Piston Airplane Engine Management

by Philip Greenspun in April 2003

The best way to manage an airplane engine is to delegate the task to a computer via a Full Authority Digital Engine Control (FADEC). As the pilot you have much more important things to do with your time and attention. Why not focus on maintaining the correct airspeed and being correctly positioned on an instrument approach while a computer does a much more precise job at adjusting air/fuel mixture and prop speed than you ever could.

Sadly, however, most piston-engine airplanes being manufactured in 2003 offer a three-lever engine control setup that dates back more than 50 years. This article is written for pilots of airplanes with the standard three levers: throttle, prop speed, mixture. It contains some useful information for airplanes that have simpler manual controls. The numbers are appropriate for a Diamond Star DA40, which has a Lycoming IO-360 180 horsepower nonturbocharged engine; you should refer to your airplane's A.F.M. to make sure that they are sensible for your airplane.

Taxi Out

Lean, lean, lean. Your best chance of fouling a plug is right now.

Runup

If you're at a high-altitude airport or taking off from sea level on a hot day, the runup is your opportunity to determine what mixture setting will result in maximum engine power. You do not want to take off full-rich on a hot day. The air is thin, which means that your airplane needs to develop a higher ground speed to reach a given airspeed. Developing a higher ground speed implies achieving a higher kinetic energy, which is accomplished with engine power. If you're not developing near-maximum engine power, your takeoff distance will be extended, possibly beyond the end of the runway!

With the prop speed control set for max RPM and the throttle set to give an approximately correct runup RPM (for a DA-40, 2000 RPM), play with the mixture control to find the spot where the RPM peaks. This is the max power setting and is an appropriate place to leave the mixture control for runup, i.e., nice and lean so that you won't foul your plugs.

After you're done with the runup, push the mixture lever forward "a bunch" (in the DA40 about one inch). This will substantially richen the mixture for climbout, thus providing extra engine cooling, but on a hot day or at a high-altitude airport, it will be much leaner than full rich.

Clearing a Fouled Plug

If your engine failed to run up, i.e., if it ran very poorly on one mag, chances are good that you have a fouled spark plug. This is especially easy to verify if you have a temperature readout for each cylinder of your engine; the cylinder with the fouled plug will be much cooler than the others.

You may be able to clear the plug by running the engine hard and lean, e.g., 2400 RPM and just lean of peak. Keep this up for a solid two minutes unless the cylinder head temperatures become excessive. Then try the runup again.

Some engines are more susceptible to fouling than others. You may want to invest in a set of fine-wire or "iridium" spark plugs. These last almost indefinitely and are virtually immune to fouling. The massive electrode spark plugs that are in most engines do foul and need to be replaced after 500 hours. Why don't airplanes come with fine-wire plugs to begin with? They cost about $55 each, compared to $18 for massive electrode plugs (iridium plugs for cars are about $7 each, compared to $1 or $2 for old-style spark plugs).

If you don't want to go Iridium and you are worried about getting stuck at an airport where no mechanics are available, an alternative is to learn how to change a spark plug yourself, which is one of the things that the FAA authorizes an aircraft owner to do him- or herself. You will need to carry a 3/4" socket, a special spark plug socket, a torque wrench with 3/8" drive, and a regular 3/8" socket driver. And don't forget the spare plug!

Climb

You want to be "way rich" when your engine is working really hard, i.e., producing more than 75 percent power. Without a turbocharger, however, your engine will begin to run out of steam as the air thins. It doesn't make sense to keep the mixture at "takeoff rich" all the way up to 7,000' because it is very likely that by the time you get to 5,000' the full-throttle performance is no better than 75 percent power. The engine doesn't know that the airplane is climbing. It should probably get the same mixture setting that would be appropriate if you were cruising along at 5,000' straight and level using 75 percent power. Unless the cylinder head temperatures go above 400 degrees, it is probably okay to lean for the rest of your climb.

Cruise

If you like a quiet airplane, it is a good idea to throttle back to a low prop speed during cruise flight. You might give up 10 knots, but the vibration and noise will be considerably reduced, as will fuel consumption. If the max cruise RPM is 2400, try 2200.

There are various schools of thought on the "lean of peak" or "rich of peak" debate. Here's how "rich of peak" kept the author alive (excerpt from a Weblog targeted at nonpilots):

Yesterday I flew from Bedford, Massachusetts to Gaithersburg, Maryland. East Coast airspace was complex to begin with and has become further complicated by restrictions around the Washington, DC area. If you're an instrument-rated pilot, you can avoid all of this complexity by filing an instrument flight plan and taking advantage of Air Traffic Control (ATC) services. The assigned route took me straight over JFK airport at 6,000' and then through central New Jersey before proceeding over Balitmore-Washington Intl. airport and into the Montgomery Country Airpark.

My Diamond Star (DA40) is a brand-new design, but it uses an engine that hasn't changed for 50 years. Old-style piston-airplane engines require that the pilot constantly adjust the air-fuel mixture as the plane rises into thinner air or descends into denser air. When you're done with your flight and parked at the airport, you pull the mixture control all the way back to "full lean" and the engine stops, starved of fuel.

Descending out of 6,000' over Baltimore, I noticed that my exhaust gas temperatures were rising, despite the fact that I was enriching the mixture. Between talking to ATC and the other pilots at the busy nontowered Gaithersburg airport, I didn't have much time to reflect on this odd behavior. After parking the airplane, I pulled the mixture control back. The engine kept running. I shut the airplane down by shutting off the flow from the fuel tanks, then hopped out and unscrewed the cowling.

The mixture control itself is an L-shaped arm on the throttle body of the fuel injection system. It is attached to the mixture cable by a bolt. In case the mixture cable snaps, a spring is also attached to the arm to pull the mixture to "full rich" (engine runs but not necessarily efficiently). Sadly, the engineers at Diamond decided that both the spring and the cable should be attached with the same bolt. The bolt was rattling around loose in the bottom of the cowl. The spring was hanging free. The end of the mixture cable was hanging free. **My engine continued to run because (a) I had been conservative in running moderately rich at altitude**, (b) the difference between 6,000' and sea level isn't enormous, and (c) the L-shaped arm, free to rattle around a bit, hadn't rattled its way to "full lean". [This is more than a theoretical possibility; rumor has it that a plane similar to mine landed in a farmer's field in the Midwest back in the Spring of 2002 after the mixture cable came loose. The incident led to a redesign, which was retrofitted to my airplane in June 2002.]

My mixture control was held together with a regular bolt and a locking nut (that apparently did not lock and is now on the ground somewhere between Long Island and Baltimore). Tull, one of the best mechanics at Gaithersburg, happened to be on the field at 6:00 pm on a Saturday and he reassembled the airplane, this time using a bolt with a little hole in the middle so that a safety cotter pin could be inserted to prevent future separations.

There are a bunch of ways to look at this incident. One is despair at the state of engineering in this world. Had an extra hole been drilled in the L-shaped arm, the spring could have been attached separately from the mixture cable. The engine would have gone to full rich after the mixture cable detached. Alternatively, Diamond could have used a bolt with a hole in the middle and a safety, like the one that the mechanic in Gaithersburg used. A few extra cents and the plane would have been spared the risk of an emergency landing.

Another way to look at this incident is to be ever-vigilant when flying a piston single-engine airplane: have an emergency landing spot in mind at all times. The #1 reason for engine stoppage is running out of gas, but it apparently is not the only reason.

Had I been running lean-of-peak, my engine probably would have quit as I came down out of 6,000'.

I've found that peak exhaust gas temperatures are around 1525-1550 degrees F. I lean until I see 1450-1475 (i.e., about 75 degrees rich of peak).

Descent

There are two schools of thought for managing mixture while descending.

School 1 suggests that you're going down to where the air is thicker so you should richen preemptively. If you plan to land, in fact, why not go full rich while at altitude so that you don't have to think about mixture again?

School 2 notes that you're probably cutting back engine power while descending. You don't want to come screaming into the pattern at 150 knots. Pulling back engine power cools the cylinder heads. Richening the mixture cools the cylinder heads. To avoid damaging the cylinder heads from shock-cooling, why not let the mixture get leaner as the airplane descends and the power comes back?

The risk with School 2 is that you forget to go full rich before landing and the engine might therefore quit as you're attempting to go-around.

Landing

You always want to be ahead of the airplane. On downwind this means saying to yourself "after I turn base I'm going to push the prop speed and the mixture controls fully forward". Always have your next move in mind.

Go-Around

It won't cost you anything extra to feel the prop and mixture controls after opening the throttle for a go-around. Just double-check that they are fully forward.

Clear of the Runway

Lean, lean, lean. If you don't want a fouled plug to spoil your next runup, lean aggressively whenever you are taxing. Add this to your "clear of the runway" checklist.

Shutdown

Remember that an airplane engine's ignition system does not require battery power, only a bit of rotation translated to the magnetos. So that your prop does not become a loaded weapon, generating an explosion when touched, you want to make sure that the cylinders are emptied of their explosive fuel-air mixture. Shut the airplane off by pulling the throttle back to idle, double-checking that all avionics and electrics are off, then **mixture, mags, master.** Pull the **mixture** control back to full lean. After the engine jerks to a stop, turn the **magneto** (ignition) key to off. Then shut off the **master** switch.

Some flight schools teach a "burn-off" procedure in which the throttle is opened to about 1600 RPM, the engine is leaned for max RPM and run for 30 seconds, and finally the throttle is pulled back to idle before the mixture is pulled full lean for shutdown. This procedure may result in cleaner spark plugs and therefore less chance of fouling.

More

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