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Application of Ergonomics in the Installation of Silage Mechanical Coating Module

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Abstract. In the high-speed innovation of agricultural machinery, the main means of competition among different brands has shifted from product function to good user experience. Modular silage machinery has gradually become the development trend of agricultural machinery industry. In order to reduce the purchase cost of large silage machinery, improve installation efficiency and operational comfort, the silage machinery is divided into modules based on the functional flow model. Taking silage mechanical coating module installation as an example, analyzing the installation difficulties from the perspective of ergonomics, the module division and installation process design of the lifting device, the design of the coating module armrest and the connection mode between the lifting device and the coating module are obtained. The installation plan of the silage mechanical coating module. It relieves the pressure on the lumbar spine of the operator during the installation process and provides a design basis for the installation of other modules.

1. Introduction

The realization of agricultural modernization has affected the advancement of the country's modernization process. In the "Made in China 2025", agricultural machinery and equipment was proposed as one of the 10 key development areas. In addition to satisfying users' diversification and individualization requirements, today's silage machinery needs to embody the "people-oriented" design principle under the guidance of ergonomics and other theories. Lu Bing et al [1] proposed a self-combining module partitioning method based on functional flow model, which modularizes silage machinery, and divides independent functional modules and dependent functional modules; Qin Qun et al [2] according to ergonomics Designed a sitting and standing dual-use multimedia console; Xu Qingjun et al [3] for the shifting control device of China Yituo SG series tractor, based on ergonomics theory to improve and optimize the operating comfort of the whole machine Liu Guizhi et al [4] through the ergonomics analysis of the height of the large-size CNC lathe console, the control panel, and the operating handle of the console, the ergonomics that engineers and technicians must follow when designing the CNC machine console principle. In order to enable users to purchase according to their own needs when purchasing silage machinery, and reduce the harvesting cost of farmers, this paper introduces the modular design into the field of silage machinery, and combines the ergonomics



design of the packaging module to make the user Save time and effort when installing modules, convenient and fast.

2. Theoretical basis

Modular design refers to the division and design of a series of functional modules based on different functional functions within a certain range or products with the same functions but different performances and different specifications. The selection and combination of modules constitute different products. A design method to meet the needs of different market needs. The application of ergonomics in product functions is mainly to determine the function through the needs of users. The ergonomic installation analysis of the silage mechanical coating module after the module is divided to reduce the weight load of the operator's spine during the installation process is the focus of this paper.

2.1. Modular design

The module partitioning based on the functional flow model extends the scope of functional relationships between product components, indicating that the functional relationship includes not only the hierarchical relationship between the superior and the subordinate, but also the input and output relationships. The method starts from the product functional structure model and follows the principles of the mainstream principle, the tributary principle and the transformation and transportation principle. Based on the user's needs, the input and output are related to the three functional flows of material flow, energy flow and information flow. The way it is expressed, quantitatively studies the relationship between function and demand.

2.2. Ergonomics

Ergonomics is a comprehensive marginal discipline that studies the interaction between human-machine and environment. Through human-to-machine operational control, users are assured of high efficiency while feeling safe and comfortable. The significance of ergonomics lies in the fact that designers have the basis of rational thinking on the premise of perceptual thinking, that is, mechanical design itself is designed for the use of human beings, rather than purely for the aesthetic experience of human beings. Ergonomics, by measuring the size of the human body, is adapted to the corresponding design dimensions of most people.

The modular design can meet the individual needs of users and reduce costs. Ergonomics can make products more in line with the people-oriented design concept. Combining modular design with ergonomics, the ergonomic packaging module installation process is summarized, as shown in Figure 1.

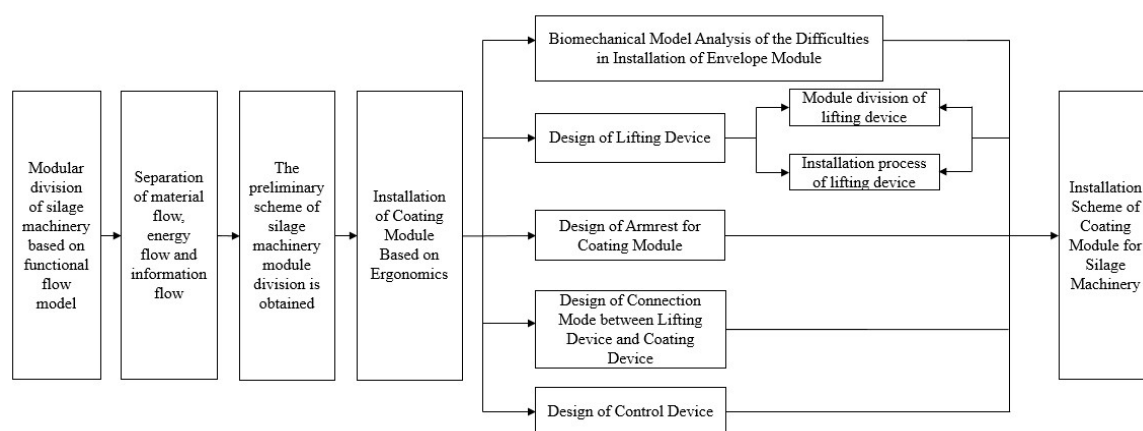


Figure 1. Ergonomics-based coating module installation process.

3. Silage mechanical function flow module division

The heuristic module based on the function flow divides the material flow, the energy flow, and the information flow, as shown in Figure 2-4, and completes the preliminary division scheme. As shown in Table 1.

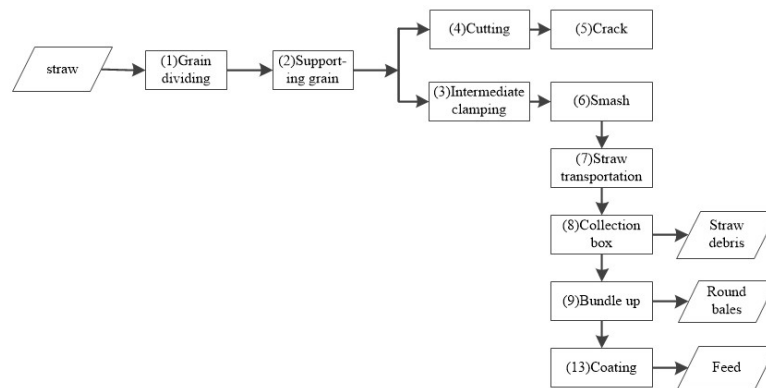


Figure 2. Material flow module division.

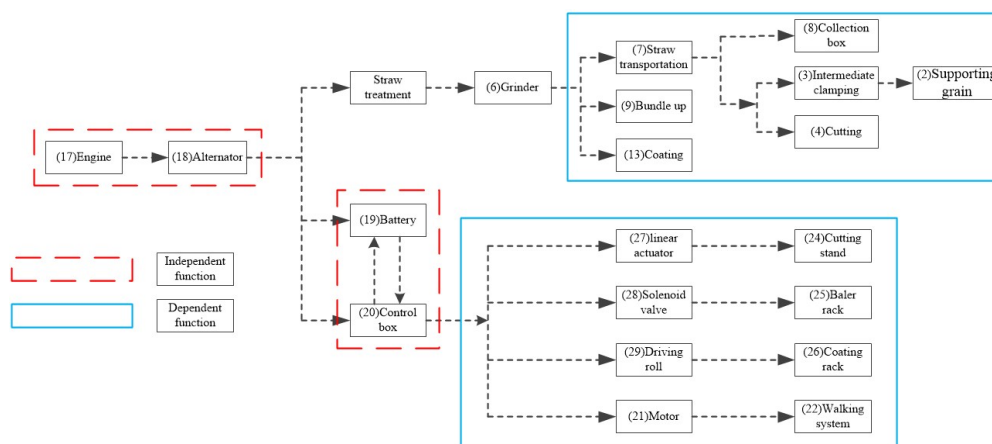


Figure 3. Material flow module division.

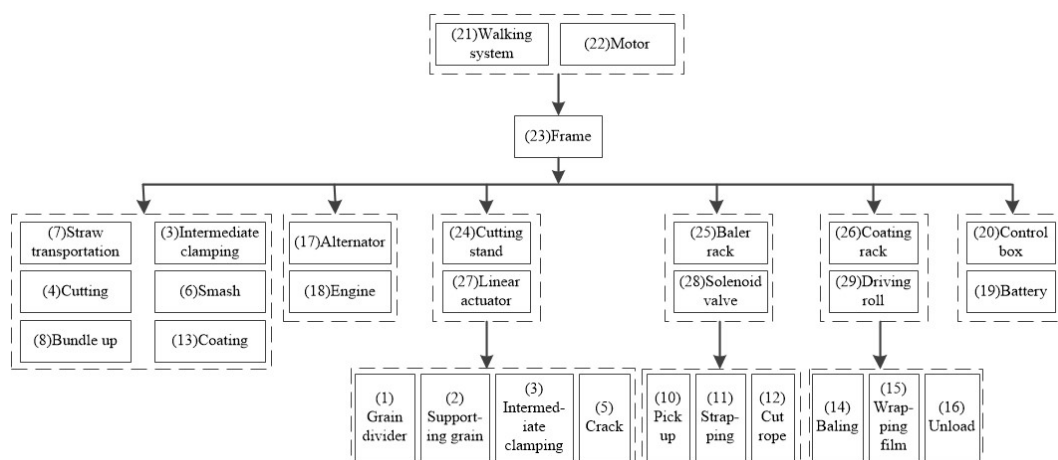


Figure 4. Information flow module division.

Table 1. Preliminary plan for the division of silage machinery modules.

Functional module	Module name	Number
Independent Function modules	Grain distributing and supporting modules	1, 2
	Intermediate clamping conveyor modules	3
	Cutting and pulverizing modules	4, 5, 6, 24
	Straw transportation	7, 8
	Bundling modules	9, 10, 11, 12, 25
	Coating modules	13, 14, 15, 16, 26
Dependent function modules	Drive power modules	17, 18, 19, 20, 21, 22
	fixed support modules	23
	control modules	27, 28, 29

4. Installation of coating module based on ergonomics

According to the preliminary scheme of the silage mechanical module division, the silage machinery is divided into 9 modules, wherein the independent functional modules are divided into a Grain distributing and supporting module, an intermediate clamping conveying module, a cutting and pulverizing module, a straw transportation module, a bundling module, and a coating modules, dependent function modules are divided into drive power modules, fixed support modules and control modules. In order to ensure that the modular silage machinery is suitable for users, it needs to be ergonomically designed. This paper mainly takes the installation of the coating module as an example.

4.1. Operator-encapsulated module biomechanical model

Ergonomics has shown that lifting heavy objects, bending objects, and twisting objects are the main causes of pain in the lower back. As shown in Figure 5, the waist is farthest from the hands and is the weakest lever in the human body. The weight of the torso and the weight of the cargo will exert tremendous pressure on the waist. According to the biomechanical static plane model of the waist at the time of lifting, the human body's torso gravity is the W_{torso} , and the raised weight is the W_{weight} , and the clockwise moment is generated.

$$M_{CT} = W_{weight} \times h + W_{torso} \times b$$

Counterclockwise torque is generated by the back muscles, and its force arm is usually 5cm, so

$$M_{Back\ muscles} = F_{Back\ muscles} \times 5(N.cm)$$

To achieve static balance,

$$F_{Back\ muscles} \times 5 = W_{weight} \times h + W_{torso} \times b$$

$$F_{Back\ muscles} = W_{weight} \times h / 5 + W_{torso} \times b / 5$$

Assuming $h=40\text{cm}$, $b=20\text{cm}$, the trunk gravity is 350N, and the envelope module gravity is about 490N, the force on the back of the human body when lifting the envelope module is

$$F_{Back\ muscles} = 490 \times 40 / 5 + 350 \times 20 / 5 = 5320(N)$$

Normal people's waist erect muscle can withstand an upper limit of 5000N. Therefore, how to reduce the back endurance when installing the capsule module is the primary problem in ergonomic design.

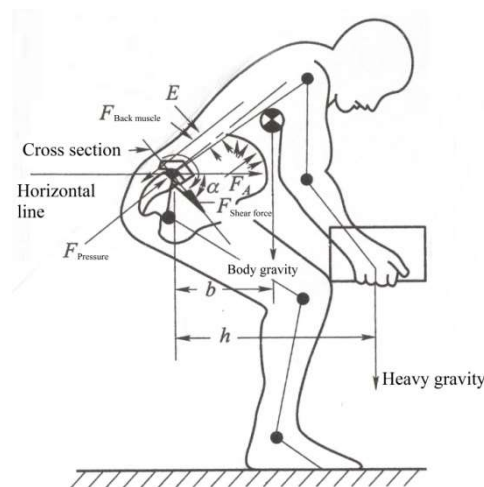


Figure 5. Biomechanical static plane model of the waist at the time of lifting.

4.2. Lifting device design

When transporting large cargo placed on the ground or close to the ground, the body must be bent forward and the pressure on the lumbar disc will increase significantly. Carrying heavy objects in different ways has different effects on the waist load. After long-term scientific research, summarize a set of correct lifting methods, as shown in Figure 6, that is, straight waist bending knee.

In order to minimize the torsion angle of the body, eliminate the unnecessary body twist during the operation of the operator, and reduce the possibility of discomfort and injury, the lifting device support rod adopts an arc design to prevent the operator from supporting the capsule module at a higher position.

The design of the lifting device requires the installation of the module of the envelope module and the baling module on the tractor. According to the 5th percentile position of the male and female in China, the maximum height of the two-handed function is 1868mm and 1741mm respectively, and the modular silage machinery needs The assembly of each module can also be achieved by people who are relatively weak in labor. Therefore, the height of the lifting device is designed to be 1700mm, which meets the needs of most people. The bottom of the envelope module has a fixed width of 380mm and a maximum width of 600mm. In order to stably place the envelope module on the lifting device platform and reserve the space for the connection structure, the width of the lifting device platform is designed to be 560mm.

The height of the lifting device designed in this paper is 1700mm, the width is 560mm, the length of the bracket is 700mm, and the bottom of the support rod adopts the arc design, as shown in Figure 7.

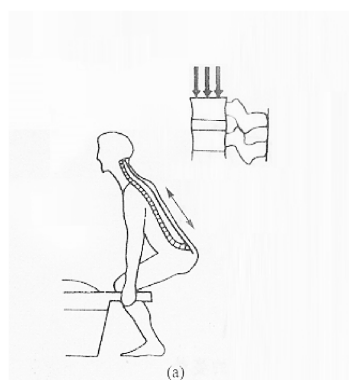
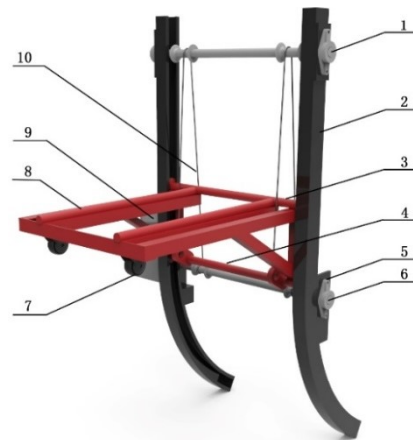


Figure 6. Straight waist bending knee.



1-driven shaft 2-support rod 3-upper rod 4-lower rod 5-fixing valve 6-actuator shaft 7-wheel 8-rail 9-transmission mechanism 10-wire rope

Figure 7. Lifting device design.

(1) Lifting device function flow module division

The structure of the lifting device is as shown in the above figure. According to the functional decomposition of the lifting device, the functional structure diagram of the product is established. The heuristic module division method based on the functional flow is used to divide the module [6], as shown in Figure 8, and the divided modules are performed. Description, as shown in Table 2.

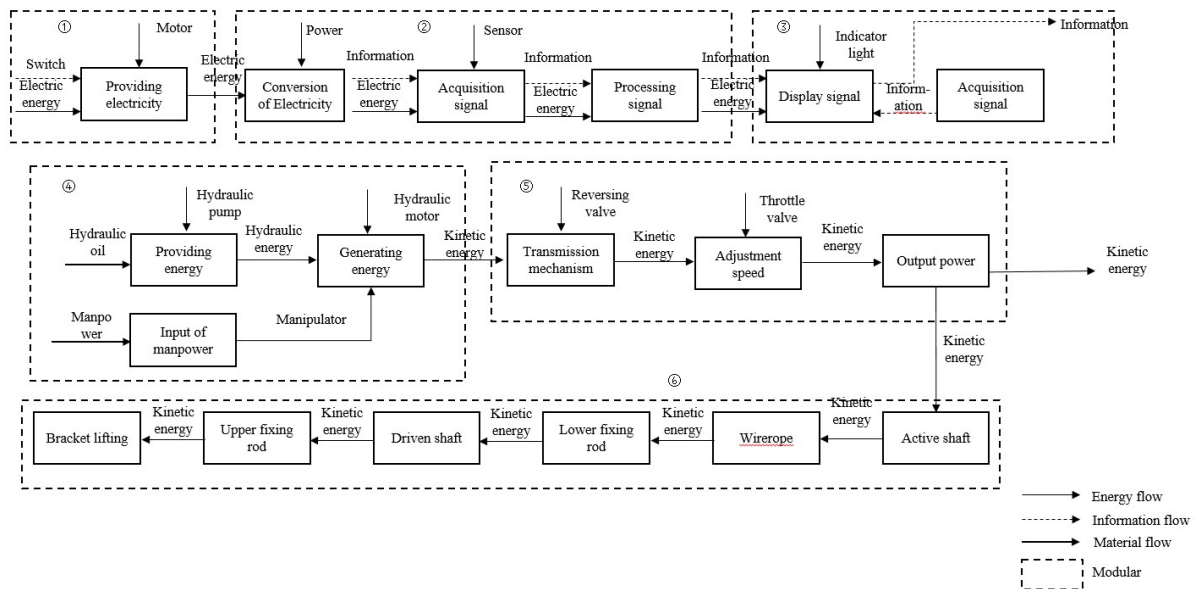


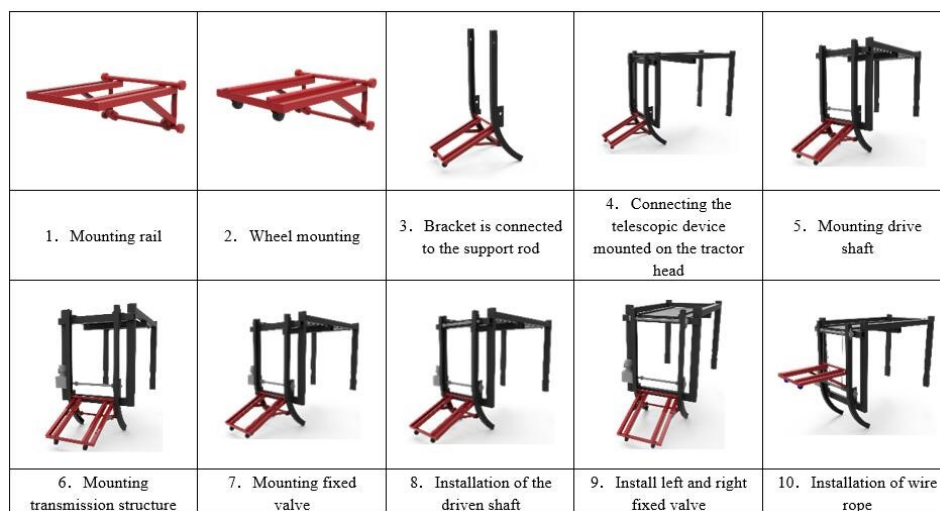
Figure 8. Functional flow based lifting device module division.

Table 2. Description of the division module.

Module name	Module description
(1) Drive power module	Mainly power input and conversion, consisting of parts such as motors
(2) Information processing module	Realize the signal acquisition, signal processing and control of the sensor through the information flow
(3) Information output module	Lights up when the working position is reached during installation
(4) Energy input module	Material (hydraulic oil) is converted into hydraulic energy with the participation of energy flow
(5) Power output module	Complete the conversion of hydraulic energy to kinetic energy and pass the output
(6) Fixed support module	Provide component protection and body support

(2) Lifting device installation process

The lifting device is mainly composed of a driven shaft, a support rod, an upper fixing rod, a lower fixing rod, a fixed valve, a driving shaft, a wheel, a guide rail, a transmission mechanism, a wire rope and the like. According to the installation principle of bottom-up and non-interference between parts, first connect the guide rail and the wheel to the bracket, slide it from the upper end rail of the support rod into the bottom end, and form a "human" bracket with the two corners; push it and The telescopic device installed on the tractor head is connected to form a fixed support; the drive shaft is inserted through the mounting hole, and the transmission mechanism and the fixed valve are respectively fixed at both ends; then the driven shaft is inserted through the mounting hole and fixed by the fixed valve respectively. Finally, the wire rope is wound around the driven shaft, and the two ends are respectively connected with the driving shaft and the lower fixing rod of the bracket to realize the installation of the lifting device. The specific installation process is shown in Figure 9.

**Figure 9.** Lifting device installation process.**4.3. Coating module armrest design**

The envelope module needs to be placed on the bracket of the lifting device during installation, so it is necessary to design an armrest that is easy to grasp. Reasonable handrails, in addition to meeting operational requirements, also need to conform to the structure, dimensions and tactile characteristics of the hand. In the palm of the hand, the palm muscles are the least, the interphalangeal muscles and the finger parts of the nerve endings are more, and the finger muscles, the big fish muscles, and the

small fish muscles are the natural shock absorbers on the palm, as shown in Figure 10. When designing the shape of the armrest, avoid holding the armrest close to the grip space of the hand, and not close to the palm. The length of the armrest must be close to or exceed the length of the hand so that the hand has a range of motion and selection on the grip; the radial dimension must match the normal grip size or be smaller than the hand grip. According to the above ergonomics principle, the armor of the coating module is as shown in Figure 11, which is 110mm long and 20mm wide. Installed on the envelope module as shown in Figure 12.

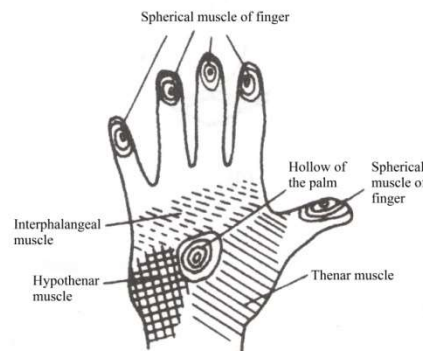


Figure 10. Hand structure.

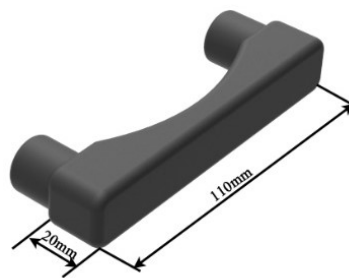


Figure 11. Coating module armrest design.

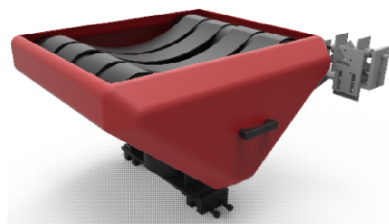


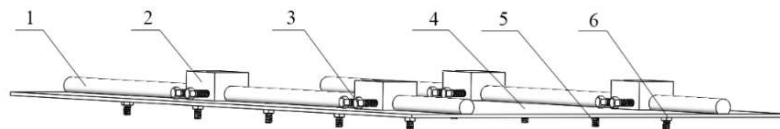
Figure 12. Coating module.

4.4. Connection design of lifting device and envelope module

There is a sliding connection and a rigid connection between the lifting device and the coating module during the installation process, and it is required to realize fast switching between the two states, which requires the connection mode to be simple and reliable. The existence of two different movement modes of lifting and lowering requires the connection mode to complete the motion locking, that is, when one action is performed, the other action is locked.

In combination with the design requirements of the above connection method, the rail slider mechanism is used to complete the connection between the lifting device and the coating module.

The lifting device bracket is provided with guide rails, the rails are approximately 3/4 round in cross section, and each of the rails is welded with 5 studs, and is fastened and mounted on the bracket by nuts. A slider is arranged on the left and right sides of the bottom support position of the envelope module, and four fastening bolts are arranged on each of the sliders. When sliding to the proper position, the fastening bolts fix the slider to the guide rail to ensure the rigid connection during the lifting process. . As shown in Figure 13.



1-Guide rail 2- Slider 3-Fastening bolt 4- Lifting device bracket 5-Stud 6-Nut

Figure 13. Rail slider.

4.5. Control device design

The operating devices are generally divided into three types: rotary, mobile and push-type. Due to the small footprint and compact arrangement of the push-type operation, the silage mechanical control device mainly includes the starting and closing of the power supply, and the lifting and lowering of the lifting device. The drop, the header, the baler, the opening and closing of the laminating machine, etc., mostly have only two working positions: on and off, so the selected operating device is in the form of a button. At the same time, in order to reduce the user's misoperation, improve the recognition and transfer the amount of information, abstract the display content of the operating device, design and control the graphics and symbols with similar characteristics on the control button, which is convenient for people to perform operations. During the task, under the influence of various stimulating factors of shape, meaning and color, the button and the object are quickly connected to improve the execution speed of the task. Some of the key diagrams are shown in Figure 14.

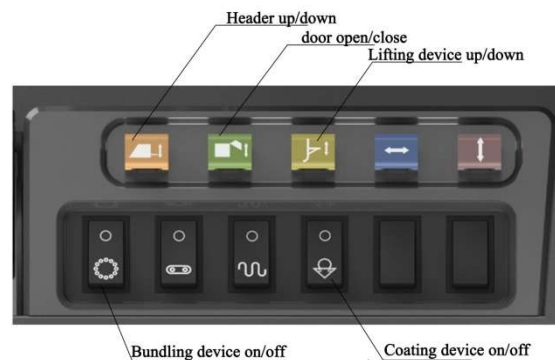


Figure 14. Part of the button schematic.

5. Coating module installation process

The total length of the envelope module is 650mm and the total height is 390mm. The bale module needs to roll the bundle of rope wrapped from the door to the envelope module. In order to ensure that the bale does not fall, the envelope module working platform and the bale module the warehouse door is on the same level. During the installation process, it is convenient for the operator to recognize that the vertical warning light is designed at a position of 390 mm from the top of the support rod of the lifting device. When the envelope module is wrapped, the driving roller is required to drive the bale to rotate, and the rotating arm rotates to drive the feeding mechanism to revolve. The center of the coating module is 325mm, and the working space of the coating module is 150mm. Therefore, the

horizontal warning light is designed at a position of 475mm from the lifting device. As shown in Figure 15.



Figure 15. Indicator position.

With the bottom arc design of the lifting device, the operator holds the handrail, connects the slider on the film module with the rail on the lifting device bracket, and fixes it with the fastening bolt; press the "L" button on the control device, the transmission mechanism And the wire rope drives the envelope module to rise, and the indicator light is bright when reaching the working position; relying on the sliding friction between the guide rail and the slider, the operator holds the handrail to push the envelope module to slide until the horizontal indicator light is bright, and is locked with the fastening bolt. As shown in Figure 16. The use of the guide rail slider mechanism and the lifting device to complete the installation of the envelope module greatly reduces the pressure on the back muscles of the operator, and avoids the pain of the waist caused by bending over the heavy objects.




			
1. Hold the handrail and dock with the lifting device bracket	2. Slider and rail connection	3. Fastening bolt	4. Press the lifting device "L"
			
5. Rise to indicator light on	6. Coating module to working height	7. Pan to indicator light on	8. The installation is complete

Figure 16. Encapsulation module installation process.

6. Conclusion

Based on the functional flow model, this paper divides the silage machinery into modules, improves product quality, reduces costs, and realizes the user's demand for product diversification and individualization. Based on ergonomics, the lifting device and operating device required for installing the coating module And the connection between the lifting device and the envelope module is designed to reduce the pressure on the back muscles of the operator during the installation process. Due to the limitation of space, this paper only preliminarily divides the silage machinery and lifting device. In the subsequent research process, the rationality of module division and the installation process of the envelope module will be verified by experiments to improve the feasibility of the scheme.

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