Design and Test of Automatic Loading and Unloading Machine for Egg Tray

Chao Huang\textsuperscript{a} and Yancong Liu\textsuperscript{b}

China University of Petroleum, Qingdao, China
e-mail: \textsuperscript{a}liuy CPC@163.com, \textsuperscript{b}hc8247@163.com

Key words: egg tray, Loading and unloading, egg truck, breeding egg

Abstract. A kind of egg tray automatic loading and unloading machine is designed for the high strength and low efficiency of egg tray loading and unloading in the egg candling process. Through the analysis of egg tray loading and unloading process, the automatic loading and unloading process of the egg tray is determined. Imitating manual handling, egg tray automatic loading and unloading machine is composed of lifting mechanism and scissors type combination mechanism. The lifting mechanism completes the positioning of the egg tray and the scissors type combination mechanism completes the delivery of the egg tray. The prototype was designed and tested, and the result shows that the unloading efficiency reached 122 trays/h, and the average time of single tray leaving the incubator was 29s. So the automatic loading and unloading machine of the egg tray improves the automation degree of the incubation industry, reduces the labor intensity, improves the detection efficiency of the egg, and shortens the time that the embryo egg leaves the incubator.

1. Introduction

Hatching is an important means of poultry breeding industry, in addition to strictly controlling the temperature, humidity and carbon dioxide concentration of the incubation environment, the hatching process should also regulate the operation process of the egg candling process. In the process of hatching, on-refined eggs and stillbirth eggs are checked out by egg candling, so as to avoid their impact on the development of normal embryos and enhance the hatching efficiency of eggs\textsuperscript{[1-3]}.

The hatching eggs are hatched for 18 days, then the dead embryo and the on-refined eggs are eliminated through egg candling, and the hatching eggs are delivered to the hatching box to continue hatching. Egg candling should be noted that the eggs should not stay outside the incubator for more than 20 minutes, and the time should be shorter when room temperature is low. If the time is too long, it will stimulate the growth and development of eggs. And the egg tray needs to be handled gently when it is loaded and unloaded, so as to avoid breaking eggs. The length, width and height of the hatching egg cart is 1660 * 570 * 2100mm, and an egg cart carries 32 egg trays and each egg tray carries 150 eggs. Due to the influence of the height of the egg truck and the size of the egg tray, the manual loading and unloading of the egg tray is very difficult and the efficiency is low. In order to solve this problem, an automatic loading and unloading machine for the egg tray is designed.

2. Structure Design of automatic loading and unloading machine

2.1 Structure design of automatic loading and unloading machine

The egg truck has 16 layers, and each layer has 2 trays, and each tray carries 150 eggs, and egg tray is rectangle with 10 line and 15 column. The weight is heavy after loading, therefore, the 150 egg tray is tiled on the double rail support board, and both ends of egg trays are protected by lock hook, and the height of the lock hook is 6mm. The supporting plate is about 1.5 meters, and 3 reinforcing bars are arranged between the two parallel supporting plates in order to prevent the middle of the supporting plate from deforming. When we use the multi-degree-of-freedom manipulator to load
and unload the egg tray, the mechanical hand will not be able to pull out the egg tray when it is deep into more than 1/2 the length of the egg tray due to the influence of the reinforcement tendons. If the length manipulator goes deep into the egg cart is less than the length of the 1/2 egg tray, the manipulator can't hold the egg tray, and the automatic loading and unloading equipment needs to overcome the influence of the lock hook and the reinforcement of the egg tray.\cite{4-17}

![Figure 1. Egg vehicle structure.](image)

1. Egg tray  2. Egg truck  3. uncut dambar

In order to solve the above-mentioned problems, we use lifting frame to provide up and down movement of the auxiliary rails. The telescopic arm and the belt mechanism realize a moving pair and a rotating pair, and the telescopic arm is composed of a guide rail and a synchronous belt, as a result, the egg tray automatic loading and unloading machine totally has 3 degrees of freedoms. The main structure of the loading and unloading machine is divided into lifting mechanism and scissors fork type delivery mechanism with high difference. The lifting mechanism mainly realizes the positioning of the egg tray and the transfer of the egg tray up and down. The delivery mechanism with high difference realizes the fetching and delivering function of the egg tray.

Automatic loading and unloading machine consists of drive motor, 4 sets of parallel rails, 4 sets of synchronous belt drive module, double chain transmission mechanism, power down brake module and lifting platform. The lifting mechanism adopts 4 sets of parallel guide rails, which is convenient to restrain lifting platform to move up and down without any front and rear, left and right swing and inclination to ensure the relative positioning accuracy of the scissor-type conveying mechanism and the egg carton. 4 groups of synchronous belt drive module to ensure the level of lifting platform even when the lifting platform is uneven in force.

![Figure 2. The structure of the automatic loader.](image)


**2.2 Design of egg tray delivery mechanism**

The automatic loading and unloading machine of the egg truck carries the egg tray to the test bench, and then sends the egg tray back to the original egg truck after the test. The use of rigid transmission mechanism, such as rail synchronous belt module, guide rail screw rod module, can pull out the egg tray, but can't send the egg tray to the test workbench because the effective stroke of the rigid transmission mechanism is less than the total length of the transmission. The flexible
transfer mechanism, such as the circumferential conveyor belt, can achieve the transfer of the egg tray, but it can't take out the egg tray. In order to pull out the egg tray and transfer the egg tray, the rigid transmission mechanism and the flexible transmission mechanism are assembled into a scissors mechanism. The support plate stretches into the egg truck driven by the synchronous belt, then the egg tray is pulled out, and the supporting plate drags the egg tray to the center of the scissors fork mechanism, and the supporting point of the egg tray is dropped onto the conveyor belt module from the supporting plate. The pallet is moved forward and the hook on the pallet is lower than the height of the conveyor belt. Then the belt drives the egg tray to move forward and sends the egg tray to the test bench.

![Image](image.png)

1. supporting plate  2. synchronous belt  3. Lifting Platform  4. Lead rail  5. conveyor belts

Figure 3. Scissor delivery mechanism.

### 3. Design of Automatic Loading and Unloading Machine Control System

The control system of automatic loading and unloading machine not only needs to complete the scheduled movement process, but also needs to take into account the system security and the efficiency. To prevent the egg shell from damaging by mechanical impact force, the acceleration should not be too large during the loading and unloading of the egg tray. For the size of the 150 egg trays is large, to prevent the interference of loading and unloading machine in the handling and transmission, the lifting platform needs 108mm as a loading and unloading interval, and it can start and stop continuously and complete the positioning. The contradiction between the low acceleration to start and stop and the high efficiency handling of loading and unloading machine puts forward higher requirements for the control system. The egg tray is delivered among truck, loader and egg detection platform, to prevent the interference of loading and unloading machine, the control system of loading and unloading machine is composed of proximity switch, photoelectric switch, photoelectric encoder, stepping motor, driver, control of the core components.

![Image](image.png)

Figure 4. Composition of control system.

### 4. The design of the coordinated movement process of the loading and unloading egg tray

The loading and unloading machine deliver the egg tray between the egg truck and the test bench, and the height of the work bench is 900mm. After turning on the loading and unloading machine, it will return to the machine origin, and the egg truck is pushed into the positioning mechanism of the loading and unloading machine, and the lifting platform drives the supporting plate to load and unload from the first layer of the egg truck. If the layer has an egg tray, the support
plate is positioned at the lower part of the layer 5mm, and the support plate extends into the egg cart about 150mm, and the lifting platform is lifted up by 30 mm under the traction of the lifting mechanism, which is separated from the anti-detaching hook. The pallet is retracted under the drive of the synchronous belt module, and the egg tray is hooked and pulled out by the hook on the pallet. When the egg tray was dragged to the conveyor belt at the left position of the sensor, the conveyor belt and the pallet move synchronously, when the egg tray enters the middle of the scissors assembly mechanism, the pallet is getting lower and lower relative to the upper plane of the conveyor belt, the movement of the egg tray will not be affected by the hook on the pallet, the egg plate is driven into the lifting platform under the drive of the conveyor belt, and the lifting platform moves to transfer the egg tray to the detection workbench, then the unloading process of an egg tray is completed. In the process of loading, the lifting platform is positioned at the height of the detecting worktable firstly, and the detecting table transmits the egg tray to the conveyer belt, then the egg plate enters the lifting platform completely under the function of the conveyer belt. The lifting platform is positioned at the upper part of the egg layer at 10mm, the belt drives the egg tray into the egg layer, and the egg tray is separated from the conveyer belt. The pallet stretches the egg tray into the egg cart.

5. Analysis of motion track of egg tray

Figure 5. The egg tray loading and unloading action process decomposition.

Figure 6. Analysis of the trajectory of the egg tray.
The front end cd of the egg tray is lifted 30mm under the action of the pallet B, and is separated from the anti-decoupling hook, and reaches the position of the abcd in the figure, and forms a certain angle with the supporting frame A of the egg tray. The pallet moves along the track surface B, and the front end of the traction egg tray moves to c’d’, forming a moving area of dcc’d’. The pallet continues to move along the track surface B, leaving the lower edge of the egg tray, and the focus point of the end face cd of the egg tray falls on the belt conveyor module. At this time, the synchronous belt module is started, and tow the egg tray continues to move forward to arrive at c”d” and form a d’c’c”d” area along the movement of synchronous belt conveying module. The rear end ab of the egg tray is advanced along the support frame A. The frame of the egg tray is abcd, and the front point of the egg plate c moves vertically upward under the action of the supporting plate, and the distance is H, and the moving distance of the B at the back end of the egg plate is as follows:

\[
s_b = l_{hc}(1 - \cos \alpha) \quad (1)
\]
\[
H = l_{hc} \sin \alpha + h \quad (2)
\]

Note: H——After the lifting platform is positioned, the supporting plate holds the egg plate to be advanced to the height 30mm

h——After the lifting platform is positioned, the support plate is away from the edge of the egg plate

\( l_{hc} \)——Egg tray length 720mm

\( S_b \)——The forward distance of the end of the Egg tray

\( \alpha \)——The angle between the egg tray and the supporting track is the maximum angle 0.04\( \pi \).

6. test verification

The egg tray automatic loading and unloading machine was tested and verified in an egg laying factory. The length of the egg cart is 1700mm, the height is 2100mm, the width is 560mm, and the space of each layer is 108±2mm, there are 16 layers in total and each layer has 2 egg trays, the first floor is 340mm from the ground. The size of the tray is 720 * 500mm with 150 eggs and the total height of the egg tray is 55mm and weighs about 10kg after full of eggs. The automatic loading and unloading machine takes the egg tray off and delivers it to the egg candling platform, after the text is finished, the egg tray is sent back to the hatching egg cart, and the automatic loading and unloading test of 6 egg cars is carried out continuously.

The test results show that the prototype structure is stable and reliable, the running time is compact and efficient, and the loading and unloading of the eggs can be completed successfully. The lifting platform has the advantages of high positioning accuracy, and it can be accurately positioned to the support plate of the egg tray, the movement of the various parts is coordinate, without Interference, stuck, friction abrupt change phenomenon. The vertical positioning error of the loading and unloading of the egg tray is 0.5mm, the horizontal positioning error is 0.5mm, and the success rate of loading and unloading is 100%. The unloading efficiency is 122 /h regardless of replacement time of the egg cart.

![Prototype testing.](image)


Figure 7. Prototype testing.
7. **Summary**

The egg tray loading and unloading machine is composed of a lifting and driving mechanism, a lifting platform and a scissors fork type delivery mechanism with a high difference. The design model of combined multi-degree of freedom for the loading and unloading machine solves the problem of automatic loading and unloading of the egg tray. The rigid telescopic mechanism and the flexible conveyor belt are combined into a scissor-type take-off mechanism with a high degree of difference, which resolves the barrier and anti-off hook obstacles. The automatic fetching and sending of the egg plate is realized in the limited space. The automatic loading and unloading machine of the egg tray promotes the automation degree of hatching, reduces the labor intensity, improves the loading and unloading efficiency of the egg tray, shortens the time that the hatching eggs leave the incubator, and improves the hatching survival rate.

**References**


