ISSN: 2664-9640

Multi-mode High-altitude Glass Cleaning Aircraft based on Water Circulation Filtration and Wind-solar Complementation

Yuhuan Xi

School of Electrical and Control Engineering, North China University of Technology, Beijing, 100144, China

Abstract

With the development of society, there are more and more high-rise buildings, and the glass of high-altitude buildings has accumulated dust for a long time, excrement of birds and beasts, and rainwater stains, resulting in a significant decline in lighting and aesthetics. The existing scheme has two modes: manual and electric cleaning, but the manual operation faces the dilemma of danger and low efficiency. The electric power equipment is often a jet aircraft, which needs to hover in the air for a long time, needs to carry a large amount of water resources, and consumes a lot of energy. In this work, a water-saving intelligent high-altitude work cleaning aircraft based on water circulation filtration and wind-solar hybrid power storage, with functions such as self-cleaning and solid-liquid garbage separation is designed through modeling. This cleaning-system use Activated carbon to filter sewage to maximize the purification and reuse of sewage. The power storage adopts the wind-solar complementary power supply mode, which plays an energy-saving role. The foldable innovative mechanical structure can be transferred in flight mode when encountering obstacles. Adjust the water output according to the glass surface situation, and intelligently control the purpose of cleaning with the most minor water consumption.

Keywords

Water Circulation; Complementation of Scenery; Energy Saving and Water Saving; Working at Altitude; Intelligent Control.

1. Introduction

The system includes a control module, a wind-solar hybrid power generation and storage module, a two-state mechanical module for flying and climbing, and a solid-liquid separation module. In general, it includes wind power generation and photovoltaic power storage to achieve energy-saving benefits, flying two-state rotating shaft mechanical unit to complete autonomous obstacle crossing operations, solid-liquid separation unit and water circulation filtration system to achieve water-saving[2] benefits.

2. Basic System Introduction

2.1. Electrical Control

2.1.1. Main Control Unit

Stm32F407 as the core processor, real-time acquisition of aircraft gyroscope attitude information, combined with cascade PID control algorithm to drive the signal on the motor. [3]And according to the ultrasonic module, the signal of the stain detection unit completes the control of the driving motor and the signal transmission of the water tank flow control unit when the aircraft flies, folds and climbs in real time [4].

2.1.2. Water Flow Control

Real-time control of water flow according to the set threshold and the glass stain degree obtained by the glass stain detection unit.

2.1.3. Glass Stain Detection

Detect the amount and type of stains in the surrounding environment of the glass cleaner, and form a detection signal.

2.1.4. Motor Drive

Used to control the signal according to the control signal to drive the four-axis wing of the cleaner to work, and the four-axis aircraft to fly across the obstacles. In the climbing state, adsorption at one end of the cleaner and the other end extension, the cleaner is climbed and moved on the glass.

2.1.5. Ultrasonic Obstacle Avoidance

Detect wall or other obstacles, obtain position information, and feedback the distance to the central control unit in real time.

2.1.6. Wind and Solar Complementary Storage

The wind drive motor generation using ac/dc collator generator output alternating current into direct current; The electric energy obtained by solar photovoltaic panels uses dc/dc regulator to change into a stable voltage, which is jointly stored in the energy storage device.

2.1.7. 5G Communication Unit

Based on TCP communication protocol, establish WIFI communication between robot and mobile terminal or remote control terminal, connect with ESP8266 module and wireless coordination device through serial port, design the upper computer software, to realize real-time data display function, historical data storage function, gateway control parameter setting and query function, Internet remote access and control function.

2.2. Mechanical Part

The mechanical design of the floor cleaner includes flying and climbing two-state obstacle crossing components; Water circulation system; Solid-liquid separation scrubbing device; Wind-wind complementary electric storage components.

Figure 1. Mechanical explosion diagram parts display

2.2.1. Two-state Obstacle Crossing Structure of Flying and Climbing

The multimodal obstacle crossing structure can be switched between flying attitude and climbing cleaning attitude. The flight components include the body, wing arm and propeller blade. Spiral blades on the four wings rotate to move the aircraft up and down horizontally. The climbing mobile component comprises a rotating disc shaft body, which drives the wing and the suction cup to make the quadcopter rotate alternately through the wing arm in the wiping state, thus realizing the wiping of the glass. One wing arm adsorbs, one end extends, and then adsorbs and contracts. The folding components of the aircraft include connecting rod bearings that can be folded 90 degrees on both sides, so that the first body and the second body can turn back at a preset Angle when the flight attitude is changed from the folded buffer attitude. When encountering the wall and obstacles, the excessive attitude that changes from flying attitude to climbing attitude can be adsorbed and suspended on the glass.

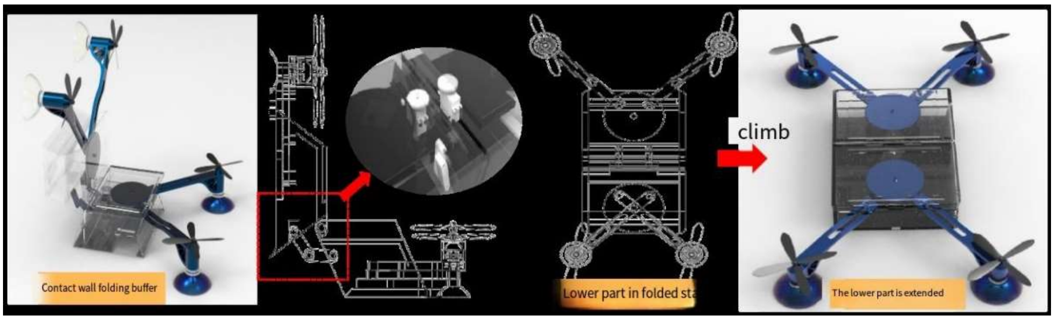

Figure 2. Schematic diagram of the climbing attitude of the glass-cleaning aircraft

2.2.2. Water Circulation Filtration System

The filter device is arranged at the bottom of the sewage tank, including a filter net, a filter shell, a diatom soil layer and an activated carbon layer. When working, the sewage flows down from the bottom hole of the sewage box, first through the filter, and filters out large particles of impurities, continues to flow into the diatom soil layer below, which can filters out magazine particles with a diameter of 0.7 microns or more, and finally flow[5]through the activated carbon layer to remove the pollution substances such as watercolor odor, organic matter, heavy metal ions and bacteria in the sewage.

2.2.3. Wind Power Generation Components

When the cleaner is attached to the glass climbing operation in the climbing state, the wind drives the rotating blade to rotate, and the second electrode is driven to rotate through the electrode lead. The first electrode layer is a magnetic electrode plate, which generates electricity by cutting the magnetic field line. The four groups of electrode rotating blades can be used as wind-drive components to generate electricity.

2.2.4. Solid-liquid Separation Scrubbing System

The floor wiping device is driven by a motor set in the sponge cylinder. It rotates counterclockwise when it drags the floor forward, driving garbage and dirt to enter the mechanism counterclockwise. Garbage passes through a guide surface that can be close to the floor and close to the sponge layer of the floor wiping device. The rotating sponge layer of the floor wiping device drives part of garbage along the guide surface into the garbage collection device through friction. The sponge layer continues to rotate upward and comes into contact with the brush roller. Since the adjacent gaps between the spirally arranged hairy cleaning pieces on the brush roller are smaller than the size of the dry waste and the hair, the dry waste will be scraped into the dry waste chute instead of passing through the brush roller. When entering the water circulation guide groove, the sewage inside the sponge cylinder is squeezed by the squeezing part, and it can flow into the inner cavity of the circulation guide groove. The garbage collection device is arranged at the back and bottom of the sponge cylinder. Under the premise of not affecting the rotation of the sponge cylinder, the distance from the sponge cylinder is as close as possible to avoid the garbage leaking out from the gap between the sponge cylinder and the dustbin.

3. Calculate the Theoretical Design

3.1. Scientific Design

Table 1. Design basis of aircraft parameters

Projects	Parameters	Design basis
Mechanical parameter	· Length: 40cm · Height: 12cm · Width: 30cm	Technical specification for glass curtain wall process JGJ1022003 4.3.12
Operation counterweight	· Self weight: 8kg · Water weight: 5kg · Stain waste: 1kg	Ultralight Aircraft -- Aircraft Design (T/AOPA 000X-2018)

3.2. Force Analysis

During the climbing process, the aircraft completes the two tasks of loading load and applying scrub pressure through the suction cup.

The model is equivalent, Ni is the normal supporting force of glass facing the i th suction cup, i=1,2,3,4; Vi is the vacuum suction force of the i th sucker, i=1,2,3,4; Ffl is the friction force of the glass against the i th sucker, i=1,2,3,4.

The friction generated by the suction cup balances the robot's gravity:

$$\sum_{1}^{4} F_{fL} = G \tag{1}$$

Want the cleaner not to overturn down, under the action of overturning torque to reach: Ni>0

Vertical force satisfied:

$$(N1+N2+N3+N4)-(V1+V2+V3+V4)=0 \tag{2}$$

Balance moment equation with center as origin column:

$$(N_1+N_3-V_1-V_3)\times\frac{L}{2}+(N_2+N_4-V_2-V_4)\times\sqrt{(\frac{L}{2})^2+D^2}=G\times \mathrm{h} \tag{3}$$

The suction produced by the sucker is:

$$V=V_{\mathrm{i}}=P\times S, i=1,2,3,4 \tag{4}$$

Where represents the vacuum degree of the sucker and S represents the effective adsorption area of a single sucker.

The critical suction force of the sucker can be obtained by the formula as follows:

$$V>Gh/2(\sqrt{(\frac{L}{2})^2+D^2}) \tag{5}$$

ISSN: 2664-9640

Bring in the cleaner parameters: h=0.12m, =0.74, D=0.05m, L=0.4m, the "u" best suction cup pressure can be obtained as 40.77N. Through manual tests, the optimal pressure required for glass cleaning is about 39N, proving that the aircraft can meet the requirements of scrubbing operation.

The equivalent stress of vacuum suction cup is analyzed when the optimal scrub pressure is applied and the average weight is balanced. It can be seen that the maximum equivalent stress is 1.0259 MPa, which is far lower than the tensile limit of Dingqing rubber 25 MPa. The total deformation is about 5mm, and four suction cups are used to work at the same time. The shape variable is far less than 5mm, the aircraft will not fall, meets the design requirements, good stability.

3.3. Wind-wind Complementary Power Storage

3.3.1. Photovoltaic Power Generation

The approximate formula for solar intensity and air mass is as follows:

$$I = 1.1 \times I_o \times 0.7^{(AM0.618)} \tag{6}$$

According to the above formula, the power density of sunlight exposure is about $P_s = 700W/m^2$, and now more mature solar cells, their power generation efficiency can be approximately reached above $\eta = 20\%$, meaning that a square meter of solar panel power is about 140W. The solar panel area of the device is $S = 0.25m^2$ .The average annual sunrise time is taken $te = 1520h$, and the annual solar power generation is calculated as:

$$Q_{1a} = P_s \eta t_e S = 0.7 \times 20\% \times 1520 \times 0.25 = 53.2KW \cdot h \tag{7}$$

Scrub once a quarter, and the average solar energy usage is:

$$Q_1 = Q_{1a} / 4 = 13.3KW \cdot h \tag{8}$$

3.3.2. Wind Power

For wind power generation, the average high-altitude wind energy utilization coefficient of the city is taken as the average $C_p = 0.27$,wind energy density $E_w = 200W/m^2$ and the fan mechanical efficiency is $\eta_w = 0.9$, then the average annual wind energy generation is:

$$Q2a = EwCp\eta w = 0.2 \times 0.27 \times 0.9 \times 24 \times 365 = 425.7KW \cdot h \tag{9}$$

Scrub once a quarter, and the average solar energy usage is:

$$Q_2 = Q_{2a} / 4 = 106.4KW \cdot h \tag{10}$$

3.3.3. Total Energy Consumption of the System

According to the above theoretical calculation, it can be obtained that the total annual power generation of four wind power generation and one solar energy storage device is: the rated power of this device is about 6.9kW, the cleaner works continuously for 15h every quarter, and its power consumption is: Q=119.7KW.h,W=103.5KW.h .It can be seen that Q>W, so the installation of the 4 groups of wind power generation and a solar panel, the power generation is fully enough to support the power supply work.

ISSN: 2664-9640

4. Working Principle and Performance Analysis

Figure 3. Schematic diagram of the workflow of the glass-cleaning aircraft

Data interaction with the aircraft is carried out through 5G communication, and the completion area of high-altitude work is set.

The aircraft performs attitude calculation through the gyroscope module, and the propeller blade and four-axis motor drive the flight. After arriving at the working area, the ultrasonic module receives the distance information of the wall, and the connecting rod is folded and tilted 90 degrees to the wall. The four-axis wings are equipped with suction cups, which are fixed behind the glass. Begin to complete the task of scrubbing the climbing attitude.

When the sponge layer contacts the glass, one wing is extended through the internal turntable structure of the body, and the other side is still fixed, so that the aircraft can climb on the glass. When the sponge layer of the scrubbing and cleaning device rolls, it can drive solid waste along the guide surface into the garbage collection device.

The sponge layer continues to rotate upward and comes into contact with the brush roller part of the cleaning device. Since the adjacent gap between the spirally arranged hairy cleaning pieces on the brush roller is smaller than the size of the dry garbage and the flocculent, the dry garbage and the flocculent are scraped into the dry garbage chute and separated from the liquid. The sponge cylinder is extruded by the extruding rod, and the extruded sewage enters the inner cavity of the guide tank. Under the action of the pump, the sewage will be pumped from the side of the water circulation guide tank through the pipeline into the upper sewage box. The sewage box is connected to the filter below, the sewage flows down from the bottom hole of the sewage box, first through the filter net, and filter out large particles of impurities, continue to flow into the diatom soil layer below, which can filter out magazine particles with a diameter of 0.7 microns or more, and finally flow through the activated carbon layer [6] to remove the pollution substances such as heterocolor odor, organic matter, heavy metal ions and bacteria in the sewage. After sewage treatment, it flows into the clean water storage box, waiting for secondary use.

The wind-swept process is accompanied by the entire task. The wind drives the four-axis wing blades to rotate, and the mechanical energy is converted into electrical energy by acting on the motor. When light energy is abundant, the photovoltaic panel accumulates electricity, and the above two kinds of electric power are arranged and stored in the battery through the circuit. When the aircraft meets the wall and other obstacles, it can be restored to the folded state and transferred to flight mode for regional transfer. After completing the operation, return according to the set area.

ISSN: 2664-9640

5. Conclusion

The multi-modal high-altitude glass cleaning aircraft with water circulation filtration and wind-solar complementation innovatively uses the wind-solar hybrid power storage, flight and climb two-state obstacle crossing mechanical structure and 5G data exchange transmission technology, which is convenient to operate, excellent cleaning effect, low cost, long service life, and has significant energy-saving and water-saving impact, and can solve the problem of transferring obstacles encountered in high-altitude work, and has a wide range of applications.

References

[1] WANG Qiang. Research on Mechanism and Control System of Household glass cleaning Robot based on Modularization [D]. Hebei university of technology, 2018. DOI: 10.27105 /, dc nki. Ghbgu. 2018. 000310.

[2] Lihan. Solar battery system design and optimization of the [D]. Harbin Institute of Technology study, 2021. The DOI: 10.27061 /, dc nki. Ghengdu. 2021.002552.

[3] Yang Shangjun. Research on Control Simulation of wind-wind complementary Power Generation System [J]. Journal of Jiamusi University (Natural Science Edition),2022,40(05):20-24+38.

[4] FENG Liang, Xu Jianxin, CHANG Fengjun. Design of high-altitude intelligent glass cleaning Robot based on STM32 [J]. Science and Technology Innovation,2020(14):191-192.

[5] NIU Liqun, Sun Xiaopu. Household cleaning robot technology development trend and present situation of [J]. Science and technology to create new, 2020, No. 156 (12) : 74-75. The DOI: 10.15913 /j.carol carroll nki kjycx. 2020.12.030.

[6] Cao Yunheng. Study on optimization of combined treatment of landfill leachate with diatomite, zeolite and activated carbon [D]. Northeastern University,2014. (in Chinese).