Design and Implementation a Measurement System for Aircraft Cabin Heat Comfort Test

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Abstract. A measure system is designed for aircraft cabin thermal comfort test, which can measure temperature, wind speed, humidity, pressure, flux, position parameters. The test results can be used to calibrate the model of temperature field simulation and cabin flow field simulation. The system synchronization accuracy is achieved 1mS. The measure system uses distributed configuration which comprises many measure cells. Test datum in the cabin can be set parameters and controlled re are transmitted to computer via internet. The measure equipment motely via internet, so that the measurement interfere affected by human activities can be reduced and the measurement accuracy can be improved. The measure system can communicate with instrument installation, making the cabin airflow field test automatism come true.

1 Background

With the development of civil aircraft design, in addition to meeting the safety and economic requirements for the design of civil aircraft, cabin comfort design is becoming more and more important. Due to the complexity of aircraft flight conditions, aircraft cabin comfort is often affected by many factors, including physical, physiological and psychological aspects. One of the important controllable factors in comfort factors is thermal comfort, including chamber ventilation, wind speed, pressure, temperature, humidity, radiation, etc [1-4]. Figure 1 is a schematic diagram of the cabin environment test platform. The platform uses the test samples produced during the development phase of the aircraft. Through the high and low temperature environment simulation test system and the outside environment simulation facilities such as the sunshine simulation system, a close-to-real aircraft cabin environment is created to develop cabins thermal comfort test study.

Cabin thermal comfort test, a large number of temperature, wind speed, humidity, pressure, flow, location, illumination and other parameters need to be tested. In this paper, a set of distributed test systems that can be monitored remotely is designed to meet the multi-parameter test requirements for cabin thermal comfort tests. In addition to the multi-parameter synchronization test of each measuring point in the cabin, the test system can also interact with the instrument installation platform to complete the automatic collection of cabin flow field data.

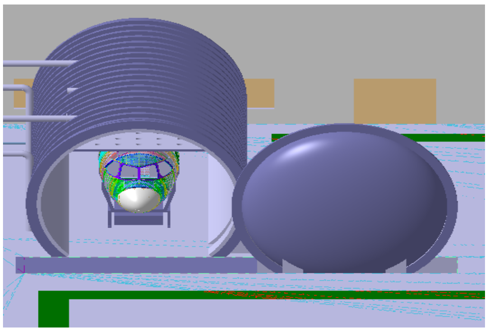

Figure 1 Schematic Diagram of Cabin Environment Test Platform

2 Test system architecture

The number of sensors for cabin thermal comfort test reaches several hundred. The test sensors are distributed outside the cabins of the cockpit and passenger cabin, cabin skin surface, the interior of the cabin structure, the surface of the cabin interior trim panels, and the vicinity of the seats .The distribution of the sensors is very scattered. Therefore, the test system adopts a distributed architecture, that is, the test terminal is composed of multiple test units, placed near the test sensor nearby, and the data collected by the test unit is transmitted to the measurement and control room through Ethernet [5-6]. This architecture requires only a few network cables to pass through the cabin wall and the bulkhead of the high- and low-temperature cabins to reach the monitoring and control room, which reduces the difficulty of wiring the sensors, shortens the transmission distance of the analog signals from the sensors, and reduces the external interference to the analog signals. At the same time, the test personnel can carry out parameter setting and remote control of the in-cabin test equipment through the network and remotely monitor the measurement process at any time, which will effectively reduce the interference of the tester's activities to the cabin environment and improve the measurement accuracy [7]. Figure 2 is a schematic diagram of the test system architecture.

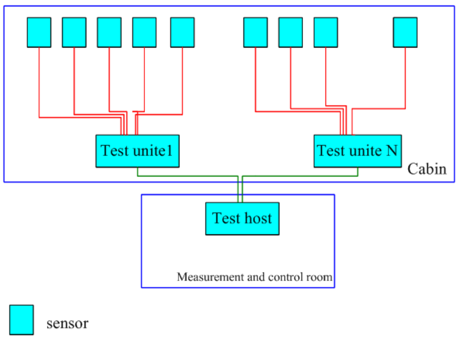

Figure 2 Test System Architecture

3 Key technical analysis and implementation of test system

3.1 Test System Synchronization

The cabin thermal comfort test system adopts a distributed architecture. The system consists of a plurality of test units. Each test unit has its own clock. It is necessary to adjust and maintain the physical or logical clocks of each test unit through some mechanism to ensure that all collected data can be analyzed and processed on the same time axis. Therefore, how to adjust and maintain the physical or logical clock of each test unit is the key to system design.

The full name of the IE1588 protocol is the "precision clock synchronization protocol standard for network measurement and control systems", abbreviated as PTP (Precision Time Protocol). This protocol is the hotspot of clock synchronization research in distributed test systems. It has the advantages of simple implementation, small occupied network bandwidth, and low requirement for system resources, thus becoming the most promising LAN clock synchronization protocol. The PTP protocol can achieve a subtle level of synchronization accuracy.

PTP defines four types of multicast packets: Sync, Follow-up, Delay-Req, and Delay-Resp. The order of interaction of these messages and the information received are related to the current state of the clock.

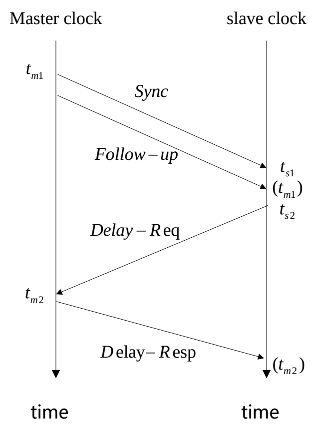

Figure 3 Clock synchronization process

Figure 3 is a schematic diagram of the clock synchronization process. To describe the clock synchronization problem of the test system, we illustrate the clock synchronization process by taking the synchronization process of a master clock and a slave clock as examples.

a) The master clock periodically sends synchronization messages (Sync) to the slave clock at defined intervals. The time stamp of this message is the expected transmission time of the master clock, and the master clock records the actual transmission time tm1; At the receiving end, the text is recorded from the clock at the receiving time ts1.

b) The master clock sends a follow-up message to the slave clock. The message contains the exact transmission time tm1 of the previous synchronization message. The network delay time is Delay and the master and slave clock offsets are Offset:

$$ts1 = tm1 + Offset + Delay \qquad (1)$$

c) Send the Delay-Request message from the clock to the master clock (the delay request message interval is set independently). After the message is sent, the slave clock records the exact transmission time, ts2, at the master clock. End record accurate reception time tm2.

d) The master clock returns a delay-response message (Delay-Response) to the slave clock. This message contains the exact reception time tm2 of the previous delay request message. The slave clock uses ts2 and the transmission time tm2. You can get:

$$tm2 = ts2 - Offset + Delay \qquad (2)$$

From equations (1) and (2) can be calculated:

$$Delay = [(ts1 - tm1) + (tm2 - ts2)] / 2 \qquad (3)$$

$$Offset = [(ts1 - tm1) + (tm2 - ts2)] / 2 \qquad (4)$$

If the current slave clock time is tsOld, then the new slave clock time tsNew that should be synchronized to now can be calculated:

$$tsNew = tsOld - Offset - Delay \qquad (5)$$

According to this, in the next synchronization cycle, synchronization between the slave clock and the master clock can be achieved. The accuracy requirement of the chamber thermal comfort test system is 1mS. The PTP clock synchronization accuracy meets the requirements. Besides the hardware support of the equipment itself, there is no need to add additional synchronization cables and the networking is convenient.

3.2 Flow field automation test

In the cabin thermal comfort test, the flow field test inside the chamber needs to be completed. When testing and arranging measuring points in the cabin flow field, no less than three measuring points around the human body (head, waist, ankle, etc.) shall be arranged, and the other measuring points shall be arranged in a uniform manner. The layout of measuring points on a single cross section of the cabin As shown in Figure 4.

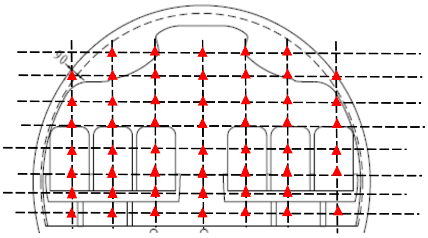

Fig. 4 Schematic diagram of layout of measuring points in cabin flow field (heading)

The cabin has the characteristics of complex space and small space and low wind speed at close distances. When the flow field is tested, if the wind speed sensor is arranged at each measuring point, the distribution of the flow field in the cabin will be seriously affected and the test result will lose significance. Therefore, the laboratory specially designed a set of instrument installation platform. The instrument installation platform can be equipped with 7 wind speed measurement devices. The installation platform can automatically control the measurement device to reach the specified measuring point.

Every time the instrument installation platform controls the measurement equipment to move to the target position, it needs to manually control the test system to start or stop the test task. The test personnel need to frequently operate the test system, and the work is very tedious. How the instrument installation platform interacts with the test system to achieve automated data acquisition and processing of the flow field is the key to the design of the test system.

According to the test requirements for automated data collection in the flow field, the instrument installation platform and test system information interaction methods and workflows were designed. The schematic diagram of information interaction between the instrument installation platform and test system is shown in Figure 5. The instrument installation platform controller receives an instruction from the tester to control the measurement instrument to reach the specified measurement point position, and sends a trigger signal after the “set time 1” waits for the flow field in the chamber to stabilize. The test system receives the trigger signal and starts data acquisition. The instrument installation platform sends a trigger signal according to the "set time 2" waiting for the test system to complete data acquisition. The test system receives the trigger signal and ends the data acquisition. Among them, “set time 1” refers to the time required for the stability of the cabin flow field input by the tester in the interface of the instrument installation platform controller; “set time 2” refers to the test personnel's interface in the instrument installation platform controller. The time of the input data acquisition. "Set time 1" and "Set time 2" need to be determined by tests or previous test experience. According to the workflow input in advance, the instrument installation platform issues a trigger signal, and the test system receives the trigger signal to start or stop the collection of tasks, thereby realizing the automatic collection of the flow field in the cabin.

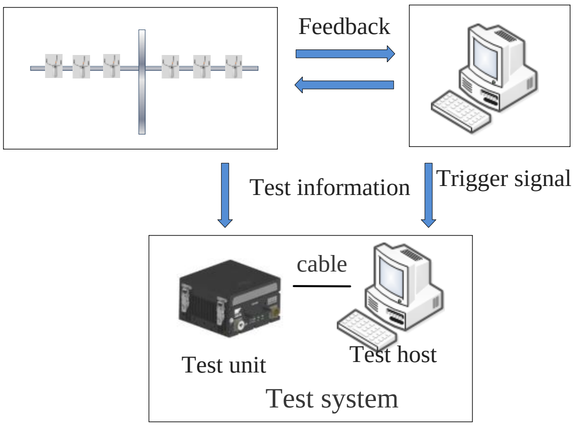

Figure 5 flow field test experimental equipment information exchange diagram

4 Test system software and hardware implementation

4.1 Test System Hardware

The system is mainly composed of test units, switches, operation and display terminals. Since part of the cabin test is required to be performed within the temperature range, the selected test unit must be able to operate normally within the temperature range. The test unit selected in this paper is the VTX company RX series of rugged field data acquisition equipment, the equipment to meet the test accuracy, sampling frequency and other test requirements, at the same time, the test equipment supports PTP protocol, can achieve the test system 1mS synchronization accuracy requirements.

4.2 Test System Software

The cabin thermal comfort test system software has commonly used functions such as system configuration, channel parameter setting, data recording, data display, data export, data playback, etc. At the same time, the system software needs to have certain data when testing the flow field. Processing function. When the cabin flow field test, the test system collects the position sensor signals of the instrument installation platform, and the obtained information includes “time information” and “position information”. The test system collects the sensor signals of the measurement point, and the obtained information includes “time information” and “measurement point parameter information”. The test system software can match the "position information" and "measurement point parameter information" of the measurement point according to "time information", and the final output of the test text measurement point information includes "time information", "position information", and "measurement point parameter". information". The test personnel can analyze the flow field in the cabin according to the "position information" and "measurement point parameter information" of each measuring point.

5 Conclusion

In this paper, a set of multi-parameter distributed testing system, such as temperature, wind speed, humidity, pressure, flow, illumination and position, is designed based on the test requirements of civil aircraft cabin thermal comfort test. The test system consists of multiple test units. The VTI RX series rugged field data acquisition equipment is used in the test unit. The device can work normally in the temperature range. At the same time, the test equipment supports the PTP protocol and can be tested. System 1mS synchronization accuracy requirements. The test system can interact with the instrument mounting platform to complete the automated collection and processing of cabin flow field data.

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