Research on a New Type of Self-adaptive and High-efficiency Umbrella Dryer

Zijun Long

School of Naval Architecture, Ocean and Energy Power Engineering, Wuhan University of Technology, Wuhan 430070, China

longzijun0802@whut.edu.cn

Abstract. The new adaptive and high-efficiency umbrella dryer dries the wet umbrella during the rotation and translation process through the upper and lower conveyor belts. The detection module collects parameters such as the diameter of the umbrella surface structure, and by controlling the wind pressure, wind temperature, and tracking the transmission position of the umbrella surface through the adaptive blowing port, the umbrella surface can be dried efficiently. The air outlet of the umbrella dryer faces the road surface of the shopping mall to ensure the drying of the road surface and realize the "one wind and two uses" of the centrifugal fan. The whole device has high air-drying efficiency and short waiting time for customers. the umbrella air-drying device runs through the transition space between the inner and outer doors of large shopping malls and supermarkets. When consumers enter, they place the umbrella on the conveyor belt of the device, and then they can directly walk into the inner door of the mall to take out the dried umbrella. The whole set of devices is efficient and intelligent, ensuring that consumers do not need to stay and waiting in the case of high traffic in shopping malls, improving consumers' shopping comfort, greatly reducing the use of umbrella bags, and preventing white pollution.

Keywords: New Adaptive; Umbrella Dryer; Centrifugal Fan.

1. Research Background and Meaning

In rainy and snowy weather, major shopping malls, supermarkets, cinemas and other commercial venues will provide free plastic umbrella covers in order to improve consumer experience and consider environmental safety issues. On the one hand, it solves the inconvenience of carrying wet umbrellas for consumers, and on the other hand, it prevents slippery roads in shopping malls and supermarkets, and avoids people falling, especially the safety hazards caused by trampling in the case of large traffic [1]. Because the umbrella cover is one-time use, the demand is large and it is difficult to recycle, resulting in a lot of "white pollution". According to the survey and statistics, in the first quarter, the monthly consumption of disposable umbrella bags in commercial establishments has maintained an average of hundreds of thousands to millions. There are news reports that a shopping mall in Guangzhou consumes more than 20,000 umbrella bags on rainy days, as shown in Figure 1.



Figure 1. The trash can and related news at the entrance of the shopping mall after the rain

2. Research Status at Home and Abroad

At present, there are more than 10 patents related to umbrella water removal devices, which can be roughly divided into two methods: rotary drying method and heating drying method. Announcement numbers CN205536899U, CN205316891U and other Chinese patents do not involve structural optimization, and the method of rotating and drying is used, which is difficult to quickly dry the umbrella surface and has low efficiency, which is prone to retention. The patent with the announcement number CN104976874A does not realize mechanical automation and still uses the method of packaging umbrellas in plastic bags, which is inefficient and continues to cause white pollution. The existing foreign research programs are consistent with the existing Chinese patents, and they do not follow the trend of energy conservation and emission reduction, nor do they meet the market demand. There are a series of problems such as low efficiency, long time, high energy consumption, and high cost[2].

Due to the special structure of the umbrella, the violent centrifugal motion of the above-mentioned patent not only cannot completely dry the rainwater remaining on the pleated umbrella surface, but also easily causes damage to the umbrella handle, skeleton and umbrella surface. After investigation, analysis and comparison, the team team designed a new type of adaptive and efficient umbrella drying machine, which can achieve the effect of water removal and quick drying of the umbrella[3].

3. Device Introduction

The device consists of four modules: a transmission module, a detection module, an adaptive control module, and an air temperature and air pressure adjustment module. The conveying module consists of two upper and lower conveying belts. The umbrellas are clamped by clamps and fed into the device for drying. Customers can easily pick them up at the exit. The detection module detects whether there is an umbrella on the conveyor belt to control the operation of the conveyor belt; by detecting the diameter of the umbrella surface and the humidity of the umbrella surface, the heat generated by the PTC ceramic material and the output wind pressure of the centrifugal fan are regulated. The air temperature and air pressure adjustment module is composed of a centrifugal fan, a variable frequency speed controller and a PTC electric heating element. It controls the rotational speed of the centrifugal fan to realize wind pressure control, and controls the current of the ceramic electric heating element to realize air temperature adjustment [4]. The self-adaptive control module adopts the programmable logic controller (PLC) as the control core, through the real-time data collected by the detection module, the control logic output controls the transmission module, adjusts the air temperature and air pressure, and reduces the energy consumption of the device. And control the dot gust air outlet switch, so that the umbrella can achieve the drying effect after the conveying stroke. The whole device is equipped with an air outlet on one side of the pedestrian passage, which can ensure the dryness of the road surface of the shopping mall at the same time. Based on the above four modules, the team team completed the design of the new adaptive and efficient umbrella dryer. The simplified 3D modeling of the design idea is shown in Figure 2.

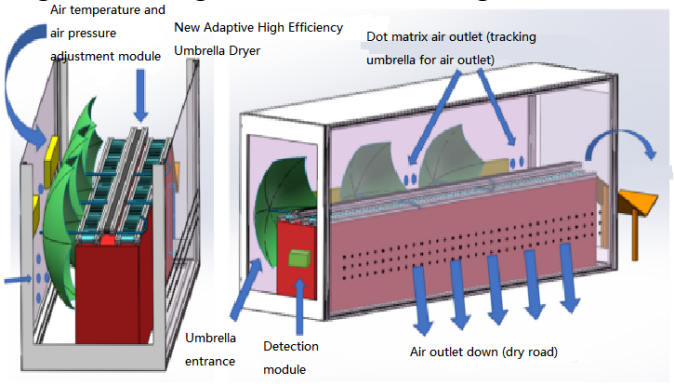


Figure 2. 3D sketch of the air-drying umbrella device

4. Project Innovation Point

The device effectively replaces the disposable umbrella bags provided by large commercial places, greatly reducing white pollution.

According to the parameters simulated by the static experimental bench, using MATLAB simulation, the functional relationship between the diameter of the umbrella surface and the drying time, wind pressure and wind temperature is obtained, which is the theory for realizing the fine control of umbrella drying[5].

An adaptive control method based on dot tuyere tuyere tracking is proposed, that is, after the drying of the temperature and pressure regulating module is controlled according to the real-time parameters of the umbrella, the dryness of the umbrella surface is detected, and the secondary drying is judged to realize self-adaptive adjustment and energy efficiency control.

5. Energy Saving and Emission Reduction Benefit Analysis

5.1 Economic Benefits

Based on the requirements of the "plastic restriction order", the use of non-degradable plastic bags has been gradually banned across the country, and the cost of biodegradable plastic umbrella covers is 50 times that of the original product, reaching 0.16 yuan per bag. According to an average of 10,000 plastic umbrella covers distributed in each shopping mall on rainy days, it costs 1,600 yuan, but the environmental problems and white pollution caused by plastic umbrella covers cannot be measured in numbers. The air temperature and air pressure adjustment module in the device realizes "one air and two uses", which can replace the centrifugal fan originally used for drying the road at the entrance of the shopping mall. Taking Guangzhou as an example, the average annual rainy days in each district is 152 days, and there are about 170 shopping malls. The cost of the centrifugal fan is about 340,000 yuan. Enlarging this number to rainy cities across the country will bring considerable environmental protection effects. This product is a new type of self-adaptive and efficient umbrella dryer suitable for large public places. It changes the original method of handling umbrellas and saves a lot of manpower and financial resources [6].

5.2 Social Benefit

"Not only invaluable assets, but also lucid waters and lush mountains", the concept of environmental protection in my country has become more and more popular. On January 19 this year, the National Development and Reform Commission and the Ministry of Ecology and Environment issued the "Opinions on Further Strengthening the Control of Plastic Pollution". A phased ban on 13 types of plastic products in 2020, 2022 and 2025. The device not only greatly reduces the use of umbrella covers and eliminates the generation of white pollution, but also helps to promote the concept of environmental protection and promote a low-carbon and healthy lifestyle [7].

5.3 Promotion Prospects

The device replaces the disposable plastic umbrella covers distributed in large public places, can effectively solve many problems caused by wet umbrellas to the indoor environment, and at the same time helps to solve white pollution. It not only complies with the national "plastic limit order" policy requirements, but also brings good economic and social benefits. At the same time, the device can face all large indoor public places, such as large shopping malls, office buildings, etc. in the text, and can also face public places such as high-speed rail stations and subway stations, bringing convenience to people and benefits to enterprises, and has a good promotion prospect [8].

6. Research Content

The operating relationship of the modules is shown in Figure 3. The detection module inputs data to the adaptive control module, and the control module judges whether the umbrella exists, so as to control the transmission module; judges whether the umbrella is dry, so as to control the wind temperature and pressure adjustment module. Finally, the dot matrix air outlet is controlled according to the speed of the conveyor belt to ensure that the umbrella is transported to the corresponding position by the drying effect of the blowing hole, so as to realize the efficient and energy-saving operation of the whole device.

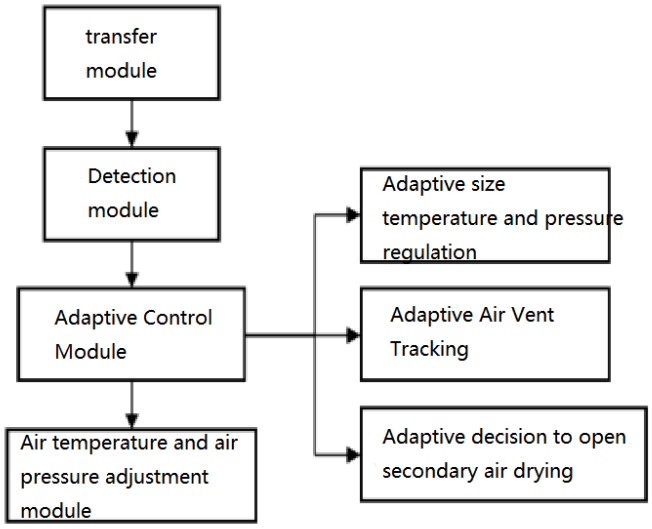


Figure 3. Diagram of module coordination and operation

6.1 Transfer Module

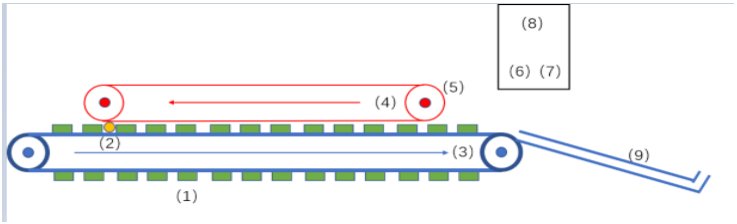


Figure 4. Sketch map of the upper and lower conveyor belts

The transfer module can rotate and transfer the umbrella to the end, which is convenient for users to pick up. The schematic front view is shown in Figure 4. The module includes a specially customized "skirt-shaped corrugated sidewall" conveyor belt (1) at the bottom. Some umbrella handles have the same diameter. Below the umbrella is a forward transmission mechanism (3), and above the umbrella is a reverse fixed pressing mechanism (4) and a synchronous pulley (5). Connected to the two conveyor belts is a gear box (8), which contains a transmission shaft (6) and a servo motor (7) connected to the transmission shaft. The rear of the device is provided with a double-layer umbrella buffer guide rail (9).

The "skirt wavy sidewall" conveyor belt can fix the umbrella pole laterally and carry the umbrella horizontally[9]. The compression conveyor belt above the umbrella can compress the umbrella handle in the groove to limit the radial movement of the umbrella. The relative movement of the upper and lower conveyor belts drives the rotation of the umbrella shaft to force the umbrella surface to rotate, and the centrifugal force generated by the rotation can be taken away. Most of the remaining water droplets on the umbrella surface improve the drying efficiency of the umbrella. And the length of the bottom "skirt corrugated sidewall" conveyor belt is longer than that of the top conveyor belt, which

is convenient for putting in and picking up umbrellas. The schematic diagram of 3D modeling is shown in Figure 5.

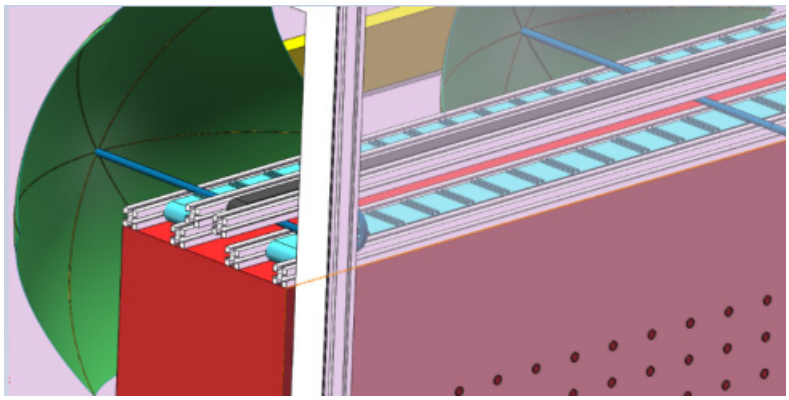


Figure 5. Schematic diagram of umbrella transmission module assembly

6.2 Detection Module

The intelligent detection module is divided into three areas, namely the placement area, the water removal area, and the umbrella removal area. The distribution diagram is shown in Figure 7.

The placement area contains 2 infrared sensors, the infrared sensor 1 is used to detect whether there is an umbrella on the conveyor belt, and the infrared sensor 2 is used to detect the time when the umbrella completely passes through it. The ABB PLC processor can calculate the diameter parameter of the umbrella surface through the speed of the conveyor belt and the time when the umbrella completely passes through the infrared sensor 2, and at the same time call up the corresponding wind temperature and wind pressure in the database.

The water removal area is divided into A area, detection area, and B area. Both areas contain air temperature and air pressure adjustment modules and adaptive control modules. Area A is the main drying area for the umbrella, and the wind temperature and pressure adjustment module dries the umbrella according to the corresponding wind pressure and wind temperature output from the database. When the umbrella passes through the detection area, the temperature sensor measures the ambient temperature T1, the infrared temperature sensor measures the umbrella surface temperature T2, and the ABB PLC processor judges whether the umbrella is dry by comparing the difference between the temperature values T1 and T2. Area B is an additional drying area with adaptive function. If the umbrella surface is dry, it means that the size of the umbrella surface meets the expectations of the database, and all components in Area B will stop working. If the umbrella surface is not dry, the centrifugal fan and the air temperature and pressure adjustment module in the B area are restarted, and the drying of the umbrella surface is accelerated through the adaptive control module[10].

The umbrella taking area contains an infrared sensor 3, which is used to detect whether the dried umbrella in the umbrella taking area is successfully taken away by the user. If there is umbrella accumulation, the umbrella transmission module is controlled by the control module to reduce the speed of the conveyor belt or directly command the module. Stop running.

6.3 Adaptive Intelligent Control Module

6.3.1 Adaptive Size Temperature and Pressure Regulation

The relevant database is established by designing experiments, and the data is detected by the detection module to find the temperature and pressure of the wind corresponding to the state of the umbrella surface, and manipulate the PTC ceramic heating and the fan frequency conversion governor to quickly adjust, forming a negative feedback with the temperature sensor and the wind pressure sensor. Accurate control of air temperature and air pressure combined with adaptive air outlet system to complete accurate control of air pressure, air temperature and three-sided tracking.

6.3.2 Adaptive Air Vent Tracking

Through the big data analysis of pedestrian step length and walking habits in the early stage and the design of the mechanical length of the device, the team calculated the appropriate transmission speed. According to the sensor opening and closing time difference returned by the infrared sensor, combined with the calculated rotation speed, calculate the umbrella surface diameter d and area S:

$$S = \pi[d^2 + (v_o \cdot \Delta_t)^2]$$

Calculate the position of the center point of the umbrella according to the on-time of the infrared sensor recorded by the PLC and the speed v of the conveyor belt, control the opening of the solenoid valve of the air vent within the umbrella surface according to its position and area, and open or close the corresponding solenoid valve with the movement of the umbrella.

6.3.3 Adaptive Decision to Open Secondary Air Drying

Adaptive pressure and temperature regulation according to size

Temperature adjustment module: Area A compares the database with the detection results of the infrared temperature sensor to find out the umbrella surface condition and the temperature data corresponding to the umbrella surface parameters, and quickly heat up to meet the demand. If it is detected that the umbrella surface is not dry in the B area, it will be heated.

Pressure regulating module: During operation, area A compares the detection results of the infrared temperature sensor with the database to find out the condition of the umbrella surface and the wind pressure data corresponding to the parameters of the umbrella surface. The frequency conversion governor controls the motor frequency, differential pressure, adjusts the fan speed, and quickly meets the demand. In area B, after the decision of the intelligent control module, if it is detected that the umbrella surface has not been dried, a large air volume will be activated to carry out the next drying.
Adaptive air outlet module

It is divided into two areas, A and B. Area A is a 510-dot matrix air outlet with a total area of 1600mm3200mm, and area B is a 55-dot matrix air outlet with a total area of 1600mm1600mm. The single hole area is a circular hole with a diameter of 24mm, and the valve is Small solenoid valve used to control the opening and closing of through holes. The infrared temperature sensor between the area A and the area B detects the drying condition of the umbrella and determines whether the area B heats the umbrella in real time. Zone B uses the same method to dry the umbrella to ensure the drying of the umbrella.



Figure 6. Schematic diagram of small solenoid valve

6.3.4 Temperature and Pressure Regulation Module

Hardware: It is composed of centrifugal fan, PTC ceramic heating component and frequency converter.

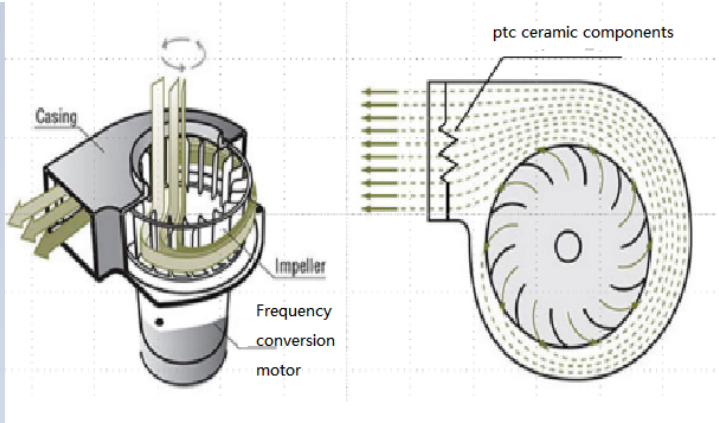


Figure 7. Schematic diagram of air temperature and air pressure module components

Temperature adjustment method: The generation of hot air in the process of drying the umbrella is mainly provided by the PTC ceramic components placed at the outlet of the fan. PTC is a positive temperature coefficient heat-sensitive material, which has the characteristic that the resistivity increases with the increase of temperature, and it can heat up rapidly, as shown in Figure 8. Its regulation can be achieved by changing the voltage.

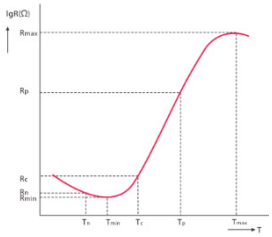


Figure 8. Relationship between temperature and resistance of PTC ceramic components

7. Analysis Conclusion

The device has the characteristics of easy acquisition of materials, low cost, simple mechanical structure and the like. The device adopts the synchronous transmission of the upper and lower conveyor belts, and the gearbox has a simple structure to ensure the feasibility of the mechanical structure. The follow-up team will use the AMADS software to simulate and analyze the performance, range of motion, peak load, and input load of the finite element calculation of the mechanical system of the entire device to ensure operational stability.

The adaptive control device plans to use ABB AC500-eCo programmable logic controller (PLC) as the core of the control module. The PLC is a small, scalable and flexible PLC with simple structure, low cost and strong compatibility. AC500-eCo has been recognized by the world certification body, and users can build the system architecture safely and reliably.

References

[1] Design of an umbrella automatic arrangement and quick-drying device [J]. Li Jiang, Qu Huiqin. Information Communication. 2019(03).

[2] Research and Design on the Disposal Method of Entrance Umbrellas in Indoor Public Places [J]. Huang Xiaotian. Design. 2019(20).

[3] Utility model patent "Umbrella Companion" environmental protection rain gear filter bag design - a research report on Hangzhou as an example [J]. Jin Xia, Li Ou. Science and Technology Prospect. 2016(04).

[4] Research and Design of a Portable Umbrella Dryer [J]. Cheng Xin, Zhou Jie, Shi Daoling, Jiao David, Shi Shuosuo, Wang Qiang, Ding Tongmin, Yu Hengfeng, Cao Jingwei, Wang Xin. Science and Technology Innovation. 2021(04).

[5] Design of Umbrella Dryer Umbrella Dryer [J]. Li Xuange. Beauty and Times (Urban Edition). 2021(06).

[6] Flower Umbrella [J]. Guo Ruigang. Portrait Photography. 2010(08).

[7] Big Ben's umbrella stand[J]. Lin Shudi. Video Vision. 2010(12).

[8] Using a bicycle umbrella stand to shield the camera from wind and rain[J]. Chen Yao. Camera. 2007(03).

[9] Trend Frame [J]. Shaanxi Archives. 2012(03).

[10] Automatic drying umbrella bag machine[J]. Chang Yuancheng, Li Zhenglong, Wang Yan. China New Communication. 2020.