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Design of Lubricating Oil Circulation Refrigeration System for Cigarette Machine

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Abstract. In order to solve the problems of high lubricating oil temperature, fast aging of seals and serious wear of parts during high-speed operation of equipment, a lubricating oil circulation refrigeration system for cigarette machine was designed. The system uses PLC as the main controller, and controls the motor speed through Profibus bus mode to realize the circulating refrigeration of lubricating oil. Through the test with ZJ112 unit as the object,we found that the system runs well and the failure rate is low. The temperature of each lubricating part of the equipment is significantly reduced and kept below 40 ˚C. At the same time, the maintenance time of the equipment is reduced, and the occurrence of cigarette quality accidents is reduced. This technology can provide support for improving the production adaptability of cigarette units.

Keywords: Lubricating oil; PLC control; Cycle refrigeration; Constant temperature control.

1. Introduction

With the development of cigarette equipment for high-speed intelligence, the requirements of the machine for the cooling system are getting higher and higher [1-3].However, in the actual production process, there are lubricating oil leakage, gear wear and other phenomena in the cigarette packaging equipment. The main reason is that the lubricating parts accumulate heat continuously during the high-speed and long-term operation of the equipment, which leads to the continuous increase of the temperature of the lubricating oil, thus accelerating the aging of the rubber seals and the wear of the parts. The phenomenon of running, falling, dripping and leaking of the lubricating oil on the equipment is common. In severe cases, it will pollute cigarettes, cause product quality accidents, and even cause abnormal operation of the equipment and reduced service life. The equipment seals are replaced frequently, and the equipment maintenance workload is large.

In view of the above problems, Wang Jifeng et al designed a cooling oil circulation system by analyzing the working principle of the oil seal in the transfer device and the cause of the oil leakage, which effectively reduced the oil temperature of the thermal balance in the cavity of the transfer device, and prolonged the maintenance cycle of the transfer device by 6 months, but it did not completely solve the essence of the aging of the oil seal of the manipulator [4]. Lin Zhihua used the clean wind of the equipment to transfer the heat in the lubricating oil. This measure has a certain cooling effect, but the maximum temperature is still 55 ˚*C* [5]. Wang Shangrong added a flow control device and an automatic oil shortage alarm system to the oil supply pipeline of the auxiliary gearbox, which effectively solved the running bar fault caused by the wear of the internal gear of the auxiliary gearbox [6]. Han Weizhong et al used closed water circulation to transform the central cooling of the lubricating oil system of the flue gas turbine through the two-stage heat exchange method, which effectively solved the problem of oil temperature cooling of the lubricating oil system of the flue gas turbine [7]. However, this method is special and does not apply to all cigarette factories. Therefore, this paper optimizes the design of the lubrication system of the cigarette machine, and explores a greener, safer and more efficient heat exchange method. Through the Thermostat control method to achieve preventive maintenance, solve the problem of high temperature caused by closed centralized oil supply, and improve product quality.

2. Problem description

At present, the lubricating oil of the mechanical transmission of the VE and SE parts in the cigarette unit is supplied by the main oil tank of the equipment. When the equipment is in long-term operation, the heat generated by the lubricating parts of the VE and SE parts of the equipment is accumulated back into the main oil tank through the lubricating oil, resulting in the oil temperature of the main oil tank getting higher and higher. Through the temperature accumulation of continuous circulation lubrication, the operating oil temperature of the equipment is about 60 $^{\circ}C$.When the temperature reaches a certain value, the viscosity of the lubricating oil will decrease sharply with the increase of temperature. The viscosity is too high, the oil film is difficult to form ; the viscosity is too low, the oil film layer is too thin, the lubrication effect will decrease, and the wear of the parts will increase, so the temperature of the lubricating oil is generally controlled between 30-40 $^{\circ}C$. At the same time, for rubber products, the aging rate is about doubled for every 10 $^{\circ}C$ increase in the use temperature, so the aging of the seal has become the culprit for the leakage of lubricating oil and the pollution of cigarettes. In particular, the spider hand gearbox in the SE part, which is lubricated with a closed oil bath, accumulates heat after a long period of continuous operation of the cigarette equipment, up to 70 $^{\circ}C$. If the lubrication system lacks an effective heat exchange method, the heat generated under high-speed operation will always be unable to dissipate.

3. System design

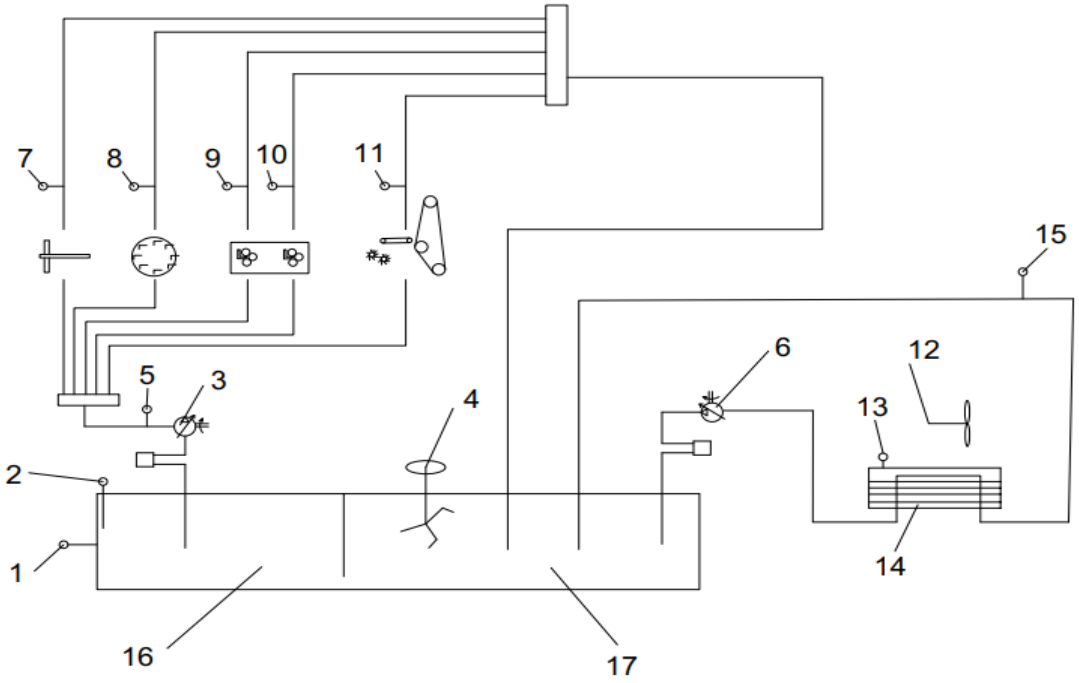
3.1. Structure composition

The lubricating oil cycle refrigeration system is mainly composed of oil pool, oil supply unit, oil temperature outlet detection unit and thermostat control cycle unit, as shown in figure 1. The oil pool is divided into the oil supply area and the thermostat control circulation area through the bottom connected partition.

The oil supply unit includes oil temperature sensor, oil level sensor, oil supply motor and inlet oil pressure sensor. The oil temperature sensor is set on the left side of the oil pool to detect the oil temperature in the oil supply area. The liquid level sensor and the oil supply motor are set above the oil pool cover plate, which are used to detect the level of the oil pool and the oil supply respectively. The inlet oil pressure sensor is set on the pipeline at the oil supply inlet to detect the oil supply pressure of the pipeline, and the oil supply pressure is adjusted by adjusting the speed of the oil supply motor to keep the oil supply pressure constant.

The oil temperature outlet detection unit includes spindle oil return temperature sensor, spider hand oil return temperature sensor, first brand box oil return temperature sensor, second brand box oil return temperature sensor and VE oil return temperature sensor for information transmission and feedback.

Thermostat cycle unit includes oil temperature stirring motor, thermostat control cycle motor, semiconductor cooler, axial flow fan, condensation temperature sensor and circulating pipeline oil return temperature sensor. The oil temperature stirring motor and the thermostat control circulation motor are set on the oil pool cover plate in the thermostat control circulation area. The semiconductor cooler includes a condensing fin, a pipeline and a semiconductor. The pipeline is wound on the condensing fin, and the semiconductor is fixed on the condensing fin by patching to transmit the cold or heat generated by the semiconductor to the condensing fin. The axial flow fan is set at the rear end of the condensing fin on the semiconductor side to accelerate the conduction of cold or heat; the condensing temperature sensor is set in the condensing fin; the circulating pipeline oil return temperature sensor is set on the circulating oil return pipe far away from the side of the semiconductor cooler.



1-oil temperature sensor; 2-oil level sensor; 3-oil supply motor; 4-oil temperature stirring motor; 5-inlet oil pressure sensor; 6-thermostat circulating motor; 7-spindle oil return temperature sensor; 8-spider hand oil return temperature sensor; 9-first brand box oil return temperature sensor; 10-second brand box oil return temperature sensor; 11-VE oil return temperature sensor; 12-axial fan; 13-condensation temperature sensor; 14-semiconductor cooler; 15-circulating pipeline oil return temperature sensor; 16-oil supply area; 17-thermostat circulating area

Figure 1. Structure diagram of lubricating oil circulation refrigeration system of cigarette machine.

3.2. Control module

As shown in Figure 2, the control module uses the PLC controller with a Profibus port, and is connected to the inverter of the oil supply motor, the oil temperature stirring motor and the constant temperature circulating motor through the Profibus port, and controls the motor speed through the bus mode.

Input and output module include analog input module, analog output module, digital input module and digital output module. Analog input module is connected with the oil level sensor, the oil temperature sensor, the inlet oil pressure sensor, the spindle oil return temperature sensor, the spider hand oil return temperature sensor, the first brand box oil return temperature sensor, the second brand box oil return temperature sensor, the VE oil return temperature sensor, the condensation temperature sensor and the circulating pipeline oil return temperature sensor, respectively. It is used to collect the voltage signal of each sensor from 0 to 10 V, and convert the voltage signal into a data signal from 0 to 32000, so as to provide the data signal to the control module for data calculation. The analog output module is used to convert the data calculated by the control module into a voltage signal of 0 to 10 V, and the temperature of the semiconductor cooler is controlled by the current regulating control module.

The digital input module is used to collect the operation signal of the auxiliary drive of the cigarette machine. The digital output module is used to control the temperature reversal of the semiconductor cooler and the operation of the axial flow cooling fan.

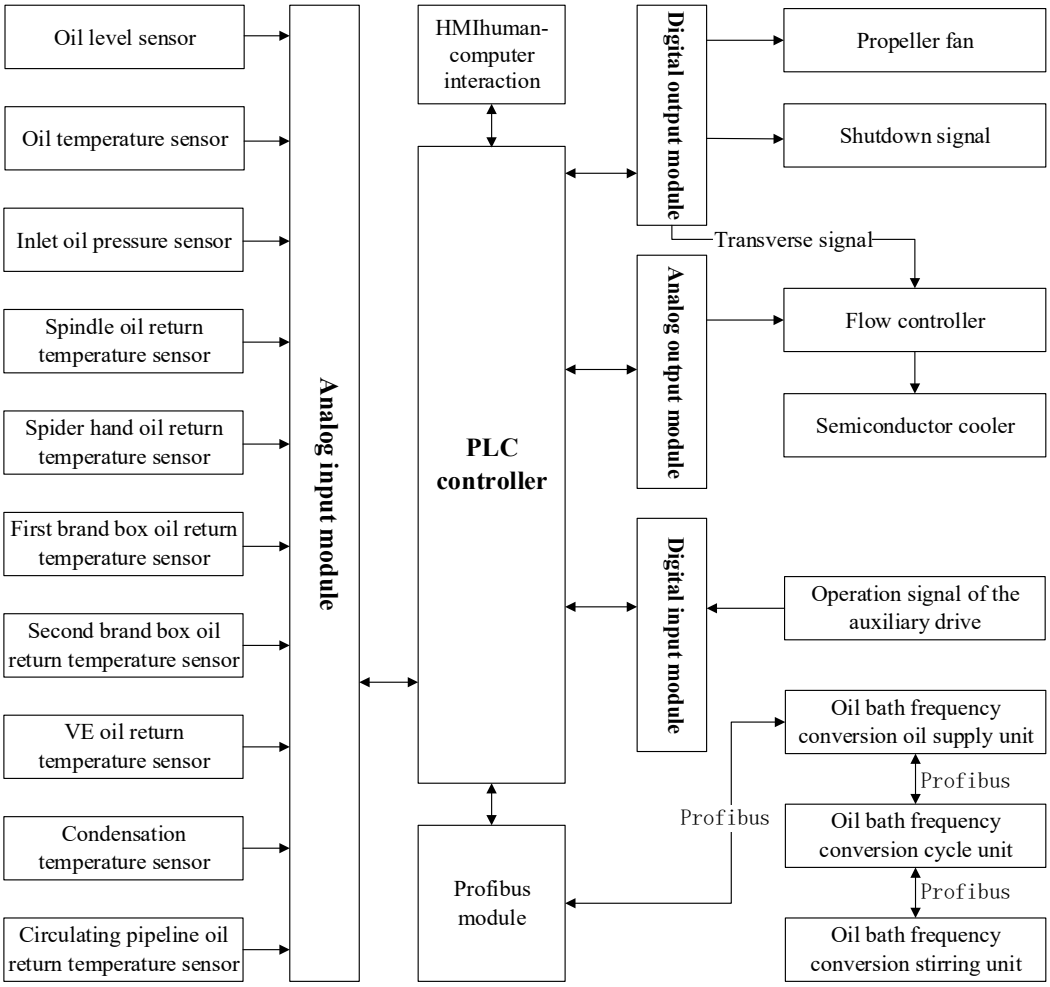


Figure 2. The control principle diagram of the lubricating oil circulation refrigeration system of the cigarette machine.

3.3. Thermostat control method

In order to ensure the stable oil supply and return of the lubrication system, it is necessary to accurately control the oil pressure. As shown in Figure 3, the auxiliary drive of the cigarette machine is turned on, and the control module judges whether to turn on the auxiliary drive according to the test results T and L of the oil temperature sensor and the liquid level sensor. If the starting requirements are met, the control module controls the oil supply motor to supply oil at a preset oil supply starting frequency, and controls the oil temperature stirring motor to stir at a preset stirring starting frequency. At the same time, according to the oil supply pressure P and the preset pressure threshold, the frequency converter adjusts the speed of the oil supply motor to adjust the oil supply pressure, and after the preset time, the oil inlet pressure is judged in real time, so as to achieve the purpose of accurately controlling the oil pressure.

Thermostat controlof lubricating oilis shown in figure 4,The control module gradually determines the oil temperature T of the oil pool, the oil return temperature T1 of the main shaft, the oil return temperature T2 of the spider hand, the oil return temperature T3 of the first brand box, the oil return temperature T4 of the second brand box, the oil return temperature T5 of VE and And compared with the first temperature threshold and the second temperature threshold .The corresponding return oil temperature is recorded in register 0, register 1, register 2, register 3, register 4 and register 5 inside the control module.

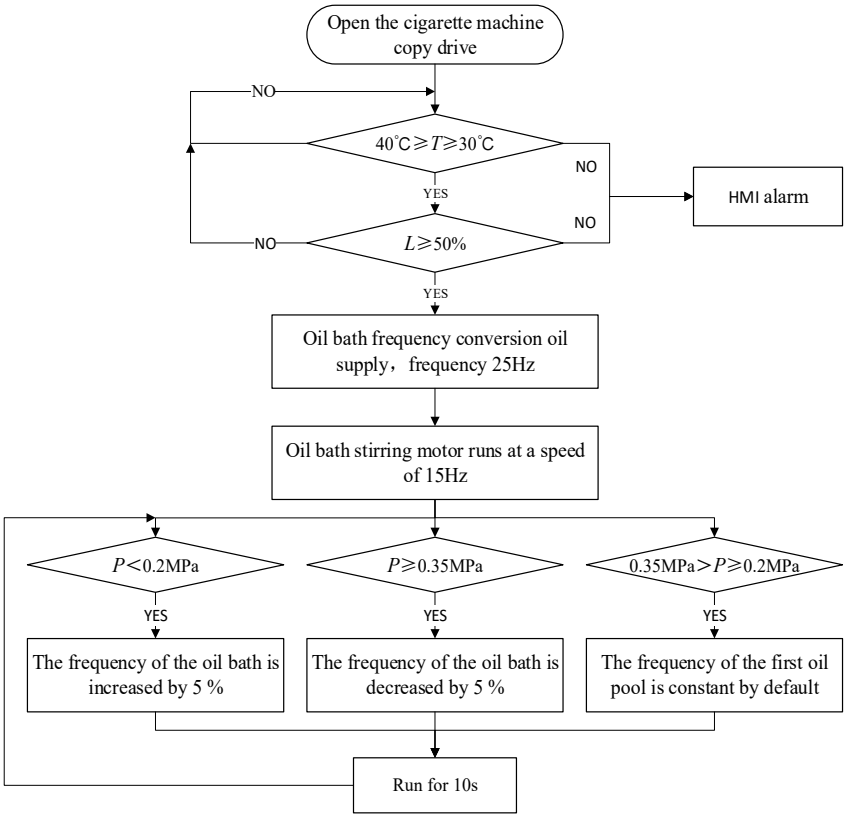


Figure 3. Logic diagram of oil pressure control of lubricating oil circulation refrigeration system of cigarette machine.

According to the size of *T* and temperature threshold, the lowest or highest term in *T*1, *T*2, *T*3, *T*4 and *T*5 is selected as the reference temperature. The control module adjusts the speed of the oil pool stirring motor through the frequency converter, and the controller controls the semiconductor cooler according to the reference temperature to heat or cool to the control temperature. The temperature data in register 1-register 5 are compared, and the minimum or maximum temperature is used as the reference value *T*da. The temperature hot spots to be reached are calculated by the following formula.

$$To = Tam\text{-}\left(Tda - \frac{(Tmax + Tmin)}{2}\right) - (Tou - Tin) \tag{1}$$

In the formula, *T*am represents the normal constant temperature, *T*da represents the reference temperature, *T*max represents the second temperature threshold, *T*min represents the first temperature threshold, *T*ou represents the oil return temperature of the circulating pipeline, *T*in represents the temperature of the semiconductor cooler, and *T*o represents the temperature hot spot to be reached.

The semiconductor refrigerator performs heating work, and the temperature heating is regulated by the following formula.

$$U(t) = kp\left(err(t) + \frac{1}{Ti}\int err(t)\,dt + \frac{Td\,derr(t)}{dt}\right) \tag{2}$$

In the formula, *k*p represents the proportional coefficient from high temperature to low temperature range, *T*i represents the response time coefficient close to low temperature range, and *T*d represents the pre-regulation time coefficient close to low temperature range.

The constant temperature circulating motor runs at different frequencies, and for every 1 ˚*C* increase in the oil temperature of the oil pool, the frequency increases by 1Hz.When the feedback oil return temperature of the circulating pipeline reaches the constant temperature range, the temperature acquisition and control are carried out again after 5s delay.

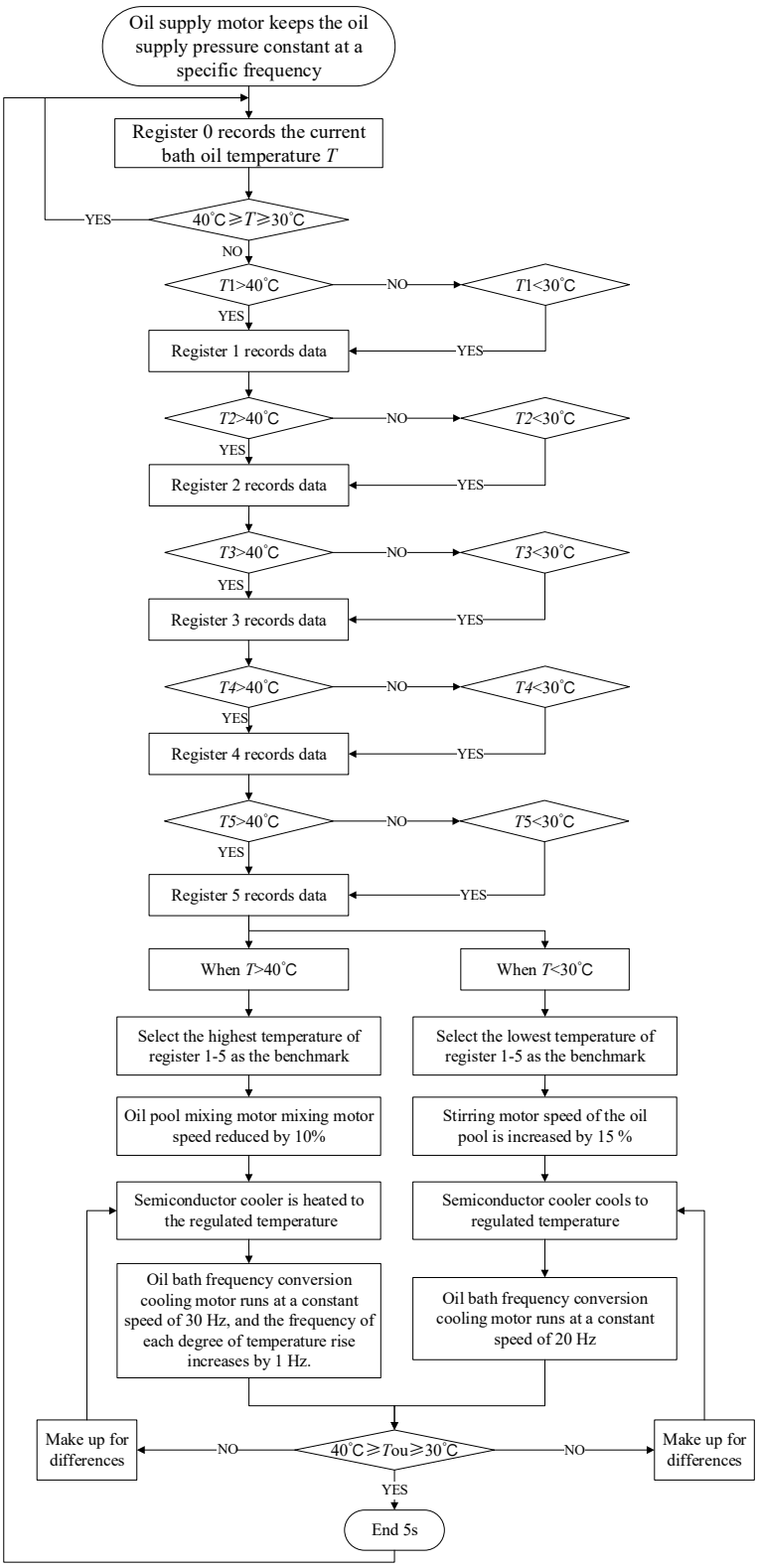


Figure 4. Temperature control logic diagram of lubricating oil cycle refrigeration system of cigarette maker.

4. Application effect

4.1. Experimental design

Test equipment: The equipment selected is ZJ112 cigarette machine which specified speed 10000 sticks a minute and the workshop PLC (Siemens 400).

Testing method: according to the calculation formula of the standard index of the cigarette enterprise and the data statistics of the equipment information management system, after the installation and commissioning of the lubricating oil circulation refrigeration system in the ZJ112 unit, the equipment is operated at the rated production speed of 10000 /min. The equipment operation status of each month before and after the improvement was counted, and the average temperature of each component of the oil temperature outlet detection unit was recorded.

4.2. Data analysis

It can be seen from Table 1 that after the above improvement measures, the temperature of each lubricating part of the equipment is significantly reduced, and the temperature of each lubricating part is less than 40 ˚C.It has been 20 months since the lubricating oil circulation refrigeration system was put into operation. The system runs well and the failure rate is low. At the same time, the number of equipment maintenance is significantly reduced. The equipment needs to be repaired once a month. Now it only needs to be repaired once a quarter, which greatly reduces the labor intensity of employees. The equipment also has no leakage, which virtually improves the quality of cigarettes.

Table 1. The temperature of each lubrication part after (˚*C*).

Oil site	Oil outlet point	Spindle	Spider hand	First brand box	Second brand box	VE
Before	58.4	60.2	68	46.6	48.8	50.5
After	31.5	33.4	36.7	30.7	31.5	32.6

5. Conclusion

The design of the lubricating oil circulation refrigeration system of the cigarette machine realizes the lubricating oil circulation refrigeration of the equipment through PLC control, and maintains the stable fluctuation of the temperature, which solves the aging of the rubber seals and the wear of the parts caused by the increase of the oil temperature of the equipment at high speed. The ZJ112 unit is tested. The results show that the system runs well and the failure rate is low, which significantly reduces the temperature of each lubricating part of the equipment and controls the temperature below 40 ˚C. At the same time, it reduces the maintenance time of the equipment, improves the effective operation rate of the equipment, and reduces the occurrence of cigarette quality accidents. This technology can also be applied to new special packaging equipment such as PROTOS 70, ZJ17, ZJ17M and ZJ17S.

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