

# Malibu

Volume 16 Number 3 FALL 2007

# Mirage



***FADEC is Here!***

*by Chad Menne*

Representing Owners and Pilots of High Performance Single Engine Pressurized Aircraft Worldwide

# Full Authority Digital Engine Control

by Chad Menne



Chad Menne is a commercial pilot with over 5,000 hours in all variants of the PA46 and serves as the Manager of Product Development and Sales, as well as Chief Test Pilot for Malibu Power & Propeller Int'l, LLC in Minneapolis, MN. Chad can be reached at 877-6-MALIBU.



Many of you have heard some buzz about FADEC in the aviation press and through gossip at flying conventions. But as with most new technologies, the information circulating in the community seems to have outpaced fact. So let us examine what FADEC is, and why the technology is such a big deal (or not).

## Digital Control

FADEC is an acronym for Full Authority Digital Engine Control. FADEC for piston aircraft engines is a system of computers, sensors and actuators that monitor and control the fuel and ignition portions of the powerplant. In some ways the system is much like what we find in modern automobiles, but some significant differences are worth noting, as we do below.

Considering the trials we all face in managing magnetos and setting mixtures, with one lever for six cylinders, computer control is a huge improvement. A Powerlink FADEC® system, designed by Aerosance Inc., controls manifold air temperature, manifold pressure, fuel pressure, cylinder head temperature, exhaust gas temperature, engine speed and timing sensors, electronic fuel injectors, Engine Control Units (computers) and a low voltage electrical harness that connects them all together. Each of the sensors is used to control the engine to varying degrees. The sensors are

all redundant, with the exception of those monitoring CHT and EGT, and they are also backed up by a computer "map" in the event of a dual sensor failure.

## Sensitive Sensors Sensing

So what does all of this computer control do for you and your engine? Some of the sensors, such as engine speed and timing sensors, manifold pressure, fuel pressure and the fuel injectors, are simply needed for the engine to run properly. These basic sensors inform the computers that the engine is operating, and at what power setting, so that fuel delivery and ignition are properly set.

Other sensors, such as various temperature monitors, are used to refine the operating quality of the engine. For example, on an ISA +15°C day versus an ISA -15°C day, at the same manifold pressure, the volume of air will be different, so FADEC will measure manifold air temperature and adjust the amount of fuel injected accordingly. I know, you are thinking that this is pretty basic. But things get better.

Cars use oxygen sensors to control mixture settings, virtually instantaneously. The stop-and-go nature of driving makes this mandatory. Airplanes, on the other hand, cannot use oxygen sensors because we still use leaded fuel. So FADEC uses temperatures instead, just like you manually do now with

cont. page 16 ▶

your mixture lever and TIT gauge. However, FADEC does this on a cylinder-by-cylinder basis, using the corresponding EGT. Still no big surprise? The magic, and safety enhancements, are found in how the data are used and controlled, in conjunction with the tremendous speed of computers. Let's see why.

### A New Start

When you start your Malibu or Mirage engine now, either impulse couplings or a starting vibrator are used to modify the timing enough

Next you would cycle the prop, right? Well, the blue lever is gone with FADEC! To cycle the propeller, you simply increase power to about 32 inches and then quickly reduce to less than 30 inches. You can hear the propeller actuating; simple as that. Now you can complete the remainder of your usual pre-takeoff items.

### Full-Forward

For takeoff, simply push the throttle full-forward. What you get is 39.5" Hg and 2600 RPM, which is full-power, but not full-rich. Why not full-

cylinder wear seems to be better than usual due to this reduction in fuel flow, despite the sometimes higher CHTs during climb.

Once at cruise altitude, the real magic begins. When you reduce power to cruise, generally 28" to 30" MP, the prop speed will drop to 2400 RPM. With this configuration you will enter either "Best Power" (rich-of-peak) or "Best Economy" (lean-of-peak) mode, depending on what setting you have selected: above 75% is always Best Power. Once in the selected cruise mode, the engine will go into a "mapped stability mode" for a minute or two to allow temperatures to stabilize. Following that phase, the system will start calibrating each cylinder individually to find peak EGT by richening or leaning in order to set the mixture for each cylinder to approximately 70 °F rich or lean of peak. FADEC is like having six individual mixture control knobs, but is fully automatic. In addition to much improved fuel control, at low power settings the ignition timing will be adjusted more efficiently, which will produce more torque than the magneto engine's standard 24° BTDC (before top dead center).

### Magneto Memories

The FADEC system brings several safety benefits to aircraft piston engines. As most of us know from experience, magnetos are not terribly reliable and can be a frequent maintenance problem. Prior to FADEC, we inspected our mags every 70 hours and always found something that needed attention. With FADEC, the ignition is a distributor-less system with no moving parts, and the ignition coils are integrated into the ECUs (computers). For redundancy, two separate computers control

**"With FADEC, the ignition is a distributor-less system with no moving parts, and the ignition coils are integrated into the ECUs (computers)."**

in order for the engine kick over. You, the pilot, must guess how much fuel should be introduced to start. Sometimes that requires a little finesse. Once running, the ignition timing is optimized for high power, not for idle. With FADEC, however, you simply leave the throttle closed, turn on electrical power, turn on FADEC and press the start button. A second or two later, your engine is running, with fuel and ignition adjusted for idle. What a concept!

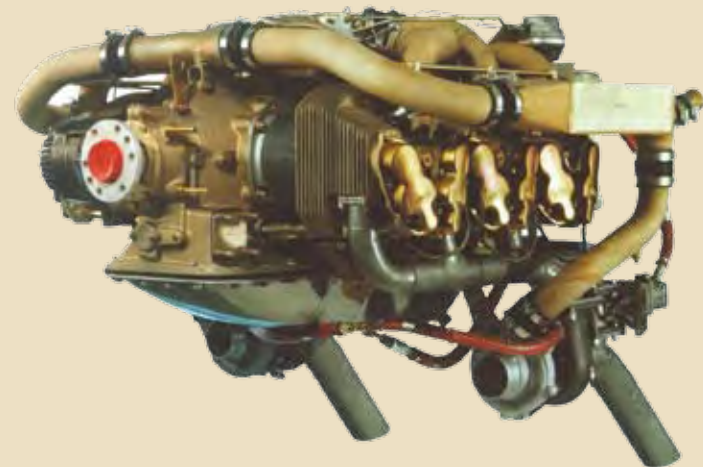
rich? Well, why go to full-rich when you have computers monitoring all engine parameters? FADEC allows you to use less fuel at full-power, which results in an increase in full-power output to about 370 horsepower, measured statically. Of course, if the engine needs fuel for cooling, FADEC will go to full-rich and still put out 350 horsepower. But most likely you will never see the engine go full-rich at takeoff.

### You Calling Me a Hot Head?

Now let's return to the various sensors for engine control. At takeoff power, the computers are monitoring all sensors for normal operation. Critically, FADEC is also monitoring CHTs for what is called "Hot Head" operation. Hot Head operation is when any CHT goes above 420°F, at which point the FADEC system starts adding fuel to the offending cylinder to reduce power and reduce temperatures. If the CHT reaches 440°F, that cylinder will be at full-rich. This approach to engine management allows a higher power output by using fuel to cool specific cylinders only as needed, while not inundating the remaining cylinders with excess fuel. After 500 hours of development testing,

### Channel Check

With the engine humming along, we are now ready for the run-up and takeoff. With FADEC, your run-up is much the same, except instead of a "mag" check, you perform a "channel" check. A channel check is completed by independently turning off each FADEC-enable switch, one at a time. You are testing the redundancy of each of the three computers, with two channels per computer, as well as each ignition system.



ignition on two opposing cylinders, working both on the combustion and exhaust cycles. This arrangement doubles the ignition sparks, giving simple redundancy. The worry-free ignition system requires no maintenance.

### Fuel Fetish

The new fuel control system certainly represents the greatest improvement in safety. On a Lycoming engine, fuel ratios are maintained by a non-redundant mechanical fuel servo that can be troublesome at times. Many Mirage owners have experienced problems with the fuel servo. On a Continental engine, the fuel is controlled by an altitude-compensating fuel pump, which can also cause trouble. In either case, mechanical adjustments are critical for proper operation. With FADEC, the fuel pump is a basic device that simply outputs pressure based on RPM and flow, with no controls. Instead, fuel is controlled by FADEC and electronic fuel injectors, which will adjust in milliseconds to any system pressure changes. In the event of a fuel pump failure, the FADEC system will automatically turn on the boost pump, returning engine power to

for trend analysis. That means that potential engine problems can be identified before they become serious or leave you stranded.

### Entirely New Bird

Now that you have learned a little about FADEC, I would like to talk specifically about the new FADEC engine model that we have developed with TCM for the PA46. The powerplant starts out as a standard TSIO-550, which is then modified to include: tapered cylinder barrel fins for weight reduction, a lightweight 100 amp gear-driven alternator, lightweight 85 amp belt-driven alternator, and larger, more efficient turbochargers that reduce manifold air temps and increase critical altitude. Of course, the engine also boasts single-lever power control operations and a FADEC control system, including software that has been optimized specifically for the PA46. In addition to the engine, integration of FADEC into the PA46 consists of an improved electrical system that operates as two independent systems, with automatic bus-tie capability and automatic load shedding.

normal within less than two seconds. As long as fuel gets to the engine at some measurable pressure, FADEC will adjust injection to compensate in order to operate the engine smoothly. Possibly the most noteworthy safety enhancement is the ability to use trend monitoring. Since FADEC is acquiring all engine parameters for operation, these data can be recorded and sent to TCM

## POWER PACKAGE

FADEC comes with an impressive improvement to the electrical system. In the event of an alternator failure, the automatic bus-tie will connect the buses together and drop off all non-essential equipment. The event requires no input from the pilot. Plus, the alternator still online can support the remaining required equipment, including night time operations with de-ice equipment powered on.

Due to the increase in horsepower, a new stronger engine mount has been developed that employs six vibration isolators (instead of four) and has a projected fatigue life of nearly 200,000 hours. The PA46 FADEC conversion also includes all-new baffles and a new nose cowl, due to changed installation geometry. Finally, the conversion includes a 3-blade composite propeller that generates nearly double the static thrust of the original Malibu 2-blade propeller and engine combination.

### Push a Button

Imagine getting into your Malibu or Mirage and starting up simply by pushing a button! No more racing to move levers back and forth; no more effort spent on setting power or mixture. You will see even a bigger change when bringing your plane in for maintenance. Instead of repairing the magnetos and cleaning fuel injectors, the mechanic performs an oil change, cleans the fuel filter and downloads data from a Compact Flash card. The data is e-mailed to TCM.

Flying with FADEC is pure joy; you have shed the burden of engine management. You simply set manifold pressure and let the computer manage the engine. This frees up more time fly the plane, instead of nervously watching engine parameters and adjusting levers. A FADEC upgrade is not just a modified engine for the PA46, but a significant improvement in performance and safety.

## IMPRESSIVE CLIMBS

Among many benefits, FADEC comes with some impressive performance enhancements. With higher horsepower output, due to leaner mixtures when CHTs are below 420°F, and with cooler manifold air temperatures, due to more efficient turbochargers, we can climb at 1,000-1,500 feet/min or better. We can do so with indicated airspeeds ranging from 140 to 160 knots, all the way up to about 20,000 feet, which is the critical altitude.