Design of Lane Separation and Centralized Collection Mechanical Device for Detergent

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Abstract. The filling and packing of liquid heterotypic bottle products are the necessary process for them to enter the market. For the packing operation of detergent, it is necessary to transfer the single row state of continuous transportation after filling to the collection and packing of multiple products at one time, and the lane separation and centralized collection device plays an important role in this process. The prototype design and structure design are carried out. Aiming at the problems of jamming, dumping and belt deviation in actual production, the cause analysis and structure improvement design are completed. The experimental results show that the improved structure operates stably and meets the use requirements.

1. Introduction
Irregular product packaging is called abnormal state packaging [1] [2]. Irregular bottle product packaging is very common in daily chemical, food, medicine and other industries [3]. For its packaging production process, especially for packing into cartons [4], in order to improve the efficiency, it is usually necessary to complete the operation of grabbing or dropping multiple single products at a time to achieve packing. For this reason, it is necessary to carry out separate transportation, collection and arrangement of the single sequentially transmitted products after filling. This design takes the detergent product as an example, designs the lane separation and centralized collection mechanical device on the basis of the demand analysis, analyzes the problems in the actual production process, and seeks the structural improvement method.

2. Virtual prototype design
2.1. Design requirement
The function of the mechanical device is to complete the lane separation and centralized collection of the continuously transmitted detergent. The purpose of the lane separation is to change the moving direction of the items transferred and make them enter a certain channel in the set collection area. Fig. 1 schematically shows this process. When the detergent (block in Fig. 1) enters the multiple channels from a single moving channel, there is a tendency of shunting, but because the detergent is in a single channel in the motion channel, it is not possible to realize shunting, but to enter one channel successively under control, and then the shunting mechanism completes the switching of its own channel (so that it can transport detergent to a certain channel in the collection area). The collection
area is composed of multiple channels. When each channel gathers a predetermined number of detergent, the collection is completed once. At this time, the relevant signals can be sent to the controller for judgment through sensor detection to determine the implementation of packing. In this device, the design of lane separation actuator is the most important.

![Diagram](image_url)

**Figure 1.** Separation and collection function diagram.

2.2. **Principle Design**

Fig. 2 is the mechanism schematic diagram of the lane separation actuator. Slide 1, guide rod 1, slide 2, guide rod 2 (rocker) [5] [6] constitute the moving pair respectively, slide 1, slide 2 constitute the rotating pair, guide rod 2 and frame constitute the rotating pair, guide rod 1 is the frame, slide 1 is the original moving part, it can be known that the degree of freedom of the mechanism is 1. The driving slider 1 moves back and forth along the guide rod 1, which will make the guide rod 2 swing around the O point. With reference to Fig. 3, it is further explained that the bearing is arranged between the swing bar and the frame in the rotating joint part; the bearing is arranged between the connecting block and the moving platform to form the rotating pair, while the moving platform part supports the whole swing bar and its accessories; the linear bearing is arranged between the guide shaft and the connecting block fixedly connected at the front end of the swing bar to make the movement more flexible; the mobile platform is driven by an external motor, and finally realizes the swing back and forth of the swing rod, that is to say, realizes the lane separation movement. In order to deal with the sudden imbalance of the system, a buffer with a certain capacity is reserved in the collection area, and its capacity is taken as 1.5 times of packing collection. Figure 3 is a virtual prototype [7] [8] designed.
3. Fault analysis and solutions

3.1. Prevention of jamming and dumping of detergent

Jamming of detergent bottle in the machine may occur when the detergent is divided into lanes. The location is at the junction of the outlet of the lane separation mechanism and a collection lane. The reasons are: the accumulated deviation of the lane separation location; the lane separation speed is too fast, which causes the vibration of the lane separation part; the control law is not good, and the acceleration and deceleration are too fast, which causes the vibration of the lane separation part. In addition, in the structural design of the lane separation mechanism, it should be taken into consideration. As shown in Fig. 4 (a), during transmission of detergent, the front lane needs to be deflected, and the transmission direction of detergent always faces forward. In this way, there is a small angle between the movement direction of detergent and the movement direction of the conveyor belt, resulting in the inclination of detergent dumping, which is limited by the side plate structure. In fact, the detergent is inclined in the forward direction, and its dumping is limited by the two side plates, and the degree of inclination is positively related to the offset angle of the position of being divided from the center line and the distance between the two side plates, and also related to the height of the two side plates. Fig. 4 (a) shows the height and width adjustment part of the side plates which can be adjusted according to the actual situation and the type of detergent bottle. There is a certain length of connection part between the outlet of the side plate and the collection area, so that when the inclined detergent bottle enters a certain lane, it can directly buffer the transition.
Dumping of detergent bottle may also occur when the detergent is collected in the collection channels. Because the lane separation has an impact on the speed and state of motion, and it is from one area to another, the condition of motion constraint has also changed, which mainly occurs in the channel of entering the collection area. When there is inertia force or external resistance around a certain fulcrum (such as the front and rear edge) of detergent in the forward direction, the bottle will overturn. When the overturn moment reaches the critical value, the detergent bottle will overturn. The premise is that there is sufficient space for detergent to move in the overturn direction. Based on this, anti-dumping can achieve the expected purpose by limiting the active space and eliminating the conditions caused by dumping. Fig. 4 (b) add a baffle at the top of the channel plate in the collection area to make the detergent enter the collection area and limit its active space as much as possible under the condition of ensuring the basic active space.

3.2. Conveyor belt deviation correction
In the process of debugging, when the conveyor belt transmits detergent, there will be "deviation", which cannot be corrected by itself. In serious cases, due to the sharp reduction of contact area, the increase of resistance caused by excessive contact with the side and the trend of further increase, the belt will stop running due to slipping.

The causes of the deviation are analyzed as follows: as shown in Fig. 5, when the power roll is parallel to the drive roller, the tightness of both sides of the conveyor belt is the same, and the speed of each point on the contact surface of the conveyor belt and the power roll is exactly the same. For convenience, the speed of point A and point B shown in the figure is selected for explanation. At this time, \( v_A = v_B \), and the conveyor belt runs stably (as shown in fig.5 (a)); during the commissioning, the tightness of both sides is often inconsistent, when there is a big difference, for example, the left side of the conveyor belt represented by point A is loose, and small slip will occur during continuous transmission, resulting in average speed. The intuitive explanation is that side B runs fast, so the conveyor belt state shown in Fig.5 (b) will appear. When the driving direction does not change, the deviation trend is increasing, that is to say, it will run more and more, and the resistance will increase when there is too much contact between the right rear side and the left front side of the conveyor belt and the side plate. At the same time, due to the deviation, the contact surface between the conveyor belt and the driving roller may be reduced and or the average contact pressure will be reduced, which makes the static friction force unable to overcome the resistance caused by the contact with the side plate.

According to the above analysis, it can be solved by setting and adjusting the elastic devices on both sides of the conveyor belt.

Figure 4. The structure design of avoiding fault.
4. Debugging and experiment

The goal of the debugging is to make the lane separation stable, and the phenomenon of jamming and dumping of detergent will not appear in the process. Generally speaking, there are two types of lane separation movement: continuous and intermittent. Continuous separation movement (Figure 6 (a)) means that the machine moves at a uniform speed, and shunts the detergent during the movement; intermittent separation movement (Figure 6 (b)) means that there are several time intervals between each two shunts, and the machine will pause at the moment of shunting.

Under the condition of a certain delivery speed, through the experiment, it is found that the probability of jamming of detergent bottle in the way of continuous separation movement is higher. As shown in Figure 6 (b), analyze the speed of the detergent at the outlet of the lane, and decompose the speed, including the speed $v_{\text{for}}$ in the forward direction and the offset speed $v_{\text{dev}}$ deviation generated by the lane. When continuously separating the detergent, there is still a speed $v_{\text{dev}}$; when intermittently, the lane separation actuator stops when it reaches the lane separating point, it can be considered that the $v_{\text{dev}} = 0$ at this time. That is to say, the continuous separation causes the detergent to have a certain degree of deviation. The larger the lane separation speed is, the greater the degree of deviation is. The offset generated by the intermittent separation is almost zero, which is unfavorable for the detergent to enter a certain channel in the collection area smoothly. Therefore, the intermittent lane separation method is adopted.

**Figure 5.** Conveyor belt motion analysis.
Figure 6. Analysis of lane separation mode and speed.

Under the condition of intermittent separation, the faster the transfer speed of detergent is, the faster the required lane separation speed is, and it is easy to cause mechanism vibration under the condition of high-speed separation. The vibration can be reduced by reasonably planning the movement law of separation, such as increasing the acceleration and deceleration time properly. Fig 7 is the photo of the device.

The width and height of the lane separation mechanism shall be adjusted according to the specifications of the detergent bottle. This paper analyzes the influence of width and height on the separation process, as shown in Fig. 8. Driven by the conveyor belt, it is assumed that the conveyor belt moves inward from the paper surface (represented by symbol ⬤), and the detergent moves between two side baffles of a certain size. Due to the influence of the lane separation speed, the movement of the detergent will produce the diagrammatic inclination. Based on the analysis method of control variables, for (a) and (b), the distance between the side baffles of the lane separation is different. It can be seen that when the detergent can pass through, reducing the distance can reduce its inclination; for (b) and (c), the height of the side baffles from the conveyor belt is different. However, the higher the height is, the greater the potential overturning moment will be, when the conveyor belt speed is faster, which is not conducive to transmission, so the height should be reduced properly.

After adjusting the width and height of the shunting mechanism adjustment device, it is necessary to calibrate the position of the shunting mechanism relative to each shunting in the collection area, with the principle that the detergent enters each shunting smoothly.

Figure 7. Photo of the lane separation and centralized collection device.
5. Conclusion

In view of the packing problem of the irregular bottle detergent product, the design of the lane separation and centralized collection device, the mechanism principle design and the virtual prototype design are carried out on the basis of the demand analysis, and the detailed structure design is completed. According to the problems in the actual production process, the analysis is conducted, and the improvement design is completed from the structure. After repeated debugging and experiments, the problems are well overcome, so as to invest packaging production provides guarantee.

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