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An intelligent control method for a large multi-parameter environmental simulation cabin

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Abstract The structure and characteristics of a large multi-parameter environmental simulation cabin are introduced. Due to the difficulties of control methods and the easily damaged characteristics, control systems for the large multi-parameter environmental simulation cabin are difficult to be controlled quickly and accurately with a classical PID algorithm. Considering the dynamic state characteristics of the environmental simulation test chamber, a lumped parameter model of the control system is established to accurately control the multiple parameters of the environmental chamber and a fuzzy control algorithm combined with expert-PID decision is introduced into the temperature, pressure, and rotation speed control systems. Both simulations and experimental results have shown that compared with classical PID control, this fuzzy-expert control method can decrease overshoot as well as enhance the capacity of anti-dynamic disturbance with robustness. It can also resolve the contradiction between rapidity and small overshoot, and is suitable for application in a large multi-parameter environmental simulation cabin control system.

1. Introduction

High-altitude environment is a major factor impacting performance of aircraft environmental control systems and comprehensive environmental quality of a cockpit. Cockpit environmental quality plays not only a decisive role in flight safety as well as occupant's health and comfort, but also an important role in energy efficiency and environmental protection. High-altitude simulation cabins can simulate flying environment (e.g., height, temperature) for aircrafts and transport planes. Thus, simulation cabins play an important role in the development of feeder aircrafts.

The temperature change in a high-altitude environmental simulation cabin comprises a cooling stage, a constant temperature stage, and a heating stage.[1] The requirements can be found in the national military standards[2] in terms of temperature control precision in environmental simulation cabins, especially systems without self-balance ability, to prevent the occurrence of an overshoot phenomenon. Presently, in the field of environmental simulation control, researchers have developed many methods. For example, Li's research group introduced a PID controller to control the temperature of thermal control systems.[3–7] Dong et al. utilized a double-PID controller to control the temperature of an environmental

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chamber.[8] However, both simulation and experimental results showed that, due to the complexity of factors influencing the cabin temperature and the inertia link caused by the large volumes of most cabins, it is difficult to increase the cooling rate and prevent the overshoot simultaneously with the classic PID control method. Therefore, it is difficult to control the temperature. When an environmental cabin simulates multiple parameters such as temperature and pressure, there has been coupling and interference between these parameters. This limits the ability to simulate temperature and pressure quickly and accurately. Because of the constant increments of the air-operated valve, it is easy to have lower pressure than the target pressure. Thus, it is difficult to control the pressure without an overshoot using the classic PID control method.

To overcome the above difficulties of multi-parameter cabin control systems and ensure that a refrigeration turbine can be put into use safely and as soon as possible, we propose that the processes of automatically powering on and off the refrigeration turbine and decreasing the temperature can be automatically controlled by combining the fuzzy control strategy with an expert PID judgment and thus, the lumped parameter model of cabin temperature and pressure change, established on the basis of the dynamic-state characteristics of the environmental simulation cabin, is valid. A fuzzy controller was used to control the heater of the central air conditioning system.[9,10] The introduction of expert judgments can be used to decrease the temperature, reduce the fluctuation of turbine revolution speed, and lead the refrigeration system into a steady state as soon as possible, therefore improving experimental efficiency. The fuzzy method is a kind of simple and flexible method with the advantages of less computational efforts, strong practicability, rapidity, strong stability, and high robustness.[11] This enables the achievement of higher control accuracy. Appropriate use of this method solves the problems of revolution speed control of the air refrigeration turbine and temperature control, ensuring normal operation of experiments.

2. Control scheme

A large multi-parameter environmental simulation cabin is shown in Fig. 1. The cabin's system includes four parts: refrigeration system, vacuum system, environmental cabin, and measurement control system. The refrigeration system adopts a positive compressor reflux refrigeration air cycle and includes compressor turbine components, a reflux refrigeration device, air-operated adjusting valves, and the environmental cabin. The vacuum system can create a low atmospheric pressure environment and conduct experiments at low pressure and low or high temperature via an environmental cabin pumping system.

By means of adjusting the output power of the electric heater placed in the wind tunnel, the high temperature of the environmental cabin can be controlled. Furthermore, according to the temperature requirements in the cabin, the opening of the air-operated valve QF1 at the turbine entrance shown in Fig. 1 can not only change the pressure at the refrigeration turbine entrance and corresponding refrigeration turbine expansion ratio (and therefore adjust the temperature decrease of the turbine), but also change the refrigeration turbine flow, resulting in effective adjustment of its refrigeration capacity and control of the temperature in the cabin. Because the temperature decreases and the flow changes simultaneously in the same direction, the refrigeration capacity changes rapidly and sensibly. However, the valve QF1 opening is restricted to change only within a certain range by the revolution speed of the refrigeration turbine and the compressor surge, so it is only used to make coarse adjustments. By adjusting the opening of the air-operated valve QF2, which is set at the exit of the turbine and near the cold air entrance pipe in the back of

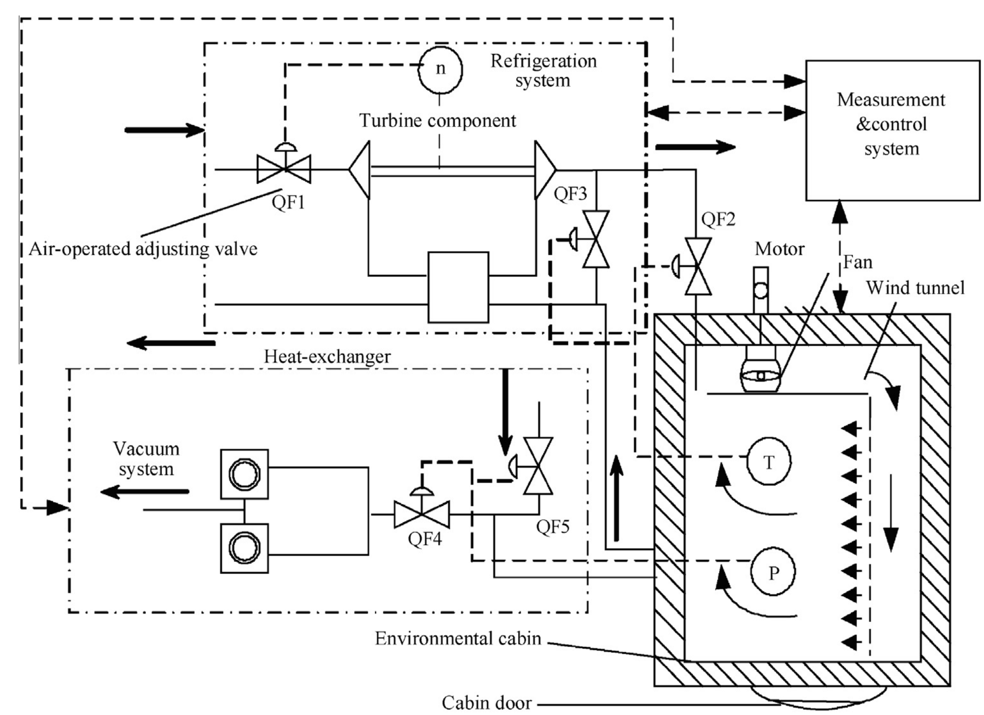

Fig. 1 Flow chart of a large multi-parameter environmental simulation cabin.