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Design of Campus Self-service Express Packaging Recycling Machine

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Abstract

Based on the concept of sustainable design, we are committed to seeking innovative solutions and designing a complete express packaging recycling machine. The device consists of a vibration device, a compression device, a winding device and an electronic control system to promote the recycling of resources and environmental protection. This device can further improve the recycling efficiency and feasibility. It provides new ideas and solutions for the express industry and promotes the development of sustainable design in the field of express packaging recycling and reuse devices.

Keywords: carton packaging; recycling machine design; strapping device; automatic recycling

1 Introduction

With the rapid development of China's e-commerce platforms, online shopping has become a new trend, driving China to rank first in the world in the express delivery industry for ten consecutive years. In 2023, China's express delivery volume reached an astonishing 132 billion pieces, and the materials generated for packaging express delivery were extremely large. Among the express packaging materials, at least 44% of the materials can be recycled [1]. According to statistics, my country generates more than 9 million tons of paper waste each year, and my country's express packaging consumes about 32.8 billion cartons annually, which contains huge economic value. There are the following problems in the recycling of express packaging in my country:

(1) Lack of awareness of recycling express packaging. After unpacking the express delivery, most people take the goods away and then throw the express packaging away. They have a weak awareness of recycling, do not fully understand the added value of packaging, and cannot distinguish the properties of packaging materials. As a result, the materials that could have been recycled are mixed with various garbage because they cannot be sorted and recycled.

(2). There are problems with express packaging materials, such as non-environmental protection and excessive packaging. In order to reduce the cost of packaging materials, some companies use highly polluting materials to produce and package goods, without considering the impact on the environment and whether they can be recycled. At the same time, some companies over-package their products to make their products look beautiful and high-end, which not only increases the cost, but also many of the packaging materials used are not environmentally friendly materials, causing a great impact on the environment [2-4].

This paper designs a machine that can recycle express packaging cartons, which can not only improve the recycling efficiency of waste cartons, but also reduce the impact on the environment, which is in line with the social concept of green environmental protection.

2 The Overall Design Scheme of Express Packaging Recycling Machine

2.1 Overall structure of the express packaging recycling machine

The express packaging recycling machine is mainly composed of a vibration device, a compression device, a winding device and an electronic control system, as shown in Figure 1. The compression device includes a clamping mechanism and a hydraulic system. Since the winding device does not require too much power, but has certain requirements for accuracy, a servo motor is selected as the power source. The normal operation of the compression device and the winding device is

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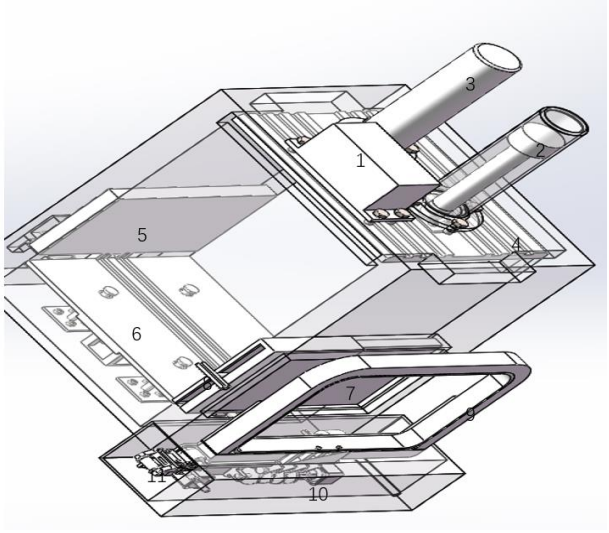
precisely controlled by the PLC program set by the electronic control system, so that the two devices can coordinately complete the compression process of compressing the express packaging into the designed shape and the packaging process of wrapping the winding rope around the surface of the express packaging.



1 - Fuel tank; 2 - Piston rod; 3 - Hydraulic cylinder; 4 - Pressure plate; 5 - Push plate; 6 - Vibration plate; 7 - Front baffle; 8 - Hand push rod; 9 - Rope baffle; 10 - Coupling ;11 - Rope sheave

Figure 1 Structure diagram of express packaging recycling machine

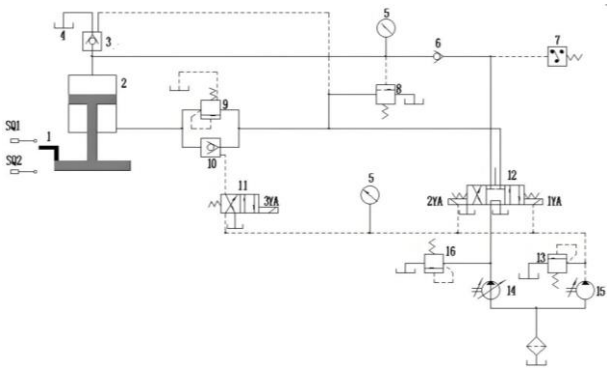
2.2 Working Principle of Express Packaging Recycling Machine

When the weight of the package in the compression device of the express packaging recycling machine reaches the set value, the pressure sensor is triggered, and the auxiliary pressure block of the vibration mechanism compresses the package forward, and stops after reaching the designed position [5]. At this time, the hydraulic system starts to work, pressurizing and maintaining the pressure to the predetermined value. The front block of the winding device moves, and the rear pressure block pushes the paper ball forward through multiple pauses (the number of pauses is determined by the number set before compression). Each pause realizes the winding of the compressed paper ball once, so that the entire express packaging compression and winding process is completed and enters the next working cycle [6].

3 The Hydraulic System Design of Express Packaging Recycling Mmachine

3.1 The working requirements of hydraulic system

The requirements for the hydraulic system of the self-service express packaging recycling machine are relatively low. It only needs to achieve rapid descent to a certain height and then slowly pressurize the paper box until it reaches a certain height and then maintains pressure for a period of time to help the auxiliary push rod push the compressed paper box. After the bundling mechanism completes the bundling of the compressed paper box, it quickly returns to its original position and the entire working cycle is completed. There are no high requirements for accuracy and speed. The proposed hydraulic system circuit is shown in Figure 2.



1-moving block; 2-hydraulic cylinder; 3,10-hydraulic control check valve; 4-oil tank; 5-pressure meter; 6-check valve; 7-pressure relay; 8-damped unloading valve; 9-back pressure valve; 11-two-position four-way electromagnetic directional valve; 12-three-position four-way electromagnetic directional valve; 13,16-overflow valve; 14,15-hydraulic pump SQ-stroke switch

Figure 2 Hydraulic system circuit diagram

3.2 Working process of hydraulic system

3.2.1 Hydraulic cylinder descends slowly

When the pressure detector of the compression mechanism detects that the pressure reaches the set value, the electromagnets IYA and 3YA are energized. The control oil output by the hydraulic pump 15 switches the three-position four-way electromagnetic reversing valve 12 to the right position on the one hand, and on the other hand, the hydraulic control check valve 10 opens when the electromagnetic reversing valve 11 is in the right position. At this time, the hydraulic cylinder and the moving block drop rapidly under the action of their own gravity. At this time, their gravity is greater than the resistance of the paper box to the block, and the hydraulic oil output by the hydraulic pump 14 is not enough to replenish the volume vacated in the upper chamber of the hydraulic cylinder. A partial vacuum is formed in the upper chamber of the hydraulic cylinder. The oil in the oil tank 4 located on the top of the hydraulic press enters the upper chamber of the hydraulic cylinder through the hydraulic control check valve 3 under the action of the atmosphere and the liquid level.

3.2.2 The hydraulic cylinder slowly approaches the carton and pressurizes it

When the moving block 1 on the slide hits the travel switch 2SQ, the electromagnet 3YA is de-energized, causing the reversing valve 11 to return to the left position and the hydraulically controlled one-way valve 10 to close. The oil in the lower part of the hydraulic cylinder must flow out through the back pressure valve 9,

and the slide cannot descend by its own weight alone. The pressure in the upper chamber of the hydraulic cylinder 2 increases, the filling valve 3 closes, and the hydraulic cylinder 2 slowly approaches the compressed paper box. As the hydraulic cylinder 2 continues to descend, the load begins to increase continuously, causing the pressure in the upper chamber to further increase, and the output flow of the variable pump automatically decreases.

3.2.3 Hydraulic cylinder pressure maintenance

As the hydraulic piston moves downward, the pressure in the upper chamber of the hydraulic cylinder increases continuously. When the pressure in the upper part of the hydraulic cylinder reaches the set value, the pressure relay 7 will send a signal to the control system, causing the electromagnet 1YA to be powered off and the electromagnetic reversing valve 12 to move to the middle position. The purpose is to close the upper and lower oil chambers of the hydraulic cylinder, and the system starts to maintain pressure and maintain the current position. The function of the one-way valve 6 is mainly to ensure that the upper chamber of the hydraulic cylinder has good sealing properties, and at the same time, the upper chamber of the main cylinder can always maintain high pressure. The length of the pressure holding time can be adjusted by the time relay controlled by the pressure relay 7. The hydraulic pump 14 is unloaded through the middle position of the reversing valve 12.

3.2.4 Hydraulic cylinder depressurizes and returns

When the pressure holding time reaches the designed time, the time relay controlled by the pressure relay 7 sends a signal to notify the control system of the machine. After processing the transmitted signal, the control system of the machine energizes the electromagnet 2YA. At this time, the reversing valve 12 will switch to the left position, and the hydraulic cylinder is in the return state. During the pressure holding stage, the energy accumulated in the hydraulic cylinder is suddenly released to produce hydraulic shock, which will cause the equipment to vibrate and the pipeline to shake violently and emit huge noise. Therefore, after the pressure is held, the pressure is released first and then the return is made.

3.2.5 Stop

When the moving block 1 on the slide presses the travel switch 1SQ, the electromagnet 2YA is de-energized, the hydraulic cylinder stops moving, and the return stroke ends. At this time, the oil of the hydraulic pump 14 returns to the oil tank through the middle position of the reversing valve 12 and is in an unloaded state, and the entire working cycle is completed. The electromagnet action sequence of the hydraulic system is shown in Table 1.

4 Design of the Bundling Mechanism of the Express Packaging Recycling Machine

4.1 Design of strapping mechanism

The push block at the rear of the machine pushes the compressed paper ball forward with frequency, and the strapping mechanism straps the compressed paper ball. After multiple strappings are completed, the strapping mechanism stops working, the baffle at the rear of the machine automatically returns, and the hydraulic press mechanism also returns to its original position, and the entire working cycle is completed. The strapping mechanism structure is shown in Figure 3.

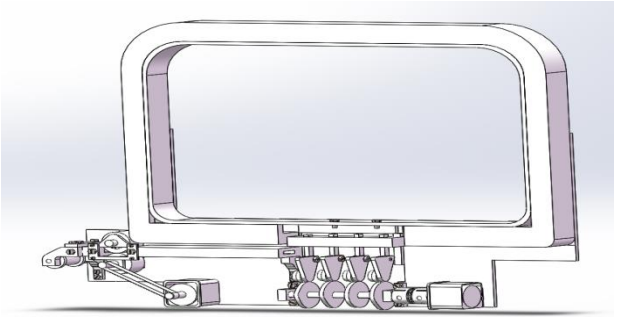


Figure 3 Structure diagram of bundling mechanism

The strapping mechanism is mainly composed of four cams of different shapes, a coupling, three motors, and strapping ropes. The working process is as follows: the package to be strapped is moved to the designated position, and the strapping rope moves forward under the push of the rubber wheel, and is pre-wound into the shape of a compressed package above the No. 1 cam. At this time, the pressure block above the cam presses the rope, and the No. 2 motor starts to work, causing the rope to fall downward under the action of its own gravity. At the same time, the No. 1 motor starts to reverse and tighten the rope. The size of the tension is set according to the actual situation of the paper ball. The block controlled by the No. 3 cam presses the rope, the block controlled by the No. 2 cam melts the rope, and the blade controlled by the No. 4 cam cuts off the excess rope to complete the complete strapping of the express package.

Table 1 Electromagnet action sequence table of hydraulic system

Working condition	Signal source	Electromagnet 1YA	Electromagnet 2YA	Electromagnet 3YA
Fast down	Pressure detector	+	-	+
Slow pressure	Block press down travel switch SQ2	+	-	-
Holding pressure	Pressure relay	-	-	-
Releasing pressure return	Time relay	-	+	-
Stop	Block press down travel switch SQ1	-	-	-

4.2 Cam mechanism design of strapping mechanism

Since the cam has fast response, high efficiency, simple structure and is not prone to failure, the cam is used to control the two fixation, melting and shearing of the binding rope.

4.2.1. Selection of cam and push rod

Since this mechanism requires four cams to move regularly on one axis, and the internal space of the strapping mechanism is limited, a disc cam is used[7].

Since this mechanism has high requirements for the precision of the push rod driven by the cam, the roller push rod has relatively small wear due to rolling friction between the roller and the cam profile, and the precision meets the requirements of this mechanism, so the roller push rod is selected. Finally, a disc cam mechanism is selected.

4.2.2. Design of cam profile

As shown in Figure 4, establish an OXY coordinate system, where the origin is the center of the cam base circle, and B_0 is the starting point of the cam push stroke contour line. At the beginning, the center of the push rod roller is located at B_0. When the cam rotates through an angle of δ, the push rod produces a corresponding displacement s. The center of the roller is located at point B, and its rectangular coordinate B ($x=(s_0+s)\sin\delta$, $y=(s_0+s)\cos\delta$) is the theoretical contour curve of the cam. Since the distance between the working curve and the theoretical curve in the normal direction is equal to the roller radius R, when determining a point $B(x,y)$ on the theoretical curve, it is only necessary to take a distance R along the normal direction of the theoretical curve at this point to obtain the corresponding point $B'(x',y')$ of the curve, where:

$$\sin\theta=(\mathrm{d}x/\,d\delta)/\sqrt{(\mathrm{d}x/\,d\delta)^2+(\mathrm{d}y/\,d\delta)^2}$$
$$\cos\theta=-(\mathrm{d}y/\,d\delta)/\sqrt{(\mathrm{d}x/\,d\delta)^2+(\mathrm{d}y/\,d\delta)^2} \quad (1)$$

Its coordinate $B'(x'=x\mp r_r\cos\theta, y'=y\mp r_r\sin\theta)$ is the working contour equation of the cam.

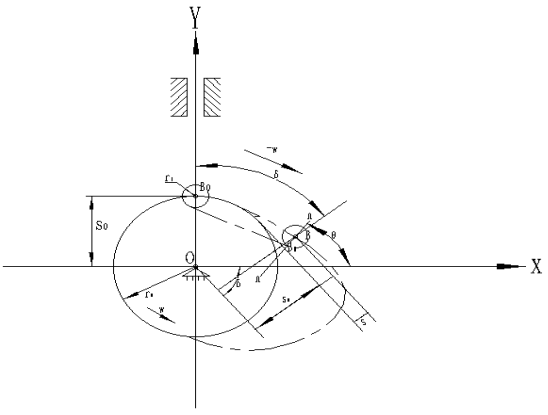


Figure 4 Cam contour line diagram

5 Conclusion

(1) Design a set of low-cost, safe and efficient recycling principle solutions suitable for express packaging in multiple scenarios.

(2) According to the planned solution, establish basic physical models and mathematical models, conduct simple kinematic analysis on the compression mechanism and strapping mechanism of the recycling machine, judge whether the design is reasonable, and provide a theoretical basis for the subsequent design of various parts of the recycling machine.

(3) Reasonably select and coordinate the required motors, hydraulic system cams and other mechanisms, while completing basic tasks without increasing additional costs, and improve economic benefits.

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