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Abstract

The active center of gravity control technology is to control the position of the center of gravity actively through reasonable fuel transmission in the course of flight, so as to realize the reasonable matching of the center of gravity and the pneumatic focus of the aircraft, so as to optimize the flight performance, reduce the maintenance cost give full play to the potential of the aircraft. This paper presents a method to change the relevant fuel control laws and implement the active center of gravity fault-tolerant control technology in fault mode. The active center of gravity fault-tolerant control technology realizes the design of fuel tank oil delivery scheme in fault mode by changing the fuel transmission logic in fault mode innovatively. The fault-tolerant control law can be verified by AMESIM and MATLAB simulation.

Keywords Active center of gravity control technology - Fuel control laws - Fault-tolerant control - Fuel transmission

Research on Active Gravity Center Fault Tolerance Control of Fuel System

Peishen Han, Jing Zhang, and Lingyu Yang

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1 Introduction

Active center of gravity control technology is an advanced technology which can effectively reduce resistance and obtain potential economic benefits. In view of the origin and development of active center of gravity control technology (see Fig. 1), literature Nonlinear Inversion Flight Control for a Superm Aneuverable Aircraft [1] proposed active center of gravity control technology in the 1980s, which has been

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L. Yan et al. (eds.), *Advances in Guidance, Navigation and Control*, Lecture Notes in Electrical Engineering 644,
https://doi.org/10.1007/978-981-15-8155-7_425

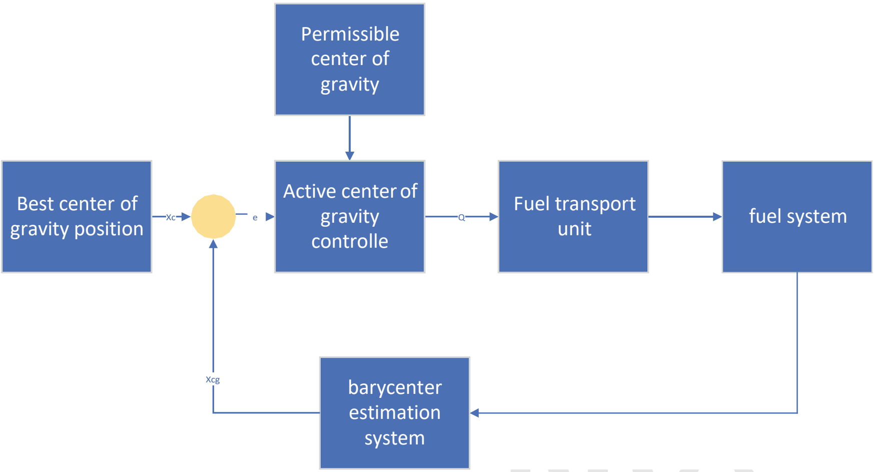

Fig. 1 Active center of gravity control system

rapidly developed in the field of aircraft design abroad. The theoretical basis of this technology is that the aircraft has the optimal center of gravity position in the cruise state, and the active center of gravity control technology [2] is to adjust the real-time center of gravity of the aircraft to make it as close as possible to the optimal center of gravity position. Western researchers have designed active center of gravity control systems for fighter jets. With the exception of military aircraft, Airbus [3] introduced the active center of gravity control system into the design of A330 and A340 long-range passenger aircraft as a means to reduce the leveling resistance in cruise phase. This is achieved by managing the fuel in the flat fuel tank (located in the horizontal stabilizer) as fuel is consumed. The application of active center of gravity control technology is presented in literature Simulation Test for Aircraft Fuel System [4]. Active center of gravity control technology is widely used in subsonic and supersonic flight of aircraft. In supersonic cruise, the active center of gravity control system makes the center of gravity move backward with the change of focus to maintain the optimal static stability of cruise. In subsonic cruise, the original design center of gravity is optimized by active center of gravity control technology to improve flight performance. The application status of active center of gravity fault-tolerant control law is demonstrated in literature Health Management of a Typical Small Aircraft Fuel System Using an Adaptive Technique [5]. The active center of gravity control technology in fault mode has started and been studied in depth abroad. Airbus introduced active center of gravity fault-tolerant control technology to the configuration design of new airbus civil airliner [6]. Compared with foreign countries, the research on active center of gravity control technology in fault mode has just started, and the results are few. Mainly focus on the integrated environment of dynamic system modeling, simulation and comprehensive analysis. The Matlab and Amesim simulation model adopted in this research is more inclined to modular design and dynamic system modeling than traditional C language and Flowmaster simulation model. The data types of simulation are more abundant, and the whole simulation is the integration of simulation and integrated analysis environment closer to the real results.

2 Impact of Fuel Model Fuel Tank Failure on Control System

2.1 Fuel System

The fuel system model includes No.3 fuel tank, No.5 and No.6 wing tank, and No.1, No.2 and No.4 other fuel tanks (see Fig. 2). The No.1 and No.2 tanks are located closest to the origin of the fuselage coordinates and act as a backward transmission fuel; the No.4 tank is farthest from the origin of the fuselage coordinates and acts as a forward transmission fuel; the No.5 and No.6 tanks are wing tanks on both sides of the fuselage; and the No.3 tank receives fuel from other tanks and undertakes the task of supplying fuel to the engine.

The whole center of gravity control law is divided into three parts

1. The six transmission schemes, 1–4, 2–4, 1–5, 2–5, 1–6, 2–6, followed from left to right by the center of gravity control oil transfer sequence in fault-free mode.
2. If the No.1 tank pump or valve fails, remove the transmission scheme of 1 and 4, 1 and 5, 1 and 6, and execute the remaining three schemes; similarly, if the No.2 tank fails, remove the relevant scheme of No. 2.

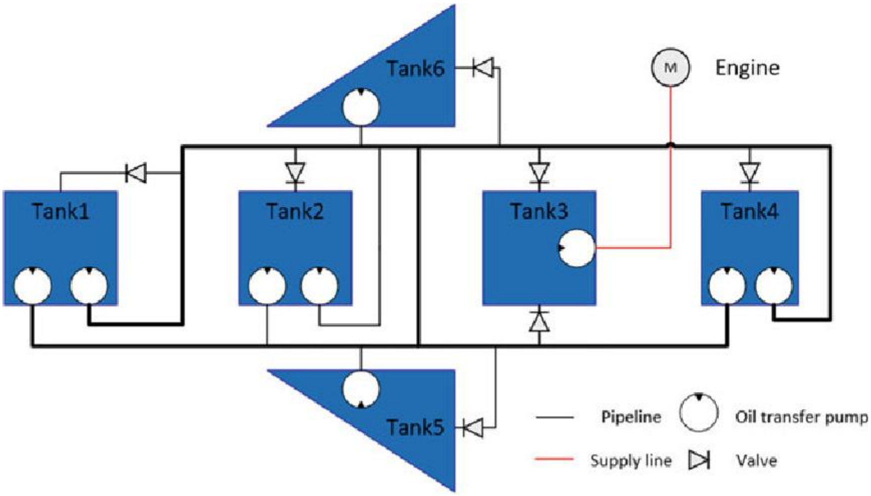

Fig. 2 Example of aircraft tank layout

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3. Sequential design basis for transmission scheme: The greater the distance between the tanks, the greater the change of the unit volume of fuel to the center of gravity; Changing the same center of gravity distance, the farther the distance between the tanks, the smaller the fuel transfer required.

2.2 *Impact of Fuel System Failure*

The simulation image of fuel system simulation in non-fault mode shows that the actual center of gravity curve and the position of the target center of gravity curve are close to coincidence, and the position of the target center of gravity curve is tracked in real time. The fuel system failure of the pump is set to 300 s for joint simulation. Because the No.1 pump fails after 300 s, the No.1 pump does not produce oil from 300 to 1000 s, and the No.1 pump is replaced by No.2 pump to complete the task of backward transmission of fuel, but after 800 s the No.2 tank has reached the lower limit of the fuel set before, and can not continue to transfer the fuel back. Since pump 1 and 2 do not transmit fuel backward after 800, the center of gravity will not move backward, and the actual center of gravity curve is separated from the target center of gravity curve at 800 s. It can be seen that the failure of the fuel system has a great impact on the whole control system. The whole actual center of gravity curve has shifted from the target center of gravity position, so it is necessary to introduce active center of gravity fault tolerance control to solve the demand problem.

3 Fault-Tolerant Control Law

Aiming at the impact of the fuel system failure mode on the simulation, Specifying a fault-tolerant control law structure (see Fig. 3), the optimal gravity center position

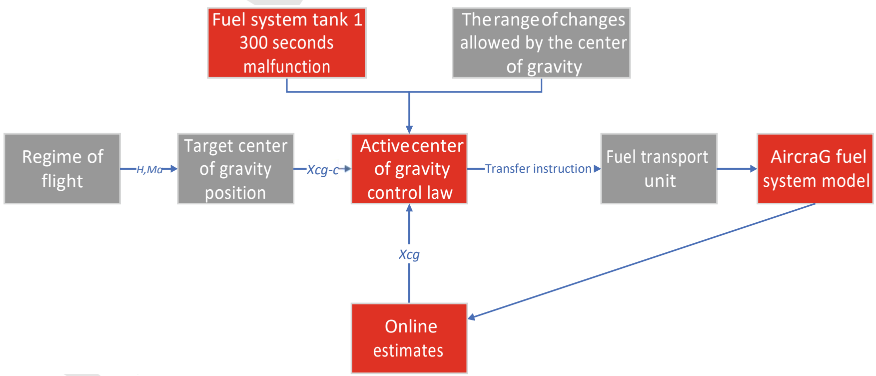

Fig. 3 Fault-tolerant control law structure

and the fuel tank parameters of the aircraft fuel system failure mode are input to the active center of gravity fault tolerance control law, which will eliminate the Fuel transfer logic associated with a faulty pump valve. Execute the set fuel transfer logic when the fuel needs to be transferred forward and backward.

The change range of the whole center of gravity needs to be kept between the front and back limits of the center of gravity. Between the front and back limits of the center of gravity, the center of gravity keeps moving forward and backward along with the forward and backward transmission of fuel oil. In the transmission process of fuel oil, one-to-one fuel oil transmission and one to many fuel oil transmission are involved. The pump valve status of each fuel tank will change with the change of the overall fuel transmission path status.

The fault diagnosis of aircraft fuel tank is added to the overall fuel system control law. The diagnosis mechanism can determine the fault mode and specific position of the aircraft fuel system through the overall verification, and transmit the fault-tolerant control command of the fuel control law to the fault mode of the aircraft fuel system, Fault Model for Fuel System remove the relevant transmission path of the current fault tank, and execute according to the priority order. According to the related fuel transfer logic, the fuel transfer between six fuel tanks is carried out in one step, and the fuel tank continuously supplies fuel to the engine. Within the allowable range of the center of gravity, the position of the center of gravity is estimated online to track the optimal position of the center of gravity in real time.

4 Simulation Verification

After changing the fuel system's active center-of-gravity fault-tolerant control law, verify the fault-tolerant control law of the fuel system in the failure mode. Change the AMESim model to set the simulation time to 1000 s. The failure of the No. 1 fuel tank pump starts from 300 s.Tracking the position of the target center of gravity curve and real-time center of gravity curve (see Fig. 4).

According to the oil quantity of 6 fuel tanks in the whole simulation process (see Fig. 5), it can be seen that because 300 fault No.1 fuel tank does not transmit fuel back, No.2 fuel tank replaces No.1 fuel tank backward in the whole simulation process, and the oil quantity of No.3 fuel tank fluctuates smoothly between thresholds during the whole simulation process. The overall simulation data show that the fuel system realizes the verification of the fault-tolerant control law of the active center of gravity.

Due to the failure of the pump 300 s to set the No.1 tank in the fault of the fuel system, the overall simulation curve shows that the pump speed of the No.1 tank(see Fig. 6) is kept to 0, and no oil is produced, which conforms to the set expected value.

Because the pump of No.1 tank fails in 300 s, according to the fault tolerance control law, No.2 tank needs to undertake the transmission task of center of gravity backward and backward oil transportation (see Fig. 7). In the whole simulation process, the No.2 fuel tank not only completes the oil supply task to the No.3 fuel

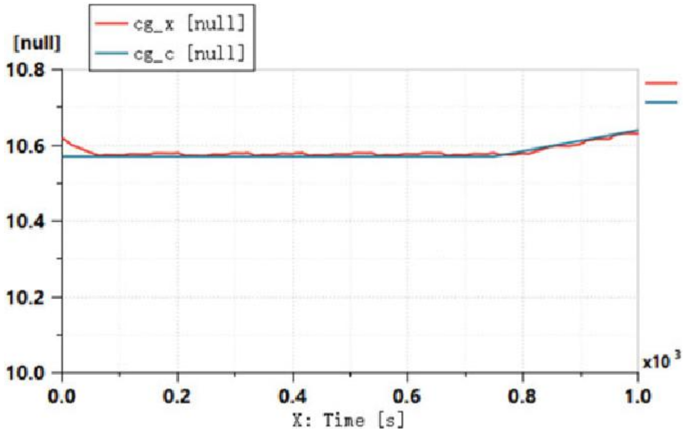

Fig. 4 Center of gravity curve of fault-tolerant control of fuel system

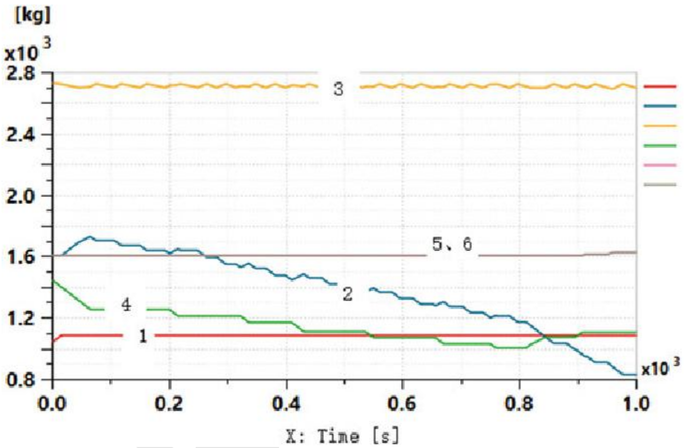

Fig. 5 Changes in fuel volume of each fuel tank

tank, but also plays the effect of adjusting the center of gravity, The simulation results are expected.

In the overall simulation process, the No.3 fuel tank on the one hand receives the fuel transmission from other fuel tanks (see Fig. 8), on the other hand, the oil supply to the engine is always kept at the maximum value, so the pump is always closed, and the valve is opened intermittently to receive the fuel, and the simulation results are in line with expectations.

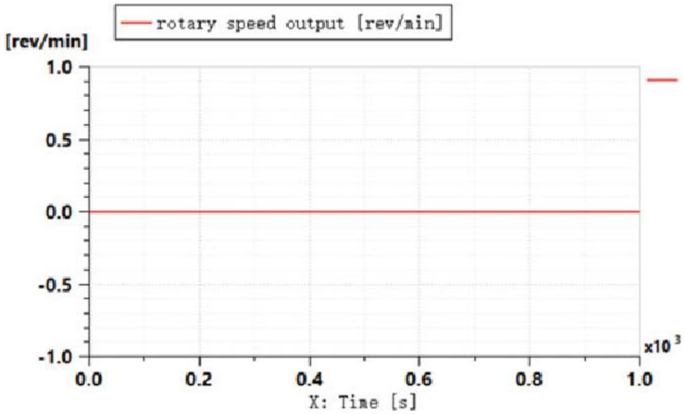

Fig. 6 Pump in tank No.1

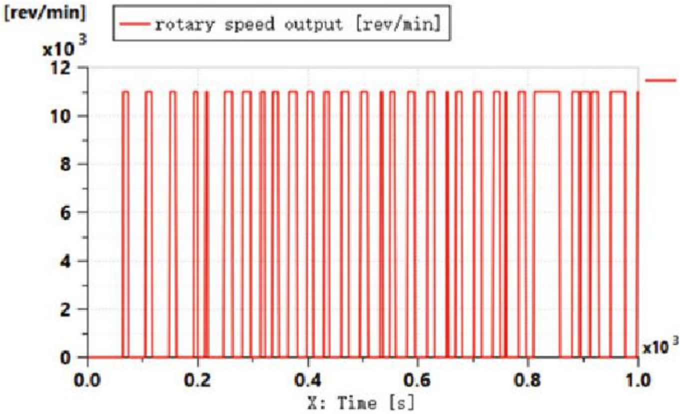

Fig. 7 Pump in tank No.2

5 Conclusion

This paper first studies the influence of the fault mode of fuel system on the whole control system, then studies the method of changing the relevant fuel control law and realizing the active center of gravity fault-tolerant control technology in fault mode. Finally, the simulation implementation of fault-tolerant control law is studied. The next research plan focus on the universality of active center of gravity control and the diversity of fault-tolerant mode.

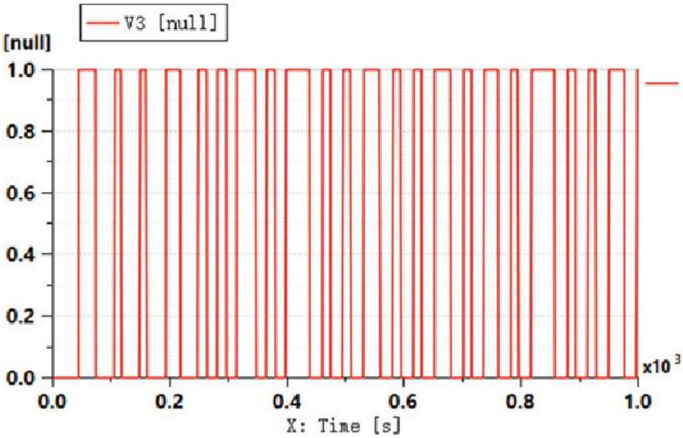

Fig. 8 Valve in tank No.3

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