

# Research and Development of Fully Automatic Alien Smoke Stack and Packaging System

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**Abstract.** The problem of low efficiency of manual sorting packaging for the current tobacco distribution center, which developed a set of safe efficient and automatic type of alien smoke stack and packaging system. The functions of fully automatic alien smoke stack and packaging system adopt PLC control technology, servo control technology, robot technology, image recognition technology and human-computer interaction technology. The characteristics, principles, control process and key technology of the system are discussed in detail. Through the installation and commissioning fully automatic alien smoke stack and packaging system has a good performance and has completed the requirements for shaped cigarette.

## 1. Introduction

For a long time, China Tobacco Distribution Center has different sizes and types of smoke, these cigarettes is difficult to achieve automatic sorting and packaging. Artificial packaging is inefficient, labor intensive and high error rate, high labor costs. It cannot meet the needs of today's tobacco sorting packaging. In order to change this situation, the scientific research institutes are committed to develop a safe and efficient packaging system. In view of this problem, a company has developed packaging system. It includes a variety of advanced automation technologies, such as robot technology, image recognition technology, internet-based distributed control technology, etc. These technologies achieve the intelligent identification, automatic sorting and packaging of special-shaped smoke, industrial robot adopts optimized stacking algorithm to realize grasp different number of different types of smoke according to the stacking requirements [1, 2]. This paper discusses the design of the packaging control about fully automatic alien cigarette packing sorting machine in detail.

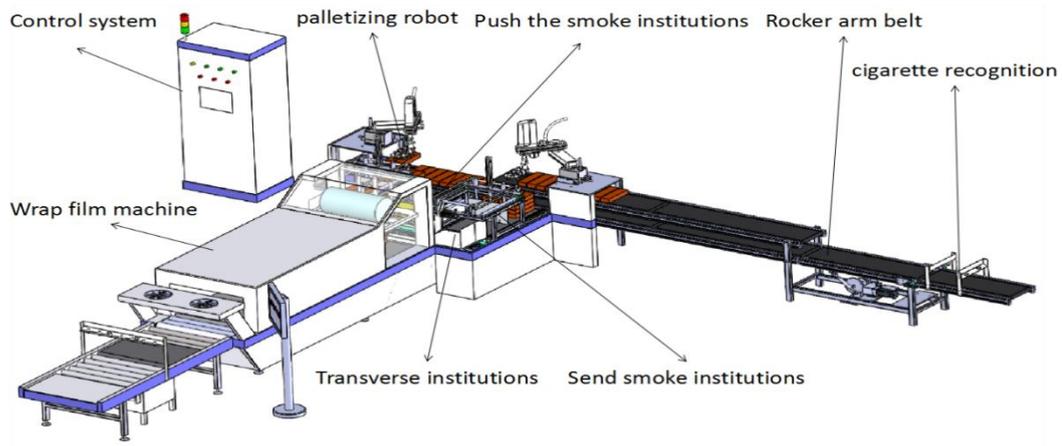
## 2. General description

### 2.1. Mechanical Composition and Principle

According to the order structure, after the identification of alien cigarettes identify is correct, The alien smoke from the main sorting line is divided into two layers by the swing arm belt machine, The robots of each station are automatically stacking each order (according to the order structure, large orders to package as a unit to adapt to the respective sorting robot), after the robot stacks cigarettes, the belt machine automatically move forward a station, so that the robot continues to pile up the stack of



cigarettes, the smoke is sent to the transverse institution by the smoking institution, finally the transverse institution automatically moves the stacking smoke to the entrances of the wrap film machine, and the smoke mechanism is put into the wrap film machine to reach the automatic wrapping membrane through its thermal contraction. The wrapping machine packs the cigarettes in order, after the image is reviewed and automatic labeling. Overall structure of alien smoke intelligent packaging line is show in this Figure.1.

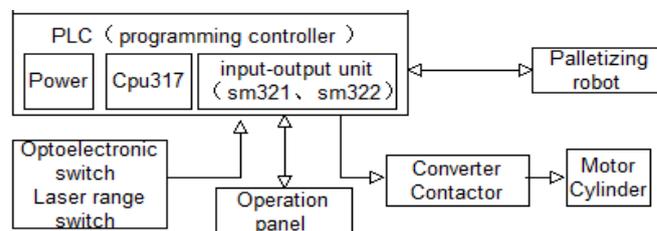


**Figure 1.**Overall structure of alien smoke intelligent packaging line

*2.2. The Composition of the Control System*

Control system of the whole equipment of alien smoke intelligent packaging line consists of four control units, it is divided into the sorting control unit, the stacking control unit, the transmission detection control unit, the packaging control unit. Each unit is controlled by the corresponding control core and auxiliary components are combined into a small control unit, this paper discusses the packaging control unit control design in detail.

Block diagram of electrical control system of packaging control unit in Figure 32. The control module is composed of the control module, the operation module, the detection module and the execution module. The control core of the control module is mainly PLC, and the operation module is mainly human-machine interface, the detection module is mainly photoelectric switch and laser ranging switch. The execution module is mainly AC contactor, solenoid valve, motor and so on.



**Figure 2.**Block diagram of electrical system

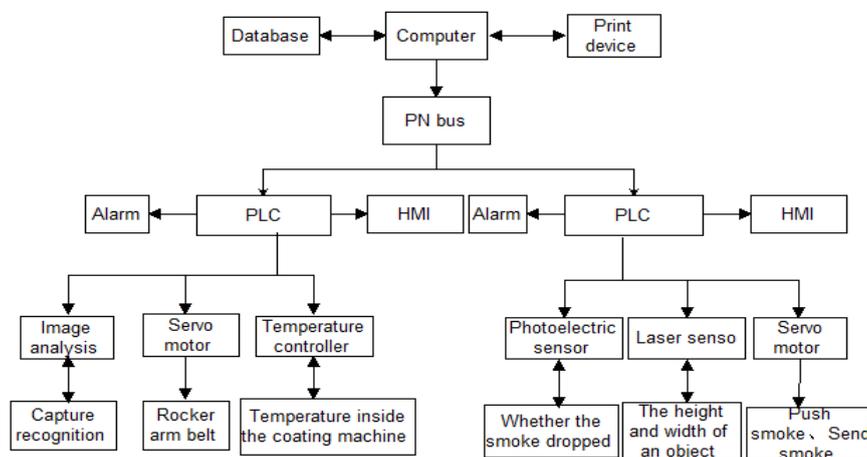
The work process: the customer submit the order, by the IPC to analyze the shape of the stacking of new orders, the new order in accordance with the prevailing conditions to determine which layer of stacking machine hand to stack, and packaging. The route is through the bar code identification system unit, the rocker belt unit, finally arrive at the stacking work unit. After the completion of the stacking, transverse institutions and send smoke institutions can effectively cooperate to the film machine for film.

### 3. System design and the main technical to determine

#### 3.1. Hardware Design

The equipment is required to high-speed continuous operation for more than 20 hours, otherwise it will affect the whole packaging process of alien cigarettes, resulting in huge losses. The PLC has high control accuracy, easy operation, good control, and to adapt to high temperature at the industrial site, shock and other harsh environments, so PLC is used by control the whole process of special-shaped cigarette packaging.

This article selected the German Siemens 317 PLC, CPU with large-capacity program memory, can be used for demanding applications and multi-task automation system, with centralized and distributed I / O production line as a centralized controller Use, binary and floating-point operations with high processing power and have a large number of I / O expansion, to achieve synchronous mode in the PROFIBUS. The hardware block diagram of alien smoke stacking and packaging composed of the upper computer in the Figure.3.



**Figure 3.**Hardware block diagram

In the PLC control system, include 96 input points, 64 output points. Consider the best possible variety, the modules adopted are as consistent as possible, It mainly includes: the Siemens brand CPU314c-2PN (6ES7 314-6EH04-0AB0), The number of the modules is 2; Siemens module input module 32-SM321 (6ES7 321-1BL00-0AA0) Number 3; Siemens output module 32 - SM322 (6ES7 322-1BL00-0AA0), number 2.

#### 3.2. Software Design

The system mainly includes stacking robot stacking design and hierarchical design. Considering the number of actuator and status detection elements of the stacking and packaging line, Therefore, the design method of trapezoidal diagram cannot be used, and the use of modular state flow chart design method to design software [], as shown in Figure 4.The main idea is to complex system, it divided into a number of simple systems, Then you do the logical design one by one, and Then a systematic synthesis of simple systems is carried out.

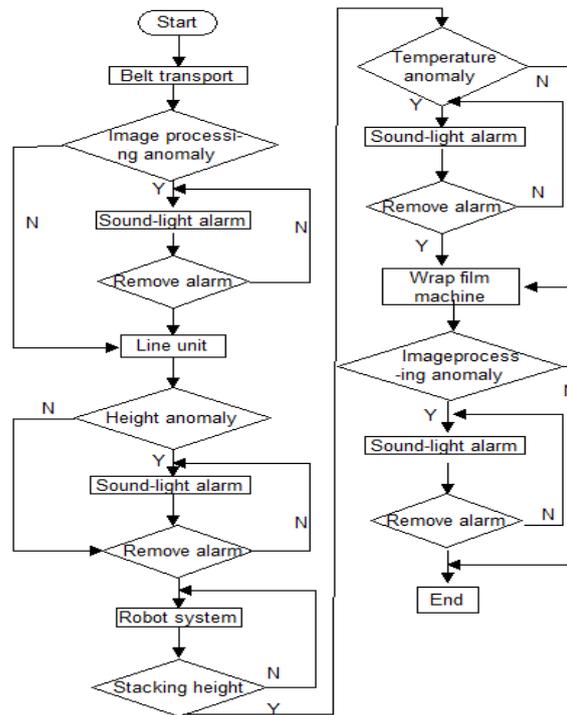


Figure 4.the Flow chart of the cell flow

3.3. Key Technologies

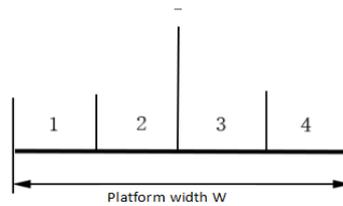
In this system, the main links include Layered links, palletizing algorithms, adaptive fuzzy adjustment links, protection links, human-computer interaction.

(1) Layered links: There is a main conveyor belt below the drop machine, to be split in hierarchical organization. When the detection switch at the asynchronous motor of the main conveyor belt detects the signal, it indicates that the alien smoke on the main conveyor belt enters the separation zone, and the asynchronous motor drives the rocker arm belt to separate the upper and lower layers. Principle of stratification: When the number of alien cigarettes in the conveyor belt does not exceed the set maximum value, the lower belt is priority, then transmitted to the upper belt until all the order processing is completed.

(2) palletizing algorithm: Compared with the standard smoke, the length and width of the alien smoke are different, and it should be suitable for the robot to put the different types of smoke in the best stacking shape, so it is necessary to put customer order to re-combination, firstly, using sorting algorithm in accordance with the height of the ascending order. Secondly, descending order according to the width of the different type of smoke, the purpose is to make the same brand of smoke row together, the width of the order in descending order [4].

In order to make the stacking robot palletizing position has a certain priorities, therefore, different types of smoke placement platform are stratified,As shown in Figure 5, Assuming that the total width of the platform is W, then divide the platform from two in the middle, the left is palletizing positions 1 and 2, and the right is pallet positions 3 and 4.Palletizing method is from the middle to both sides of the stacking [6, 7]. The location control sequence is as follows:

- Put a situation: 2-----> 1 ----->3 ----->4
- Put two of the situation: 12----->23----->34
- Put three of the situation: 123
- Put four of the situation: 1234



**Figure 5.**Stacking platform width

Industrial robots build the following mathematical models in the process of stacking:

$$w_1 + w_2 \leq \frac{W}{2} \tag{1}$$

$$w_3 + w_4 \leq \frac{W}{2} \tag{2}$$

$$\sum_{i=1}^2 h_i \leq H \tag{3}$$

$w_1, w_2, w_3, w_4$ : the width of the different type of smoke on the conveyor belt;  $h_i$ : single line of smoke on the conveyor belt;  $H$ : The total height of the same type of smoke

In order to improve the working efficiency of palletizing robots, palletizing algorithms are used for palletizing. Stacking robot is a priority to consider four smoke conditions, and then consider the situation of three cigarettes, and then second to consider the situation of two cigarettes, and finally consider a cigarette situation. To obtain height data by laser range finder, in case of exceeding the height limit, the height of the belt cannot exceed the set limit, the sum of the first and second widths on the belt, and the third and the second the sum of the four widths cannot exceed half the width of the platform. Based on the mathematical model of grasping the number of alinen tobacco smoke, the model is as follows:

When the four cigarettes were crawled:

$$\Delta H_1 = |\text{MAX}(h_1, h_2, h_3, h_4) - \text{MIN}(h_1, h_2, h_3, h_4)| \leq H_{LIM1}; \sum_{i=1}^4 w_i \leq W$$

When the three cigarettes are captured:

$$\Delta H_2 = |\text{MAX}(h_1, h_2, h_3) - \text{MIN}(h_1, h_2, h_3)| \leq H_{LIM1}; \sum_{i=1}^2 w_i \leq W/2 \text{ 或 } \sum_{i=3}^4 w_i \leq W/2$$

When the two cigarettes are crawled:

$$\Delta H_3 = |\text{MAX}(h_1, h_2) - \text{MIN}(h_1, h_2)| \leq H_{LIM1}; \sum_{i=1}^2 w_i \leq W/2, \sum_{i=3}^4 w_i \leq W/2$$

The measuring device measures the height of the four cigarettes near the end of the conveyor belt relative to the surface of the conveyor belt and the smoke width of the four cigarettes. The data are shown in Table 1:

**TABLE 1.**Test parameters.

W	$H_{LIM1}$	$h_1$	$h_2$	$h_3$	$h_4$	$w_1$	$w_2$	$w_3$	$w_4$
500	3	18	20	17	20	80	125	125	100

From the above table data:  $\Delta H_1 = 3\text{mm}$ ;  $\sum_{i=1}^2 w_i = 205\text{mm}$ ;  $\sum_{i=3}^4 w_i = 225\text{mm}$ , Satisfy the robot to capture the situation of four cigarettes.

The customer submitted an order, There are eight cigarettes from three brands, five A brand of smoke, two B brand smoke, a C brand of smoke. After the order is reorganized, the order is AAAAABBC, according to the stacking conditions, the first stacking of the robot will give priority to grasp of the four A brand of smoke, Place 1, 2, 3 and 4 of the first layer on the stacking platform, The second stacking

time to grab an A brand of cigarettes on the stacking platform on the second floor of the 2 position, the third stacking time to grab two B brand smoke on the stacking platform The second floor of the 3, 4 position. The fourth stacking time to grab a C brand of smoke on the stacking platform on the second floor of the 1 position.

(3) Fuzzy control algorithm: As the palletizing robot starts with a large initial deviation and position change rate, the controller will produce a larger torque output, in order to avoid such a situation, it can be adjusted by the error and error rate of change to control, This algorithm makes the robot system respond fast. The paste algorithm has two main input  $e$  and  $ec$ , three outputs  $\Delta K_p$ ,  $\Delta K_i$  and  $\Delta K_d$ . The domain of five parameters, they are fuzzy into seven grades, such as {NB, NM, NS, ZO, PS, PM, PB}, respectively, said negative, negative, negative small, zero.

(4) Protection links: To ensure the reliability of the entire palletizing packaging system, in addition to the use of some high-quality components, It also take the need for effective security measures. In order to prevent the actuator from wounding, the photoelectric switch and the proximity switch are set up. The signal is input to the PLC. The PLC determines whether to stop the emergency according to the data.

(5) Human-computer interaction: PLC in the system is mainly to complete real-time signal acquisition, pulse accumulation, pre-alarm signal detection and alarm output, and with the scene of the sensor connection. The host computer for complex calculations, save historical data, at the same time using the database as a system of real-time and historical database. The lower computer uses the ladder diagram preparation procedure, It's mostly about implement the data acquisition, the pulse count transformation, the alarm logic judgment, the communication form transformation. The data communication mechanism is realized by the serial communication of the computer. Through the connection between the computer and the PLC network to realize the real-time control of the stacking system. The RS-485 communication method can reduce the data in the medium Interference in the external environment. The computer can receive the relevant online information at any time, the computer can also send control instructions in real time, so that the whole system in a safe and efficient state, has reached the purpose of management. The hardware system of the computer control system Including the completion of data detection and data collection devices, The data acquisition device is used to accept signals such as temperature and current, and then transforms the received signal into a signal that can be recognized by the computer control system; complete the computer input signal and output signal conversion PLC template, PLC template connects the computer and external environment equipment, with the control system for data exchange; to complete the processing of data processing the central processing unit, the central processing unit can enter the data to calculate, the information is calculated the parameters of the system work, and then the parameters and other data output to other equipment, such as Monitors and keyboard and mouse and other special control devices, they are users and computer communication tools, can help the system online detection, the parameters to achieve online changes.

#### **4. Application effect**

Using the optimized palletizing algorithm, it is possible to achieve a different number of grips according to the specified conditions and stack a smooth stamp.

The mechanical hand pallet grabs 1 ~ 4 each time , each action time 1.5s; stacking time 2s, part of the test data as shown in Table 2.

**TABLE. 2** Test data.

Average Number of Orders(piece)	Average Fetch Frequency(times)	Average Packaging Time(s)	Average Packing Efficiency(piece/h)
1	1	4	900
3	2	5	2160
5	2.5	5.75	3130
7	2.5	5.75	4383
9	3	6.5	4985
11	4	8	4950
13	5	9.5	4926
15	6	11	4909
17	6	11	5564
19	6	11	6218



**Figure 6.**Packaging efficiency



**Figure 7.**Order completion time

From Figure6, Figure7, the number of cigarettes within the order of 9-15 of the packaging efficiency tends to be consistent, an average of 5000 / h, The average cost of 8 seconds, the average number of times the robot work 4 times, in order to stabilize the stack and easy to extract, so each order up to 20, the average packaging efficiency of 6500 / h, packaging time 11sec, the number of manipulator 6 times.

**5. Conclusion**

Practice has proved that programmable technology, frequency conversion technology, man-machine interaction technology and servo drive technology are used in fully automatic alien smoke stacking and packaging line .The clever combination simplifies the whole system, easy to operate, easy to debug, save manpower, Greatly reducing the incidence of failure, improve the efficiency of the entire line.

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