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Full Authority Digital Engine Control (FADEC)

Authors

Nikhil Kumar C[1], Shravan Kumar[2]

[1]Bachelor of Engineering (Computer Science and Engineering), REVA Institution of Technology and Management, Bengaluru, Karnataka, India

Email- *nikhilkumac@gmail.com, Mobile- +91 7259978487*

[2]Bachelor of Engineering (Computer Science and Engineering), REVA Institution of Technology and Management, Bengaluru, Karnataka, India

Email- *shravkumar7@gmail.com, Mobile- +91 8971959323*

Abstract

Full Authority Digital Engine Control (FADEC) Systems is a system consisting of a digital computer and ancillary components that control an aircraft's engine and propeller. The system consists of a digital computer, called an electronic engine controller (EEC) or engine control unit (EEU), and its related accessories that control all aspects of aircraft engine performance. This paper includes the functionality and importance of this technology.

Keywords: *FADEC, Airplane control System, EEC, ECU*

INTRODUCTION

Full Authority Digital Engine Control (FADEC) is a system consisting of digital computer, called an engine control unit (ECU) or electronic engine controller (EEC), and its related accessories that monitor and control all the aspects of aircraft engine performance. FADECs have been designed for both piston engines and jet engines. The objective of any engine control unit is to allow the engine to perform at its maximum efficiency for a given condition. The intricacy of this task is proportional to the ramification of the engine. Originally, engine control units consisted of basic mechanical linkages was operated or controlled by the pilot, and when it evolved, the EEU was controlled by a third pilot-certified crew member, the flight engineer. The flight engineer or the pilot were able to control the fuel flow, hydraulics, power output, and many other engine parameters by moving throttle levers directly connected to the engine.

After the mechanical means of engine control, came the introduction of analog electronic engine Control. Analog electronic control transmits various electrical signals to communicate the desired engine settings. In a spark ignition reciprocating engine, the FADEC uses speed, temperature, and pressure sensors which are used to monitor the status of each cylinder. A digital computer calculates the ideal pulse for each injector and varies the ignition timing as necessary to achieve optimal performance. The FADEC performs all of the same functions in a compression ignition engine, excluding those specifically related to the spark ignition process.

FADEC — THE START

The FADEC systems had not found their way to piston aircraft engines until recently for various reasons, including production cost, development and certification costs of a unit tough enough to meet the aviation safety standards. Clearly, FADEC is not just any average engine ignition and

fuel control system. In fact, FADEC is much more than just an engine ignition and control system. FADEC has three main functions: engine control, diagnostics and data logging and safety.

ENGINE CONTROL

Engine functions such as speed, manifold pressure, temperature, power setting, starting conditions, etc. are controlled electronically using TCM's PowerLink system, by advanced computer processors, that collect data automatically and compute the settings for optimum performance of the engine. These settings include the oil temperature, ignition timing and fuel mixture to deliver improved starts and maximum power as required. In the PowerLink system, each cylinder of the engine is optimized continuously, which means the pilots can always be assured of top performance and fuel efficiency.

SAFETY AND DIAGNOSTICS

The system is designed and developed with the FAA-required backups including diagnostics software that runs in the background to conduct pre-flight checks and continuously monitor the health of all the PowerLink components and their associated backup systems. PowerLink systems have shown more than 12,000 hours of continuous operation during the testing phase.

DATA LOGGING

Approximately a hundred individual elements of data every second with consolidated data being held on a flash memory chip can be recorded by the PowerLink system. All data are constantly monitored for troubleshooting and engine diagnostics and prognostics. TCM is planning on eventually pursuing an on-condition service model for its PowerLink controlled engines using the data logging function.

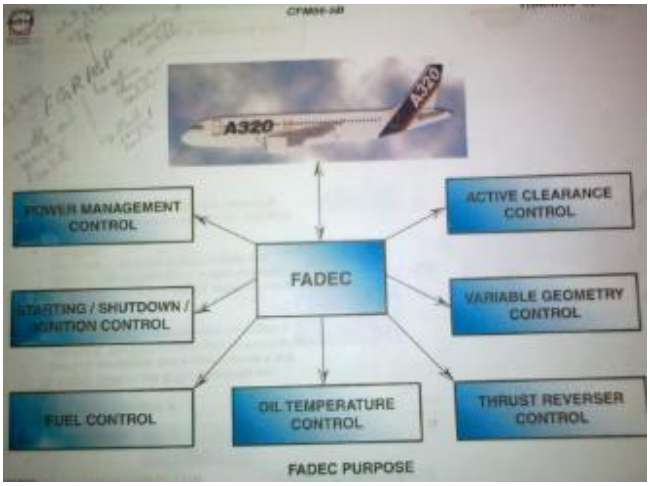

Figure 1: FADEC Purpose

FADEC SYSTEMS – IN AVIATION

FADEC systems get rid of the requirement for magnetos, carburetor heat, mixture controls, and engine priming. A single throttle lever is considered as a characteristic of an aircraft that is equipped with a FADEC system. The pilot has to only simply position the throttle lever to the desired position such as the start, idle, cruise power, or max power, and the mode that has been chosen is adjusted and applied to the engine and propeller automatically by the FADEC system. The pilot does not have to monitor or control the air/fuel mixture manually.

The FADEC readies the cylinders, adjusts the fuel mixture, and positions the throttle based on the engine temperature and ambient pressure during starting the aircraft. During the flight, the FADEC constantly observes the engine and adjusts the flow of fuel, and ignition timing in each cylinder individually. This accurate control of the combustion process leads to decreased fuel usage and boost in horsepower.

FADEC systems are considered an important part of the engine and propeller control, are generally powered by the primary electrical system of the aircraft. In many aircrafts, a separate generator connected to the engine provides power to the FADEC system. In both cases, there has to be a backup source of electricity available as the failure of a FADEC system would result in the complete loss of engine thrust. To stop the loss of thrust, two separate and identical digital channels are installed

for redundancy, each channel competent of providing all engine and propeller functions without any shortcomings.

FADEC SYSTEM FUNCTION

FADEC have no form of manual override available, equipping the computer with full authority of the operating parameters of the engine. If a total FADEC failure occurs, the engine fails. If the engine allows manual override, and is controlled digitally and electronically it is considered solely an EEC or ECU. An EEC, though is a component of the FADEC system, is not by itself FADEC. When it is working alone, all of the decisions are made by EEC until the pilot wishes to intervene.

Multiple input variables of the current flight condition including air density, the throttle lever position, engine temperatures, engine pressures, and many other parameters are received by FADEC. The inputs are received and analyzed up to 70 times per second by the EEC. Engine operating parameters such as fuel flow, stator vane position, bleed valve position, and others are computed from this data and applied appropriately. Engine starting and restarting is also controlled by FADEC. Providing optimum engine efficiency for a given flight condition is FADEC's basic purpose.

FADEC allows the manufacturer to program the engine limitations and receive health and maintenance reports of the engine. For example, FADEC can be programmed to avoid exceeding a certain engine temperature, to automatically take the necessary measures without the pilot's intervention.

APPLICATIONS

FADEC maybe illustrated by a typical civilian transport aircraft flight. Flight data such as wind conditions, runway length, or cruise altitude are first entered into the flight management system (FMS) by the flight crew. Power settings for different phases of the flight is calculated by the FMS using this data. During takeoff, the throttle is set to a predetermined setting by the flight crew advances, or is opted for an auto-throttle takeoff if available. The FADEC, now applies the calculated takeoff thrust setting by sending an electronic signal to the engines; there is no direct linkage to open fuel flow. This procedure can be repeated for any other phase of flight.

In flight, efficiency is maintained by small changes in operation that are constantly made. If the throttle is advanced to full, maximum thrust is available for emergency situations, but limitations can't be exceeded; the flight crew has no means of manually overriding the FADEC.

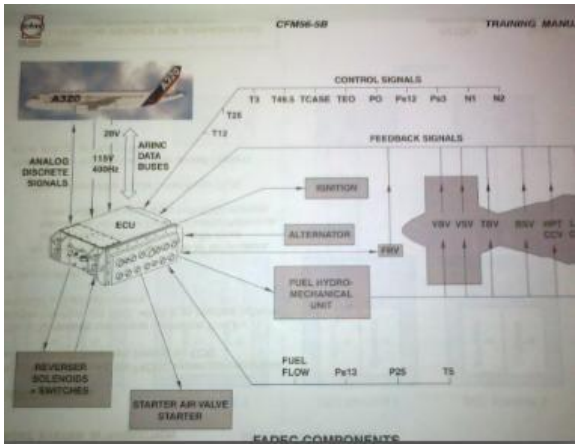

Figure 2: FADEC Components

ADVANTAGES

- higher fuel efficiency
- automatic protection of the engine against out-of-tolerance operations
- multiple channel FADEC computer provides backup in case of failure
- Guaranteed thrust settings, with care-free engine handling.
- FADECs can be reprogrammed to use single engine type for wide thrust requirements.
- provides semi-automatic engine starting
- better systems integration of engine and aircraft systems
- can provide engine diagnostics and long-term health monitoring
- the number of external and internal parameters used in the control processes increases by one order of magnitude

- less number of parameters to be monitored by flight crews
- The FADEC makes possible "Fault Tolerant Systems" due to the high number of parameters monitored
- automatic aircraft and engine emergency responses supported by FADEC

DISADVANTAGES

- the engineering processes that are used to design, manufacture, install and maintain the sensors that measure and report flight and engine parameters to the control system itself
- The path over which this data flows and the integrity and reliability of the materials
- The safety-critical control systems the software engineering processes used in the design, implementation and testing of the software requirements. This led to the development and use of specialized software such as SCADE

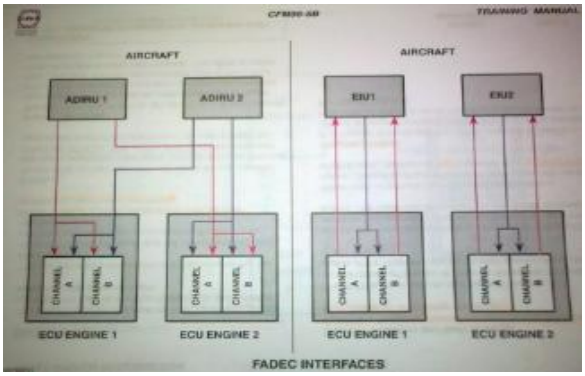

Figure 3: FADAC Interfaces

CONCLUSION AND FUTURE WORK

FADEC is the future of piston engine technology. While Diamond and Liberty are currently the only two OEMs to offer factory FADEC, other companies are already offering Thielert's FADEC-equipped, jet fuel diesel CENTURION engine as an aftermarket alternative on Cessna 172s. And, no doubt, others are in the works.

Thielert and TCM are taking steps now to help technicians prepare for the day when a FADEC-equipped engine shows up in their shop. In fact, both companies are already offering training sessions for these new-generation engines. Thielert is providing training at the Dallas, Texas headquarters of their U.S. subsidiary, Superior Air Parts.

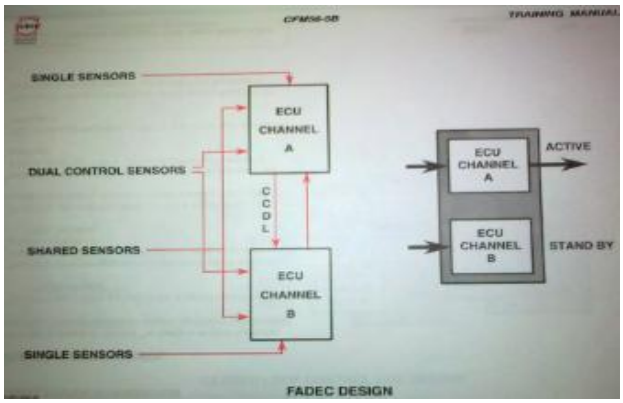

Figure 4: FADEC Design

Laptop computers, voltmeters, software updates and the like will be just as much part of diagnosing and repairing a FADEC-equipped engine as they are when working on integrated avionic in today's advanced cockpits. "Although the technical talk on FADEC often centers on improved fuel consumption and pilot friendliness," Lewis said, "the PowerLink system is expected to revolutionize the piston aircraft [engine] maintenance experience."

"The Aerosance FADEC continues to evolve both in its performance features and maintenance capabilities. For example, the system as certified today contains expansion capabilities that can contact the FBO over a cellular phone line and download required maintenance information so that the technicians are ready to service the aircraft upon its arrival," Lewis said. "This is used by commercial airlines today but is a first in piston aviation. It is such innovative advances that TCM and Aerosance are bringing to the market and both expect the PowerLink system to become standard fare on their OEM engine fleets in the future."

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AUTHOR PROFILE

NIKHIL KUMAR C is currently pursuing Bachelor of engineering in Computer Science and Engineering from REVA Institute of Technology and Management, Bengaluru, India. He Interned at Efficient Electronics Ltd. Where he successfully designed and developed Digital Battery Charge Control System using Microcontroller and Arduino tools. He also interned at Yu – Televentures owned by micromax Mobile, India, Where he was a member of technical team, providing technical support to the customers.

SHRAVAN KUMAR is currently pursuing Bachelor of engineering in Computer Science and Engineering from REVA Institute of Technology and Management, Bengaluru, India.