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Development of Hybrid VTOL Inspection UAV

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Abstract

Long-distance oil and gas pipelines are an important energy lifeline. In order to ensure the safety of pipelines, it is necessary to conduct inspections along the pipelines. The traditional inspection method is to rely on inspectors, but there are many disadvantages of inspection by inspectors. UAV inspection can be free of the constraints of terrain conditions, low cost, and high efficiency. Among them, the Vertical take-off and landing fixed wing UAV combines the characteristics of rotorcraft that can take off and land vertically and the long endurance of the fixed wing UAV. while hybrid VTOL UAV has outstanding achievability, reliable technology and low cost. It is more suitable for pipeline inspection operations and is one of the future development directions of pipeline protection.

Keywords

UAV inspection; Hybrid VTOL UAV; Pipeline.

1. Introduction

Long-distance oil and gas pipelines have significant advantages such as low transportation costs, high transportation efficiency, large transportation volume, and high safety performance. Therefore, long-distance pipelines have become the most important way for oil and gas transportation. Meanwhile pipelines have crossed extremely complicated areas such as mountains, rivers, villages, and so on. So, the safety of pipelines is also facing huge threats. These threats are mainly divided into two categories, one is natural factors, that is, various types of geological hazards, such as landslides; the other is human activities, such as third-party construction, illegal occupation. In order to detect and deal with these risk factors in time, it is necessary to inspect. Inspectors inspect pipelines is the main inspection method at this stage. However, there are many disadvantages to rely on inspectors. For example, the terrain in the mountainous areas is dangerous, there are no roads in many places, it is difficult for inspectors to reach the vicinity of the pipeline, resulting in blind spots of inspections. And the professionalism of inspectors is uneven, the quality of inspection is not up to the expected effect.

The UAV inspection is not limited by the terrain conditions, low cost, high efficiency, and can well overcome the disadvantages of traditional inspection. However, due to the limited range of one flight of a common rotorcraft, it cannot meet the long-distance requirements of inspection. And the take-off and landing of general fixed-wing drones are more demanding on the site and the cost is higher, so VTOL UAV is the most suitable for inspection work. The VTOL UAV does not require a large take-off and landing field, and can cruise in fixed-wing mode to achieve a long range. It uses the camera that is on the UAV to collect image or video data along the pipeline, and then uses the corresponding image processing technology to recognize the image or video data， and finally

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combined with manual analysis, risk factors such as geological disasters and third-party construction can be found in time to further ensure the safety of the pipeline.

2. Introduction to vertical take-off and landing fixed-wing drone

Vertical take-off and landing fixed-wing UAV can be roughly divided into four categories according to technical characteristics, tilting culvert fan type, tilting rotor type, hybrid dynamic type and tailstock type

Tilting culvert fan drones usually install multiple lift rotors on the fuselage or wing. During take-off and landing, the rotors provide vertical upward lift. When the plane is flying like a fixed wing, some of the rotors tilt and continue to provide power. The remaining rotors will shut off power. For example, in 2010, Agusta-Westland Company started the Project Zero new tilt rotor one-wing intensive fan advanced technology research machine project, successfully manufactured a verification machine and conducted a series of tests in one year [2], Fig. 1 is real machine display.

Fig.1 Project Zero verification machine on display

The tilt rotor design concept was proposed earlier, and there were already design solutions for the tilt rotor in the 1930s and 1940s, but the development of the tilt rotor drone was relatively late. In the 1990s, American bell company began to develop hawk-eye UAV based on the V22 osprey manned tilt-rotor aircraft. The shape of hawk-eye UAV is similar to that of traditional fixed-wing aircraft. The two-rotor structure at both ends of the wings is used to realize the vertical takeoff and landing and fixed-wing cruise of the UAV, which is mainly used for maritime patrol [3].

The tailstock aircraft first started in Nazi Germany during World War II. The follow-up development was more tortuous, and the tailstock drone is quite different from the other three vertical take-off and landing fixed-wing drones in overall design and control principles. tailstock drones have limited applications mainly in the military field [4].

Hybrid UAV is a new type of vertical take-off and landing fixed-wing UAV that has developed rapidly in recent years. Compared with other vertical take-off and landing technologies, hybrid UAV is simpler in structure and control , leading to its rapid development, and related technologies are becoming increasingly mature. As a new type of effective low-cost vertical take-off and landing aircraft, the hybrid VTOL UAV has considerable performance advantages and can meet the various needs of users. It is expected that the market demand is huge and the future development prospects are broad. Fig2 is a certain type of power compound drone.

Fig2 A certain type of hybrid VTOL UAV

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Combining the advantages and disadvantages of four types of vertical take-off and landing fixed-wing UAVs, the hybrid VTOL UAV has better realizability, low cost, and high reliability, which is more suitable for the development and application of inspection UAV.

3. Overall scheme design

This type of hybrid VTOL UAV adopts a fixed wing—quadrotor and inverted V-tail structure, Fig3. This drone uses Pixhawk open source flight control, and is equipped with LTE module (including WiFi module), data transmission module, Beidou communication module, which constitutes communication system on the drone, so that the drone has 4 kinds of communication means. At the same time, it will be equipped with millimeter wave obstacle avoidance radar and fixed height radar to form an obstacle avoidance module for drones. To ensure flight accuracy, drones will also be equipped with RTK modules. The onboard computer equipped with the drone can realize the intelligent control of the drone. Related parameters are shown in Table 1.

Fig3 hybrid VTOL inspection UAV

Table1 Drone related parameters

wingspan	2750mm	Power	Electric
length	1400mm	material	composite material
time of endurance	120min	practical ceiling height	5000m
maximum take-off weight	11kg	horizontal accuracy	0.01m+1ppm
cruising speed	80km/h	speed accuracy	0.05m/s
payload	1.5kg	wind loading rating	6

As a flight platform, it can be equipped with different cameras and other equipment according to different mission requirements. First the ground station analyzes the weather information and confirms that the weather meets the flight conditions, then it checks whether the communication link system is normal and whether the UAV modules are normal. After confirming that everything is normal, the system issues a take-off instruction. The drone takes off vertically, reaches the designated altitude, and enters the acceleration state. When the flight speed reaches the threshold speed, it automatically switches to the fixed-wing cruise mode. At this time, the four rotors stops working and is powered by the tail propeller. The drone start the fixed-wing cruise successfully ,and fly along the pipeline to perform inspection tasks.

During the flight, the drone keeps communicating with the ground station in real time through the communication system. With camera on the drone, image information along the line is recorded and saved. After completing the inspection, the drone will switch to rotor mode and land automatically in the designated area. The collected image information can be transmitted through the WiFi link installed in the petroleum and gas station, or manually obtained by taking out the SD card. Through the developed image processing software, different targets are identified, such as excavators, water damage. If the corresponding target is identified, an alarm will be given and specific images and location information will be given so that people take follow-up measures.

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4. Related development and debugging work

4.1 Rotor Mode Test

The rotor mode test is mainly to test the control performance of the hybrid VTOL inspection UAV in the quadrotor state. For example, whether the rotor control is stable under vertical take-off and landing, hovering, acceleration and deceleration. In this mode, the UAV only has four rotors working, and the rear thrust tail rotor does not work. Fig4 ,hybrid VTOL inspection UAV is undergoing vertical take-off and landing tests.

Fig4 Vertical take-off and landing test

4.2 Mode switching and automatic flight test

The most important and most dangerous stage of the VTOL UAV flight is its mode switching process, that is, switching from quadrotor to fixed wing and switching from fixed wing to quadrotor. When the drone climbes vertically to a certain height and hovers (at least 20m above the ground, and there is enough space to complete the conversion), the aircraft begin to enter the conversion process of the quadrotor to fixed-wing mode. At this time, the drone uses four rotors to start accelerating flight, and at the same time the tail rotor starts to accelerate. When the airspeed tube detects that the flight speed reaches the speed threshold, the rotor stops working, and the tail rotor continues to provide flight power in fixed mode. The drone has completed the conversion from rotor to fixed mode. Under normal circumstances, this process will be completed within 50-100m. When switching back from the fixed wing to the quadrotor, the push motor will immediately stop rotating, and the four rotors will start at the same time. In this way, the drone will glide in the air for some distance until it hoveres smoothly in the air [5]. Fig. 5 shows hybrid VTOL inspection UAV is undergoing automated flight tests.

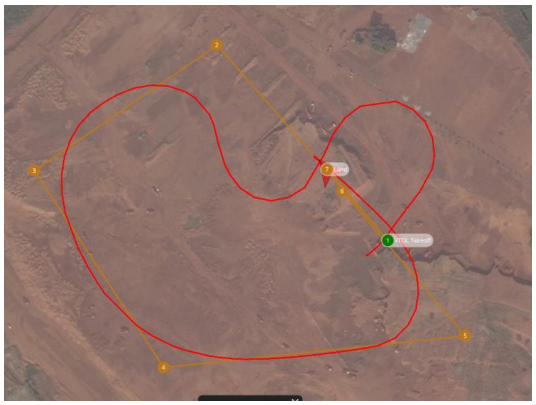

Fig5 automated flight tests

4.3 Development of ground station system for inspection UAV

The Inspection UAV needs to develop a corresponding ground station system to monitor the entire use of the UAV in real time and effectively. Its functions include trajectory planning, pre-flight inspection, acquisition of drone status, and control command sending. Fig. 6 shows the interface of the ground station for the UAV.

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Fig6 Ground Station Interface

5. Conclusion

This paper proposes a project that is using hybrid VTOL UAV to inspect oil and gas pipelines, and briefly introduces part of the development work of the hybrid VTOL inspection UAV. A mature, reliable and efficient UAV inspection system is a complex and huge system that requires constant research and exploration. The use of hybrid VTOL UAV for inspection can effectively reduce costs, greatly improve the efficiency of inspection, fill the blind areas of artificial inspection, and further ensure pipeline safety, which is the development direction of pipeline protection in the oil and gas industry in the future.

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