Design and Implementation of UAV Engine Test System

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Abstract. To meet the testing requirements of small UAV piston engine, a virtual instrument-based UAV engine test system is designed. This system has the capability of on-line testing on engine even without the UAV system-wide support. With virtual instruments, serial analog-to-digital conversion and other new technologies, it can replace the ground control station to control the engine; realize rapid and portable testing as well as integrated display of the engine performance parameters; and based on the testing data, perform fault analysis and provide maintenance instructions when appropriate. The system covers the shortage of existing test methods, and improves the efficiency of UAV engine system test in field operations.

1. Introduction

As the heart of UAV, the engine has the highest failure rate, the most complex adjustment and the heaviest maintenance workload among the mechanical equipment of UAV system. Since the engine working status has a direct influence on the flight safety of UAV\(^1\), the engine test is not only a core task in the development and production of aero-engine, but also one of the most critical tests before the UAV is launched for military use\(^2\). Research has been underway in the aero-engine testing and fault diagnosis technologies for years\(^3\)\(^4\), and most of the manufacturers have proven engine test systems\(^5\). However, these systems are not suitable for field test of the engine in battlefield, since they are expensive, not portable (with site requirements), and operational only when the engine is separated from the UAV.

For a specific type of UAV, the field test of its engine in the combat service mainly includes inspections for reliability of connectors, remote control commands and telemetry parameters (cylinder temperature, speed).

However, the above test process has the following disadvantages:

- It is executable only when the flight control system, data link system and aircraft system all operate (in the joint test state), and is dependent on the ground control station to test the engine performance. Thus, a waste of resources and an adverse effect on the service life of equipment are generated, especially in the engine running-in test.
- Except for cylinder temperature and speed, it does not fully test the main parameters such as stopping time, generator electrical performance and fuel consumption, and not provide the alarm against out-of-limit parameters, which is one of the main reasons for frequent failures of UAV engines today.
- The test results cannot be displayed at the same time. Also, the analysis of various test parameters is not intelligent but based on the engine testing personnel's knowledge about the engine and practical work experience, not satisfying the requirements in the military operation.
- It increases the electromagnetic radiation of radio waves to which the test personnel is exposed in the process of engine test, and is vulnerable to interference, which does not meet
the practical requirements of equipment training and maintenance support in the complex electromagnetic environment.

2. Conceptual Design

As an effective solution for above problems, the following design principles are proposed:

- Test on the engine performance shall be carried out independent of the ground control station.
- The system shall be portable in field operation and implement the test not requiring the engine separated from the UAV.
- The parameter test shall be added to test all main performance parameters of the UAV engine, and over-limit alarm shall be provided.
- The capability of intelligent analysis shall be provided, as well the maintenance instructions under the premise that the test parameters are kept reliable, to reduce the technical requirements for the military using personnel.

In accordance with these principles, an engine test system based on virtual instrument has been designed. With a concept of portable and modular design, this system is built as an automatic test platform, enabling intelligent test of various engine parameters through the UAV-borne cable test interface and operational test software. System hardware mainly includes IPC, data terminal box and test cable, and all the testing devices are accommodated in a portable suitcase. System software includes control software, parameter display software, fault alarm software and maintenance training software.

3. Hardware Structure

The system hardware consists of upper computer (IPC), lower computer (data terminal box), test cable, and etc., as shown in Figure 1.

![Figure 1. Structure diagram of system hardware.](image-url)

3.1. Upper Computer

A touch-type Advantech IPC is used as the upper computer. Its main parameters include CPU main frequency of 1.4ghz, 10.4 "SVGA TFT LCD, 64M FLASH DISK, external RS232C interface and automatic RS-485 data flow control. In the system, the communication with the lower computer is transmitted through RS232 interface, to simulate the command control of the engine by the ground control station. Also, the upper computer receives the engine performance parameters from the lower computer for display, analysis, record and fault indication, and provides maintenance training.
3.2. Lower Computer
The lower computer is composed of single-chip microcomputer system, power supply, data communication module, test interface circuit and other modules. Its functions include parameter acquisition, control quantity transmission and data communication, by using the original UAV power supply system, sensor system, ignition system, actuator and airborne cable.

3.2.1. Single-chip Microcomputer (SCM) System. MCS-51 AT89C52 single-chip microcomputer system produced by ATMEL is used, with internal 8K-byte EEPROM and 256-byte RAM. Space of the EEPROM meets the storage requirement of the system program.

3.2.2. Power Module. NR12D5/100A voltage regulator module is used, which converts the +12V power supply of the upper computer into ±5V as the working power supply for integrated circuit of lower computer and the reference supply of A/D and D/A conversion. This power module widely used in aviation field, is featured by wide adjustable range of input voltage, bipolar output and high stabilization accuracy, high loading capability and well environmental adaptability.

3.2.3. Data Communication Module. Serial communication is implemented between the data terminal and IPC, which is subject to RS232C protocol. The SCM in the data terminal box is provided with serial port transceiver, with TTL signal level. For the IPC, standard RS232C serial port is provided, with RS232C signal level. In the system, level translation between TTL and RS232C is executed by MAXIM MAX232C chip.

3.2.4. Test Interface Circuit. The test interface circuit is composed of speed measuring circuit, A/D circuit, D/A circuit, stop signal generation circuit, and etc., as shown in Figure 2.

3.2.5. Test Interface. The test interfaces include power interface, communication interface to the upper computer and signal interface to the airborne cable. On the hardware, an interface is used as both the power interface and communication interface, with XS12K7P receptacle used and pin definition designed independently. For the signal interface to the airborne cable, aviation sockets Y11X-18322ZJ10-2 and Y11X-2041ZJ10-2 are used. As a result, when this system tests the engine, the 32-core and 41-core plugs of the airborne cable connected to the flight control computer could be transferred to the data terminal box, enabling on-line testing of engine by the equipment itself without disassembling or changing the UAV structure.

![Figure 2. Composition diagram of the test interface circuit.](image-url)
4. Software Implementation

The system software consists of two parts: upper computer software and lower computer software.

The upper computer software provides the functions such as generation of the engine control commands, graphical display of engine performance parameters, data analysis, data recording, fault indication, and data communication with the lower computer. It is developed using graphical programming language LabVIEW that provides data acquisition, instrument control, data analysis, signal processing and display and other functions related to the instrument system integration. The developer can develop an application that meets the actual needs by simply defining and connecting the icons representing various functional modules.

![Flowchart of main program of lower computer software.](image)

The lower computer software provides the functions such as output of engine control signals, sampling and preliminary processing of engine performance parameters, and data communication with the upper computer. It includes main routine, interrupt service subroutine, functional service subroutine and other modules. This software is developed using assembly language, with simple code,
few system resources taken and high run speed. Figure 3 shows the main flow of the lower computer software program, where the data acquisition subroutine acquires the cylinder temperature, fuel quantity, generator voltage and other analog values every 25ms interruptedly. Its core device is serial A/D converter TLC1543.

5. Conclusion
This system is designed specific to the field test of the small UAV piston engine. It provides multiple functions such as real-time acquisition and analysis of engine test parameters, engine fault diagnosis and maintenance training; and carries out accurate and reliable on-line testing and fault diagnosis of the parameters of engine test performance, not requiring the engine separated from the UAV and the joint test of ground control station. With comprehensive testing parameters, friendly HMI and easy operation and maintenance, this system improves the accuracy of parameter testing and the efficiency of test and parameter adjustment. The application trials indicate that the main technologies used in the system are applicable to the field test and combat readiness training of multiple engines, and that the probability of successful UAV launch is increased significantly.

6. References
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