Helicopter Training Simulator Measurement and Control System Based on Computer Simulation Technology

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Abstract. With the development of computer software technology and simulation technology, simulation training has been widely used. Helicopter training simulation has become an important part of helicopter training, and its status is becoming more and more important. On the one hand, the air mechanic is responsible for the maintenance and organization of the helicopter during the flight, and on the other hand is responsible for the starting and stopping of the helicopter engine, the operation of related equipment, and the handling of emergencies during the flight. The simulation training has the characteristics of high training efficiency, convenient maintenance and low training cost. It will become an important means for helicopter air mechanics to troubleshoot and deal with special situations. This paper aims to study the helicopter training simulator measurement and control system based on computer software technology. Based on the analysis of the advantages of the simulator instead of the actual installation for training, the helicopter training simulator function and the simulator subsystem, the actual installation simulation instrument and signal are designed. The indicator light, the graphic instrument and the control signal are arranged in the circuit, and then the simulation experiment is carried out on the design. The experimental results show that the design can more accurately simulate the indication of the antenna elevation angle table, which meets the requirements of this article.

Key words: Computer Software Technology, Helicopter, Training Simulator, Measurement and Control System

1. Introduction

With the rapid development of modern control theory and computer technology, the development and implementation of modern aircraft has become the focus of aviation development in various countries [1-2]. More and more modern aircraft are equipped with digital flight control systems and are evolving into multi-tasking, multi-connection, automation and integration. This makes the completion of modern aircraft flight operations increasingly dependent on the integrity of the flight control system equipment [3-4].

Helicopter simulation training is currently a hot research topic. In simulation training, the helicopter simulation training system appeared relatively late, but after a period of exploration, the
first helicopter simulator was successfully developed in the early 1960s. Since then, helicopter simulation technology has developed rapidly, and various countries have invested a lot of financial and manpower, which has promoted the development of helicopter training simulators and also promoted the development of helicopter simulation training [5-6]. The advent of computers has greatly developed the simulation technology, making it possible to accurately calculate the motion characteristics. Helicopter training simulators have also developed from a simple fixed base from the beginning to advanced simulation training equipment with complex systems, multiple functions and a high degree of integration [7-8].

Based on the analysis of the advantages of the simulator instead of the actual installation for training, the helicopter training simulator function and the simulator subsystem, this paper designs the actual installation simulation instrument, signal indicator, graphic instrument and control signal ordering circuit, and then the design a simulation experiment was carried out.

2. Design and Implementation of the Measurement and Control System of Helicopter Training Simulator

2.1. Advantages of Training with Simulator Instead of Actual Installation

(1) It can effectively improve training efficiency. The use of physical installation for training requires the protection of maintenance and field personnel, which consumes a lot of manpower, material and financial resources, and the training time must be arranged according to factors such as the condition of the helicopter, the airport and the weather conditions, and the training is more restricted. And the simulator is placed in the training room, the environment has little impact on it, only a few maintenance personnel are needed, the organization training is convenient and the training can be carried out for a long time [9-10].

(2) Training costs can be greatly reduced. The helicopter simulator is much cheaper than the actual installation of the helicopter; the direct loss of simulation training is much lower than that of the actual installation training; simulation training can save a lot of aviation fuel, and does not require a large number of support personnel, which can save a lot of support costs[11-12].

(3) The safety during training is extremely high. Ensuring safety is a prerequisite for training. The use of simulators for simulation training eliminates the problem of safety accidents during the training process and will not pose a threat to trainers and equipment. In addition, aerial mechanics can repeatedly practice troubleshooting and special handling methods on the simulator to improve their psychological quality. If they encounter the same situation during actual flight training, they can act decisively according to the practice procedure.

(4) Training subjects that can't be realized in actual installation can be realized. The helicopter training simulator uses software to simulate daily maintenance and flight failures, high-risk emergencies, etc., so that air mechanics can perform failure judgments and special handling exercises, so as to improve their business skills and enhance their psychological quality. These trainings are difficult to train on actual helicopters.

2.2. Function of Helicopter Training Simulator

This kind of helicopter training simulation simulator uses a distributed architecture. The structure design of the distributed system is flexible, and the scalability is strong, which can effectively reduce network redundancy and a large amount of data. The main function of the simulator is to provide a platform for special training for this type of mechanical helicopter aerial operations. Mainly provide basic training of fault crisis operation technology, fault crisis technology training and special operation technology training. The simulator allows the trainer to understand the cockpit device, the basic performance of the helicopter and the application of other related technologies, and understand the troubleshooting methods and specific handling methods of this type of helicopter. The training of troubleshooting and special handling is the focus of this analog instrument training. The main functions of the simulator are as follows:
1) Realize the basic control performance of the helicopter by simulating the control system of the helicopter's throttle lever, control lever, total moment lever, etc., and meet the training requirements of basic control skills;

2) The cockpit can be simulated realistically to meet the training personnel's requirements for the use of cockpit equipment;

3) The power system, hydraulic system, fuel system, etc. of the helicopter can be realistically reproduced, and the internal logic and working characteristics of the main airborne equipment can be simulated to meet the training personnel's requirements for the use of each system;

4) Simulate the operation of the system equipment related to the operation of the air mechanic under most of the failures of this type of helicopter, so as to meet the training of the air mechanic to judge the failure and deal with the special situation;

5) Provide a variety of realistic sounds, etc., so that the trainers have a better sense of immersion;

6) It can control the recording, emergency interruption, and playback of the aerial mechanics simulation training process, and can judge the training situation.

2.3. Simulator Subsystem

(1) Cockpit simulation system
The cockpit simulation system consists of various control devices, including cockpit body, cockpit throttle lever, steering wheel, complete torque lever and other control devices, as well as various on-board devices, mainly to provide instructors with realistic and realistic helicopter cockpits Internal environment. The cockpit instruments, indicator lights, built-in screen, control panel and handles are all complete. Their control and commands are simulated by the logic of the main control system, and their connection and motion state are also the same as those of this type of helicopter. The front instruments of the helicopter and the instruments on the left and right control platforms are simulated by virtual instruments, while the instruments on the central control platform are simulated by electric computers. The display values of these simulated instruments are consistent with the actual measurement instruments on site.

(2) Teacher console system
The instructor console serves as a center for simulator monitoring and management. In addition to the simulation-type coordinate car, it is also composed of various industrial control computers, monitors, sound wave switches, and the power supply and control box in the simulation-type coordinate car. Students can use the control platform to monitor the simulation simulator. The main functions of the control platform include: setting and managing training topics, setting up special training courses, setting up special training plans, checking the operation and stopping of the system, recording and playing the whole process of training, including closing the emergency simulator, testing emergency simulation.

(3) Main control system
The main control system consists of a main control computer and main control software. The main control software is a control program written in accordance with the logical relationship of various helicopter flying devices. The main control computer is a general industrial control computer. The main control system can be connected to other systems through a local area network to achieve monitoring and control of the simulator.

(4) Measurement and control system
The measurement and control system consists of a measurement and control computer, various control platforms, and corresponding software. Measurement and control are mainly suitable for daily ground experiments or large amounts of data acquisition, signal monitoring and data analysis in ground practice. They are all an integral part of the ground simulator. One of the main functions of the
measurement and control system is to realize the data collection and processing of the simulator, directly communicate with the main control system through the local network, and then complete the control of the simulator.

3. Experiment

3.1. Installed Analog Instrument
Engine gauges are modified through real gauges. The real modification of the instrument is to install the original instrument directly in the cockpit of the flight simulator, and individual instruments may be slightly changed. Since the principle of each musical instrument is different, the method of modification is also different.

1. The tachometer has its own independent controller, that is, the tachometer controller. Receive direct control information from the CAN bus and generate traffic signals.
2. The control signals of other installed instruments are given by other installed instrument controllers. Cylinder head thermometer and voltameter are both ammeter and voltmeter. The controller directly provides the corresponding driving current according to the current and voltage requirements of each instrument: the fuel gauge, the lubricating oil voltmeter, and the intake temperature gauge are all current ratios, and the diaphragm instrument is driven by a servo motor.

3.2. Signal Indicator
The signal indicator shares a controller with other installed instruments. The switch signal of the control signal indicator is given by other installed instrument controllers. The output of the switch is TTL level, and the output signal of the switch must be amplified by an amplifier to drive the display device.

3.3. Graphical Instruments
The complete static pressure system instruments, flight stop and steering instruments are simulated in the form of virtual graphical instruments. The indicators, channels and other indicators are the same as the real instrument, but the internal structure is completely different. If there is no gyroscope in the plan, there is no bellows gauge in the wind speed indicator. Using computer graphics technology to create a dial interface and instrument pointer through a computer solution system, it is actually an electronic virtual instrument.

3.4. The Design of the Control Signal Arrangement Circuit
The 12-bit parallel output DA conversion chip AD5445 is used to complete the conversion from digital to analog. AD5445 uses +5V power supply with a conversion rate of up to 21MBPS and an external +2.5V reference voltage. The 12-bit data line of AD5445 is connected to the lower 12-bit data bus of T89C51CC01, the conversion control signal is connected to the XR/W pin of T89C51CC01, and the chip select line is connected to the sixth output line of the 74HC138 decoder, which is mapped to the T89C51CC01. The low address of the external extended storage area 2 is the storage space of 0x5. T89C51CC01 controls AD5445 to complete 8 DA conversions with a 6ms cycle and refresh the analog output. The operational amplifier LM324 converts the current output signal of the AD5445 into a voltage output signal.

The inlet pressure gauge is a bellows instrument, driven by a servo motor. The lubricating oil pressure gauge, intake temperature gauge, and oil volume gauge are current ratio meters and are driven by stepping motors; the cylinder head temperature gauge and voltmeter are current and voltmeters, which are relatively simple to control and operate. The drive current can be directly provided according to the drive requirements of each instrument.

The pointer corner of the current ratio table depends on the current ratio (I2/I1) of wireframes I and II, and its size is only related to the variable resistance RX, and has nothing to do with the size of the power supply voltage, as shown in equations (1)(2):
\[
\begin{align*}
I_2 &= \frac{Rr - R_p R_d}{I_1} \\
I_1 &= \frac{Rr + (R + r + R_p)R_d - (R + r + 2R_p)R_x}{(R + r + 2R_p)R_x} \\
I_2 &= \frac{Rr + (R + r + R_p)R_d - (R + r + 2R_p)R_x}{(R + r + 2R_p)R_x}
\end{align*}
\] (1)  
(2)

At present, the resistance values of general current ratio tables on airplanes are generally: \( R=1200 \Omega, \) \( R_x + R_s = 255 \Omega, \) \( r=280 \Omega \) (where \( R_5=60 \Omega, \) \( R_3=330 \Omega, \) \( R_4=2120 \Omega, \) so the current ratio \((I2/I1)\) is \( R_x \) available as input the change curve is shown in Figure 1.

![Relationship lines](image)

**Figure 1.** The relationship between current ratio and \( R_x \)

The controller first uses the control signal received by the CAN transceiver, after being adjusted by digital-to-analog conversion, and then sent to the stepper motor driver, which completes the stepper motor control, and then drives the indicator pointer to change.

Since the current ratio table is a typical non-linear system, in order to reduce the measurement error caused by non-linear factors, two methods are commonly used to correct the non-linear error, the piecewise linear interpolation method and the newton interpolation polynomial method, but the two are similar. In comparison, the piecewise linear interpolation method is more superior, as long as the measurement data points are increased, the error can be approached to zero as the measurement data points increase. Therefore, this design uses piecewise linear interpolation to control the indicator of the current ratio meter. In consideration of saving calculations and ensuring the accuracy of interpolation, the measurement range to be measured can be divided into several sampling points according to the required measurement accuracy, and linear interpolation is performed on two adjacent sampling points.

**4. Discussion**

Take the antenna elevation angle table as an example. Its measurement range is \(-10^\circ \sim 65^\circ\), the measurement accuracy is 1°, and the sampling point interval can be selected 5°. The results are shown in Table 1, where FYd1 is the angle value of the sampling point, Ud1 is the voltage value of RX and both ends corresponding to the sampling point.

According to Table 1, an interpolation table can be made to control the antenna pitch angle indicator. In order to verify the simulation effect of this simulator, the sampling point is used as the test point, different antenna pitch angle signals are sent from the flight simulator instrument control
system, and the test points are tested. The experimental results are shown in Table 2.

### Table 1. Sampling point angle value-voltage correspondence table

| FYd1 | Ud1 | FYd1 | Ud1 |
|------|-----|------|-----|
| -10.0| 2.983| 30.0 | 3.602|
| -5.0 | 3.093| 35.0 | 3.646|
| 0.0  | 3.193| 40.0 | 3.681|
| 5.0  | 3.283| 45.0 | 3.709|
| 10.0 | 3.366| 50.0 | 3.734|
| 15.0 | 3.438| 55.0 | 3.749|
| 20.0 | 3.496| 60.0 | 3.763|

### Table 2. Test point angle value-voltage correspondence table

| FYd2 | Ud2 | FYd2 | Ud2 |
|------|-----|------|-----|
| -10.0| 2.967| 30.0 | 3.603|
| -5.0 | 3.082| 35.0 | 3.644|
| 0.0  | 3.183| 40.0 | 3.679|
| 5.0  | 3.278| 45.0 | 3.709|
| 10.0 | 3.362| 50.0 | 3.732|
| 15.0 | 3.436| 55.0 | 3.747|
| 20.0 | 3.497| 60.0 | 3.760|

Among them, FYd2 is the elevation angle value of the antenna at the test point (given by the calculation computer), and Ud2 is the voltage value at both ends of the Rx corresponding to the test point. The comparison curve of Table 1 and Table 2 is shown in Figure 2. The experimental results show that the design can more accurately simulate the indication of the antenna elevation angle meter.

![Comparison curve](image)

**Figure 2.** Sampling and test results comparison curve

### 5. Conclusions
The measurement and control system is an important part of the helicopter training simulator. Its main function is to complete the simulation of driving equipment such as cockpit switches, analog detection and indicator lights, engine instruments, and digital tubes. It is the core of the simulation system and helicopter training simulation. The performance of the measurement and control system reflects the measurement and control level of the simulator. The purpose of this article is to develop a
measurement and control system that can meet the requirements.

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