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Development of the HWIL Training Simulator of UAV Engine

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Abstract: A hardware-in-the-loop (HWIL) training simulator was developed to avoid high cost and realize intuitionistic teaching in the engine maintenance teaching of a certain type of unmanned aerial vehicle (UAV). The oil free engine HWIL simulator was achieved by the driver-to-the driven switch. According to the needs of teaching , the function of dynamic real-time control in different working areas was implemented by combining dynamic monitoring of the computer with real-time controlling of the single chip microcomputer. The successful development of the simulator improved the teachers' teaching ability and cadets'operation ability, cut down the training cost and reduced the teaching risk to zero by indoor training of large weapons and equipment.

Introduction

Hi-tech weapons and equipments play an increasingly important role in modern hi-tech wars. But it is up to the operational skills and maintenance ability of the working staff whether the efficiency of the hi-tech equipment can be realized.

The certain type of UAV is a complicated system, among which engine system is the key and difficult part in UAV maintenance. [1] Cadets need to have rich engine exercise to master engine principles, structure, operational and maintenance skills. However the expensive hi-tech equipment has limited life span and can not afford frequent operation; some training missions have risky potentiality in the operation and accidents may happen. The hardware-in-the-loop (HWIL) training simulator was developed to improve the teachers' teaching ability and cadets'operation ability, cut down the training cost and improve teaching ability. Engine movement was displayed based on real-subject anatomy. With the technology of computer control and simulation, semi-real simulative control was conducted on each functional unit so that UAV engine system simulation was realized; systematicness and consistency of maintenance training was secured. Equipment training helped to reduce training losses and risks to zero and replaced real equipment field training under precondition of system precision and simulation accuracy.[2] Real UAV engine system and computer simulation interacted and interpenetrated to bring great changes of UAV engine training models and high teaching efficiency in practical teaching.

System Design

Principle

In the light of simulative features of the engine system and teaching requirements, the system used motor drive cylinder and the accurate location of cylinder movement was secured by absolute rotary encoder and principle computer control. The anatomy of the cylinder enabled the cadets to have a direct observation of corresponding piston location in each working area; with pulse width modulation (PWM) the microcontroller (mcu) had control over the motor speed and location control of steering gear was guaranteed by multi digital data.

System Configuration

According to the training simulator's principle, the system consisted of electric motor, four cylinder two-stroke gasoline engine, absolute rotating encoder, subordinate computer PWM speed control system and the control units, principal computer data acquisition and control modules. The configuration of the system was shown in Figure 1 as below.

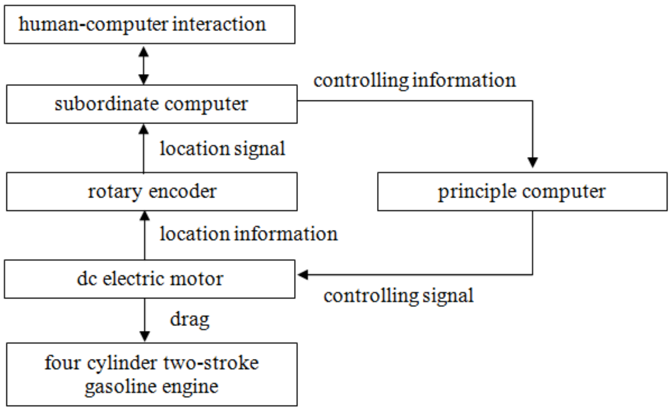


Figure 1 The configuration of the system

System Implementation

The implementation of the simulator was composed of three parts, i.e. the mechanical reformation of the gasoline engine, the design and production of subordinate computer and software programming of principal computer.

Mechanical Reformation

The aero engine was air cooled two-stroke four cylinder horizontally opposed piston engine, consisted mainly of the main body and assist system. The main body included the crankcase, cylinder block, cylinder head, piston, connecting rod, air intake valve and so on. The assist system mainly contained the systems of air and oil supply, ignition and etc. The two -exhaust cylinders on all sides, as the sine qua non of the proper operation of the engine, share the same systems of air and oil supply and ignition. [3]

The main aim of mechanical reformation was to fully present the engine's inner structure without damaging the exterior main load-carrying structure and the mechanical capacity after the anatomy had no influence on the parts motion. The four cylinders were in the pair-wise and horizontal placement, they had the same structure, the same motion pattern of piston and connecting rod. But there was phase diversity(180o). Therefore the mechanic strength of the all-round edges of the cylinder was kept in the demonstration of the half-section-cut I-cylinder. Meanwhile to fully display the relative movement between the crankshaft and the connecting rod, the adjacent parts of the main engine body had a regional anatomy. Because the gas path and the oil path were integrated closely, a composite anatomy was conducted so that the valve control, oil pump and manostat, the carburetor structure were fully presented; oil and gas migration path, the atomization process and control process were highlighted. This type of engine had the property of magnetor, high pressure pack and spark plug ignition. The magnetor and high pressure pack had large exposed parts, so it was easy to have a clear presentation; spark plug ignition lied deep in the inner cylinder, the first and the four cylinders were conducted with half section cut to present the phase of the two ignition system. The pictures were shown as below.

Figure 2 Engine training simulator

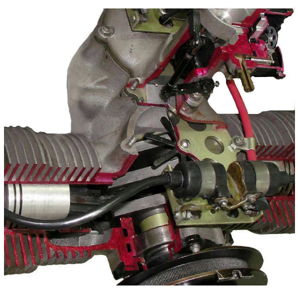


Figure 3 Engine anatomy

Subordinate Computer

To take the single chip microcomputer MCS-51 as the control core of PWM system, subordinate computer controlled the dc motor, the location of engine valve steering gear and LED of whose lighting stood for ignition in the cylinder. The system framework was presented in Figure 4

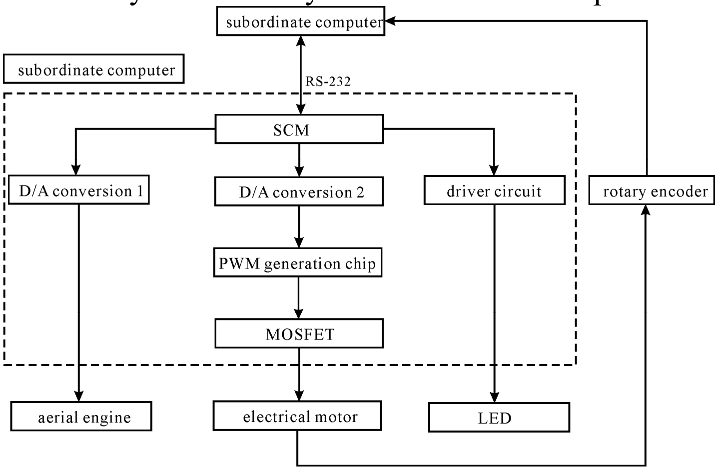


Figure 4 The system framework

Single chip AT8952 received instructions from the port serial RS-232 to control dc the motor's condition and rotational speed[4]; it also stimulated the operational condition of the aerial engine's valve steering gear; in addition, the location instructions of dc motor were given by principal computer , whether piston reached the ignition position was to be judged and LED controlling was thus conducted.

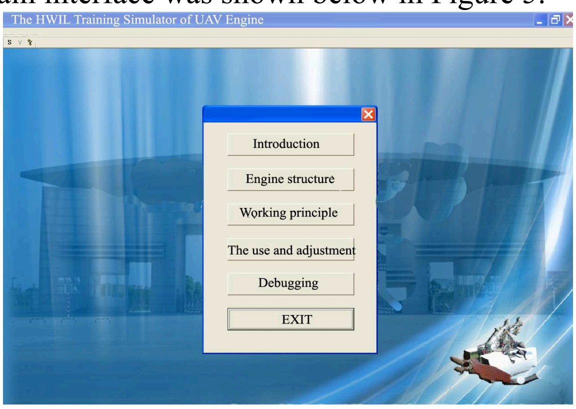
Two D/A conversion units both used 8-bit DAC chips, which could switch digital signals from 0-255 to analog signals. One of the D/A conversion units output analog voltage signals required by PWM waveform generation chip, another D/A conversion unit output the voltage signals required by steering gear position control.

PWM generation chip SG3525 was used to make a voltage, duty cycle conversion circuit, which received the voltage signals of D/A chip and transformed the signals into PWM rectangular wave with certain duty cycle. The PWM wave in this equipment was 5KHz with adjustable duty cycle from 0-90%. IRF540 with low conductive resistance was adopted in MOSFET. PWM signals generated by SG3525 were sent into IRF540 and converted into PWM signals strong enough to drive the electrical motor, therefore motor rotational speed could be controlled.

Principal Computer

The main functions of principal computer were to give instructions to the electrical motor of subordinate computer, acquire location signal of rotary encoder, control simulative gasoline engine by animation and provide video for teaching and learning,

The main interface was shown below in Figure 5.



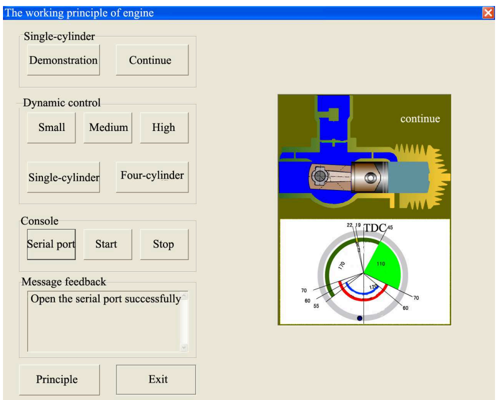
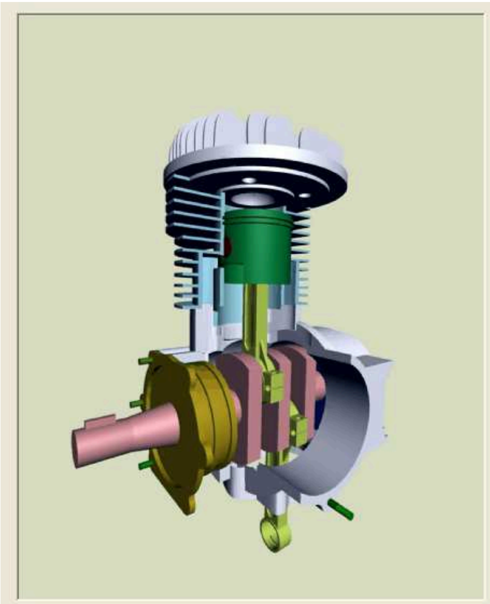


Figure 5 The main interface Figure 6 The software simulation interface of the engine's operating principle

The software simulation interface of the engine's operating principle was shown in Figure 6.It included the horizontal bar control module, power control module, total control module, feedback module and principle explanation video module.

The working condition of different parts of the engine was displayed in the horizontal bar control module. The data acquisition of the position of the rotary encoder signal was done by parallel port in the system. [6] By matching the data frame of the acquired data and the simulation animation, the animation real-time playing and control was achieved. To animate teaching, the inlet area, compression area, outlet area and expansion area were set with control points in the beginning and ending parts. In the non-control module, horizontal bar and four cylinder simulative animation were available as presented in Figure 7 and 8. The speed difference of the motor could be made by different power [7]. Meanwhile steering gear control and the operating condition of the simulative engine was presented by the communication between different power and the subordinate computer.



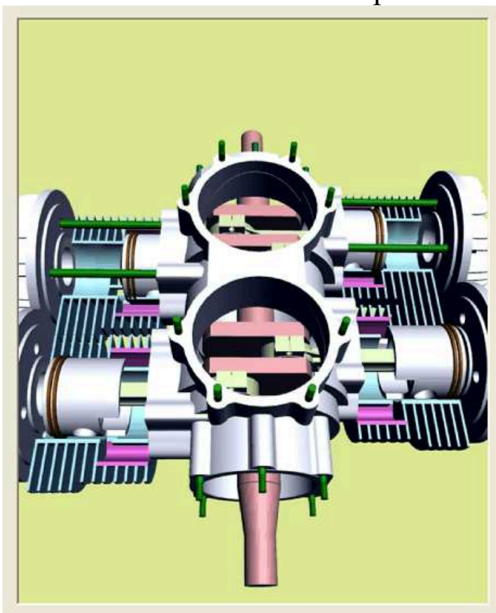


Figure 7 The simulation animation of the horizontal bar Figure 8 The simulation animation of the four bar

Teaching Application

The simulator was developed to be applied in teaching. Specific and integrated subjects teaching was conducted with the system, including video-aided principle demonstration, static display by anatomical models, function analysis of the parts by dynamic demonstration, detailed explanation and demonstration of the engine principle by the horizontal bar timing module, system-wide simulation by four bar non-control module, trouble shooting with fault database, etc. The cadets' understanding of the engine principle, structure, operation and fault diagnosis was much improved for the teaching and learning process was more vivid and simpler. The combination of real equipment and three-dimensional simulation brought out the best teaching effect, during which the engine working process was represented vividly so that the shortcomings of tradition practical teaching were overcome. The simulator was proved to be helpful and was welcomed by teachers and cadets, which ensured a promising future.

Summary

Based on the principle of motor-drive engine cylinder, the hardware-in-the-loop (HWIL) training simulator was developed. By combining real-subject anatomy demonstration, rotary encoder and subordinate computer control together, the system realized the operation condition simulation of the engine cylinder.Video-aided aero engine training teaching was conducted and achieved good performance. What is to do next is to make proper adjustments to meet the teachers' and cadets' teaching and learning requirements and try to develop more study-friendly teaching equipments.

References

[1]TANGQI, WU Yong, WU Wei. Design of Engine Smart Rotating Speed Sensor[J].GAS TURBINE EXPERIMENGT AND RESEARCH(Ouarterly), 2009,22(1):49

[2]BAO Wen, SUI Yan-feng, LIU Zhi-ming, LIU Jin-fu. Design and Realization of Hardware-in-the-loop Simulation for Turbofan-engine [J].Journal of System Simulation,2006(6):58

[3]Sun Peiyan,Fan Baoxiao.Engine Simulating Test-bed[J].SAMLL INTERNAL COMBUSTION ENGINE AND MOTORCYCLE,2001,30(6):16-17.

[4]ZHANG Yue-jing .Based on Singlechip's Electric Actuator Control Research[J].Science Technology and Engineering,2011,11(34).

[5]Zhao Hua-wei.Research and Design on Speed Control of Gasoline Engine[M].Changsha university of science and technonlogy,2011.

[6]LIAN Jie,HUANG Xiang-hua,WANG Wei-qi. Design and Implementation of Configuration Software for Aircraft Engine Control Software[J]. Measurement & Control Technology , 2012 31(6) .