Exploration of the basic flight mode of a two-axis aircraft

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Abstract. In recent years, drones have been widely used in military and civilian applications. Among them, multi-rotor UAVs have functions such as taking off and landing vertically, hovering and flighting in high speed. It is simple to operate, safe, reliable and highly serviceable. It has received great attention from people and has become a research hotspot in recent years. However, it has obvious defects in endurance performance and load capacity, and the two-axis aircraft is one of the methods to solve the problem. Therefore, this paper explores the structural form of the two-axis aircraft and the flight principle of the basic flight mode.

1. Development Background
A drone is a small unmanned aerial vehicle that can be remotely controlled, which has an independent powertrain, can carry multiple devices, and performs multiple tasks efficiently multiple times. In view of its vast space in the air and its many advantages, drones have been successfully used in many military fields such as surveillance, reconnaissance, communication relay and sub-confrontation. At present, in addition to its wide application in the military field, drone technology has also made great progress in the application of civil fields, such as agricultural plant protection, logistics and transportation, aerial photography, surface mapping, power inspection and signal base stations. field. UAVs can also perform disaster-relieving tasks with high risk and high damage, improving efficiency while reducing casualties. In addition, it is also favored by various industry sectors because of its simple operation, flexible take-off and landing, and small environmental impact. At present, the UAV is in the initial stage of the development of the research field to the market. Because the technologies have not yet broken through and the performance has not been perfected, it has not fully exerted its great influence. However, in the next 20 to 50 years, intelligent drones with many different types and functions will surely rise with the development of economy and society.

In recent years, microelectronics and computer technology have developed rapidly, and the development of multi-rotor drones has made breakthroughs. Its functions such as vertical takeoff and landing, hovering and high-speed flight have received great attention and become a research hotspot in recent years.

Among them, the flight principle and control principle of the four-rotor UAV has a complete system theory, and its disadvantages such as high quality, complicated circuit control and short battery life due to the need for more power systems; The series of problems caused by many drone enthusiasts turned their attention to the two-axis aircraft with less power system, which has the advantages of high speed, low noise, small vibration, long range, heavy load and low fuel consumption. At present, there are two-axis aircraft structures such as double-rotor and double-rotor, but no related papers have been found. Therefore, this paper mainly introduces the flight structure of the two-axis aircraft structure and basic flight mode.
2. Classification introduction
The two-axis aircraft can be divided into two types: the two-rotor and the double-rotor.

The representative of the double-rotor traversing aircraft is the V-22 tilting rotorcraft, as shown in Figure 1. The utility model adopts a variable-direction rotor, and each end of the wing has a variable-direction rotor propulsion device, and the entire propulsion device can be rotated and turned upwards and forwards around the wing axis, and can be fixed in a desired direction. There is a universal gimbal device between the rotor and the rotor seat, and the rotor can be rotated in any direction and fixed in the desired direction. This results in an upward lift or forward thrust, which is typically completed in a matter of ten seconds. It combines the advantages of fixed-wing UAVs and helicopter UAVs. It not only has the function of high-speed cruise flight of turboprop aircraft, but also has the functions of vertical take-off and landing and air hovering of ordinary helicopters.

The twin-rotor tandem represents the Chinook helicopter, as shown in Figure 2. It has two pairs of longitudinally rotating main rotors. Both rotors can be rotated around the universal pan and fixed in the desired direction. They are arranged in front, low and high, respectively at the nose and the tail. Above, the rear vertical propeller of the general helicopter is removed. It has the advantages of strong adaptability, strong transportation capacity and strong resistance to damage.

3. Principle of flight
The following is a description of the construction and flight principle of a two-rotor, two-axis UAV.

3.1 structure type
The wings of the same structure and size on both sides of the fuselage are located at the same height plane. The two rotor seats are symmetrically distributed at the end of the wing. The center of the two rotors is at the center of gravity of the fuselage and can be completed from the front of the rotor axis. Up to 180° to the rear, and there is a universal head between the rotor seat and the rotor, so that the rotor can rotate in any direction and can be fixed in the desired direction, as shown in Figure 3.
3.2 Working principle
The two-axis aircraft controls the flight attitude and position by controlling the motor speed to achieve lift changes, controlling the body tilt angle, rotor seat and rotor orientation. The motor on the left side of the two-axis aircraft rotates clockwise, and the motor on the right side rotates clockwise, so the gyro effect and the dynamic torque effect of the air are offset when the aircraft is flying in balance.

(1) Vertical motion
The center of gravity of the two-axis aircraft is at the center of a pair of propellers, and the pair of motors are turned in opposite directions to balance the counter-torque against the fuselage. When the external disturbance is zero, the output power of the two motors increases at the same time, the rotor speed increases, and the total tension generated by the rotor increases. When the total tension is enough to overcome the weight of the whole machine, the two-axis aircraft rises vertically from the ground; When the output power of the motors is reduced, the two-axis aircraft descends vertically until it reaches the balance. When the amount of external disturbance is zero, the aircraft becomes hovered when the lift generated by the rotor is equal to the self-weight of the aircraft. The key to ensuring a stable center of gravity and vertical motion when the two rotor speeds are synchronized. The schematic is shown in Figure 4.

(2) Front and rear movement
Keeping the center of gravity unchanged, the pair of rotor seats of the two-axis aircraft rotate around the rotor shaft to the oblique front side, and the rotor is rotated by the motor to generate the oblique front side pulling force, which is decomposed into the upward and forward directions of the two directions, and the two The counter torques cancel each other out, so the entire two-axis aircraft
achieves forward motion. The output power of the motor is constant, because the direction of the rotor changes, and the upward pulling force is reduced. Due to the influence of inertia, the nose of the two-axis aircraft is slightly lower, and the tail is slightly higher, resulting in a fuselage head; The state is instantaneous, increasing the output power of the motor keeps the fuselage level. The pair of rotor seats of the two-axis aircraft rotates around the rotor shaft to the oblique rear side, which similarly produces the pulling force in the upward and backward directions, while the two counter-torques are balanced, and the entire two-axis aircraft realizes the backward movement; The inertia effect is positive. The schematic is shown in Figure 5.

![Figure 5 Flight principle diagram of forward and backward movement](image)

(3) Rolling motion
The fuselage is tilted, the rotor seat has a vertical plane facing up, and the planes of the two rotors are in line with the plane of the fuselage. The two rotors produce a pulling force that is perpendicular to the plane of the rotor and is broken down into pulling forces to the left or right and upward. If the output power of the two motors does not change, the two-axis aircraft rolls sideways; the output power of the two motors increases until the resulting upward pulling force and self-weight balance, the two-axis aircraft achieve horizontal roll; if two motors As the output power continues to increase, the two-axis aircraft rolls sideways as it rises. The schematic is shown in Figure 6.

![Figure 6 Flight schematic of the roll motion](image)

(4) Yaw movement
Keeping the center of gravity constant in the horizontal plane, one rotor seat of the two-axis aircraft is inclined obliquely forward, and the other rotor seat is tilted rearward around the rotor axis. Both rotors are perpendicular to the rotor seat, and the planes of the two motors are the same angle as the fuselage. The two motors increase the rotational speed so that the combined force of the upward pulling forces generated by the two rotors is balanced with the self-weight, and the two rotors
respectively generate a forward-backward pulling force that forms a force couple, so that the fuselage realizes the yaw motion. The schematic is shown in Figure 7.

4. Advantage analysis

Common aircraft are usually divided into fixed wings, helicopters and multi-rotors (four-rotor is the mainstream) and two-axis aircraft.

With fixed-wing UAVs and helicopter drones, multi-rotor aircraft has obvious advantages in terms of handling, reliability and serviceability. In terms of maneuverability, the multi-rotor control is simple and easy to understand, the control principle is easy to grasp, and the four remote sensing operations of the manipulator correspond to the movement of the front, rear, left and right, up and down and yaw directions of the aircraft respectively; and the multi-rotor drone has vertical takeoff and landing, Features such as hovering and high-speed flight. In terms of autopilot, multi-rotor controller parameter adjustment and autopilot control methods are relatively simple. In terms of reliability, the multi-rotor has no moving parts, and the mechanical reliability is high, and its reliability basically depends on the brushless motor, so the reliability is excellent. When performing a mission, the multi-rotor can be hovered, the flight range is controlled, and it is relatively safer. In terms of serviceability, the serviceability of the multi-rotor is higher. Its structure is simple, if the motor, electronic governor, battery, paddle and frame are damaged, it is easy to disassemble, repair and replace. In terms of endurance performance and load bearing performance, the performance of the multi-rotor is significantly weaker than the other two models, and its energy conversion efficiency is low and the load is small.

In comparison, fixed-wing and helicopter have long battery life and large payload. However, in terms of maneuverability, it is difficult to learn to control fixed-wing and helicopter flight; and the fixed-wing flight site requires widening, and the inter-channel coupling occurs during helicopter flight. The design of the autopilot controller is difficult, and the controller adjustment is difficult. . In terms
of reliability, fixed-wing and helicopter have moving mechanical connecting parts, which cause wear during flight, resulting in reduced reliability. In terms of serviceability, there are more fixed-wing and helicopter parts, and installation requires skill, which is relatively troublesome.

For the first three models, maneuverability is related to aircraft structure and flight principle and is difficult to change. Multi-rotor always has an advantage in terms of reliability and serviceability. As battery energy density continues to increase, materials become lighter, and airborne equipment continues to be miniaturized, the advantages of multi-rotor will be further highlighted.

The four-rotor UAV has the disadvantages of high quality, complicated circuit control and short battery life due to the need of four power systems. The two-axis aircraft can solve the series of problems caused by more drive modules, handling, reliability and serviceability. The upper and fourth rotors have the same advantages, and are superior to the four-rotor UAV in terms of battery life and load capacity, and have the advantages of high speed, long range, heavy load, low fuel consumption, low vibration and low noise.

5. Conclusion
Analysis of the advantages and disadvantages of multi-rotor aircraft, fixed-wing aircraft and helicopters, we found that the two-axis aircraft basically has the advantages of three people's handling, reliability and serviceability, long battery life and large load capacity. The structure of the two-axis aircraft is described, and the flight principles of the four basic flight modes of vertical motion, forward and backward motion, roll motion and yaw motion are analyzed in detail, which provides a new application for the wide application and development of the two-axis aircraft. Opportunity.

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