear so that your engine can operate at the lowest possible RPM. You instinctively know that the car runs quieter, fuel consumption is lower, and the engine will last longer in this regime than if you cruised in third or fourth gear (at higher RPM). And you're absolutely right about all of this. So why doesn't the same reasoning apply to managing the powerplant of your airplane? Actually, it does!

Suppose I want to cruise at 65% power at 10,000' in my Cessna T310 on a standard day. My MP gauge has a green arc from 15" to 30" (redline is 32"), and my tachometer has a green arc from 2100 to 2350 RPM (redline is 2700). According to the cruise performance charts in my POH, I can achieve that 65% power by using a variety of MP and RPM combinations:

- 26" at 2350 RPM
- 27" at 2300 RPM
- 28.5" at 2200 RPM
- 30" at 2100 RPM

I'll choose 30" at 2100 RPM every time...for the same reasons I choose fifth gear in a sports car. Let's enumerate some of the specific reasons.

Your engine will last longer if operated at low RPM. By cruising at 2100 RPM

instead of 2350 RPM over the course of 1,000 hours, each of my engines saves 15 million crank rotations, 7 million cam rotations, and 75 million piston reciprocations! Enough said?

At 2350 RPM, each engine loses approximately 35 horsepower to internal friction (mostly reciprocating friction, some rotational friction). At 2100 RPM, that figure drops to about 25 hoursepower. So by producing 65% power at 2100 RPM rather than 2350 RPM, each of my engines delivers approximately 10 more horsepower to the prop (at the same fuel flow).

Propellers operate more efficiently at lower RPMs, too. At takeoff RPM (2700 in my airplane), the propeller tips are travelling rather close to Mach 1. The resultant sonic shock wave steals a good deal of power that would otherwise be converted into useful thrust. The slower the prop turns, the less energy is wasted making noise and the more is available as thrust. (The cabin is a lot quieter, too.) Ever notice how slowly the propellers on turboprops turn? Typically 1200-1800 RPM.

Finally (but very importantly), lower RPMs produce lower EGTs at a given power output. At 65% cruise in my airplane, the EGT at 30"/2100 is more than 50F lower than the EGT at 26"/2350. This allows me to lean very aggressively (I cruise right at peak EGT) without the danger of over-temping my exhaust valves or cylinder heads. I wind up with a cleaner engine (fewer deposits on exhaust valve stems and spark plugs) plus better fuel economy.

Please note that I've been talking about using low RPM during cruise operation. I would never suggest using low RPM during takeoff or climb, any more than you'd try to accelerate a car from a stop or drive up a hill in fifth gear! Attempting a takeoff without the propeller control full forward can result in excessive combustion chamber pressures, detonation, and possible catastrophic engine damage. Don't do it! But at conservative cruise power

settings (65% or less), detonation isn't even a remote possibility. So you can pull that prop control back to bottom-of-the-green RPM without fear. (Check your POH cruise performance charts to make sure.)

Although my engines are turbocharged, everything I've said about low RPM operation applies equally to normally aspirated engines when operated at relatively low altitudes. Of course, once you climb past the altitude at which you run out of throttle, you have no choice but to increase RPM to maintain cruise power.