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Automated Vaccine Injection Machines

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Abstract: In view of the large demand for medical staff in the current large-scale vaccination, there will be a large number of people piled up in line for injection. At present, the large-scale vaccination in China still adopts artificial injection or batch injection devices for poultry. The project team creatively developed and produced an automatic emergency vaccine injection device. The device is divided into injection module, holding module, disinfection module, feeding module, intelligent voice broadcasting system and electronic display module. Through the mutual cooperation of these five modules, the injection is realized. The whole device is made of lightweight materials to reduce the fear of needle fainting of the target population. The overall structure is simple, the cost is relatively low, and has strong universality and operability. Through preliminary experiments, users can get a good sense of vaccination experience.
Keywords: automation, injection, low cost, easy operation

Introduction

As an emergency medical device, the purpose of this product is to complete the vaccination task with high efficiency and high quality, effectively improve the work efficiency of the medical industry, and relieve the work pressure of medical staff. In addition, the use of automated vaccine injection devices can greatly reduce the impact of human factors on the work, ensure the accuracy of the work, greatly improve the quality of the work, and bring convenience and contribution to the future medical industry.

Through the investigation of vaccine injection products in the market, it is found that there are some gaps in domestic vaccine injection products. Vaccine workers and vaccinators communicate through study and discussion, and through a large number of data, their components mainly include injection module, support module, disinfection module, feeding module, intelligent voice broadcasting system and electronic display device.

The design concept of this product is to achieve more efficient vaccination work and reduce the use of human resources for medical workers. It is necessary to allow the device to automate a series of processes such as drug collection, human skin disinfection and vaccine injection, and the medical personnel only need to complete half an hour to observe the rejection of the vaccinated person after the injection, and implement the social concept of "intelligent health". Products can not only be used against large flu and viruses, but also in medical places such as hospitals.

1. Design purpose

At the end of 2019, a fierce novel coronavirus broke out in Wuhan, China. China has taken strict prevention and control measures to kill the novel coronavirus under its control. Since the epidemic prevention effect of COVID-19 vaccine needs to be initially effective when the universal injection rate reaches more than 60%, so the large-scale vaccination is imperative.

Extensive vaccination is in a high demand for health care workers, and boring and repetitive injections can also affect vaccination efficiency. According to the national WeiJian Wei news, the national cumulative report vaccination more than 200 million times, the amazing data reflects the social phenomenon is in the community vaccination point or designated point can always see a large number of queue, crowded is bound to waste a lot of time, long time waiting to experience bring irritability (figure 1), in the face of a large number of people vaccination work also greatly increased the medical staff labor (see figure 2).

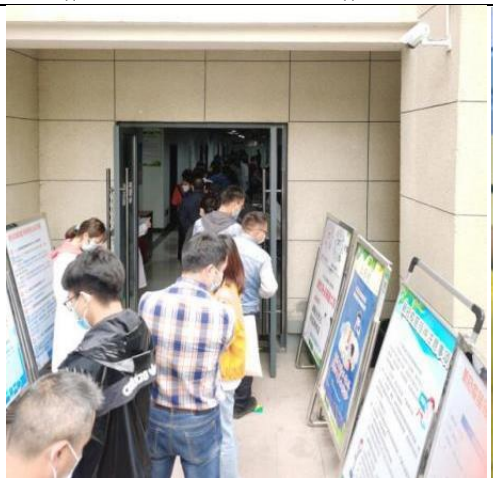


Figure 1

Figure 2

At present, a large range of domestic vaccine injection is still using artificial injection or batch injection device for poultry (Figure 3), among which the more advanced is the autonomous blood drawing machine device (Figure 4), which can be used for reference. Therefore, there is a certain gap in the injection of vaccination. According to the statistical analysis of reliable data (Figure 5), the registration amount of vaccine-related enterprises is gradually increasing, so it is inferred that the supply of automated vaccine injection devices in the medical industry should be growing and popularized in the future.

Figure 3

Figure 4

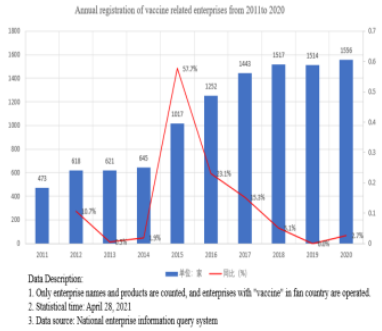


Figure 5

Since vaccination is a basic medical skill, in order to put human resources in place, an emergency vaccine injection device is needed in the most emergency places. Therefore, the research on this device has a certain social and commercial prospect and a good development trend.

Problems required to be solved for this product:

1. Reduce the length of queues for vaccinated people;
2. Improve the efficiency of vaccine injection and reduce the workload of medical staff;
3. To avoid medical problems such as deviation and deepening caused by objective factors to a large extent to ensure the accuracy of vaccine injection.

2. Design scheme

2.1 Design requirements

Therefore, this product is used by adults. For the vaccination of COVID-19 vaccine, the injection is an integrated injection (Figure 2.1).

Figure 2.1

In view of the current problems existing in market research and artificial injection, the design requirements of our proposed products can be summarized as follows:

1) The device shall be simple and light in design;
2) The device should work flexibly and easy to move;
3) Disinfection module, injection module, recycling and installation module should be between the corresponding cooperation;
4) Electronic display screen and intelligent control board are convenient for the operation of the target population
5) The injection module should respond to the control instructions quickly
6) The device gives the target population a sense of security
7) Other gain points

2.2 Design performance and indicators

(1). Working environment: 12V DC;
(2). Operating weight: 10kg;
(3). Maximum number of bearing needles of the feeding module: not less than 10;
(4). Needle injection speed: 20cm / s.

2.3 Overall design scheme

According to the above design requirements and design performance and indicators, make the overall design scheme as shown in Figure 2.2.An automated vaccine injection device should, be, simple in design, and easy to use.

When the user uses the product:

In order to prevent the user's arm shaking, imitate the doctor's left hand to pull the arm, should be held on the outside mechanism.

For hygiene and to prevent infection, there should be disinfection institutions.

In order to solve the integrated injection tail needle cap, there should be a mechanism to remove the needle cap.

In order to improve the injection efficiency and good user experience, the injection should be rapid injection institutions.

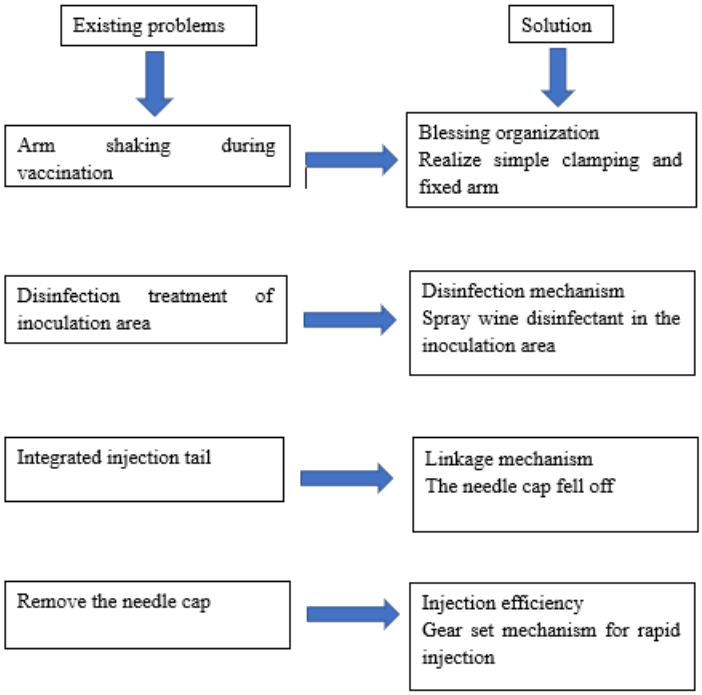


Figure 2.2

2.4 Selection and demonstration of relevant mechanical design scheme

At the beginning of the design, the research group put forward two schemes for the design requirements, which are gear group mechanism and double link mechanism. According to the working principle of double link (Fig. FIG. 2.3) and gear set (Fig. 2.4), the selection scheme of the following two advance and advance module can be formulated.

Scheme 1: The double-rod mechanism controls the advance and advance process. Advantages: simple structure, small parts, light and maintenance. Disadvantages: the operation process is unstable, which can cause the injection speed is not easy to control.

Scheme 2: gear mechanism control the advance process. Advantages: applicable load and speed range, reliable operation process stable, high efficiency and long life. Disadvantages: cannot achieve the variable speed effect, and the cost is high, not easy to maintain.

Considering the advantages and disadvantages of the above scheme and the target population of the product, we believe that the stability and classification of the injection speed are large factors in the process of vaccination injection design, so the second gear group mechanism is selected.

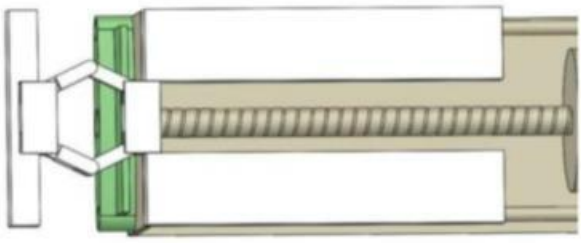


Figure 2.3

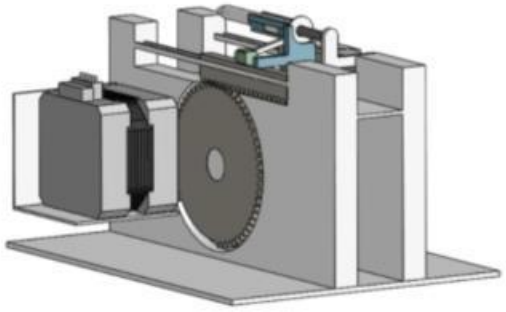
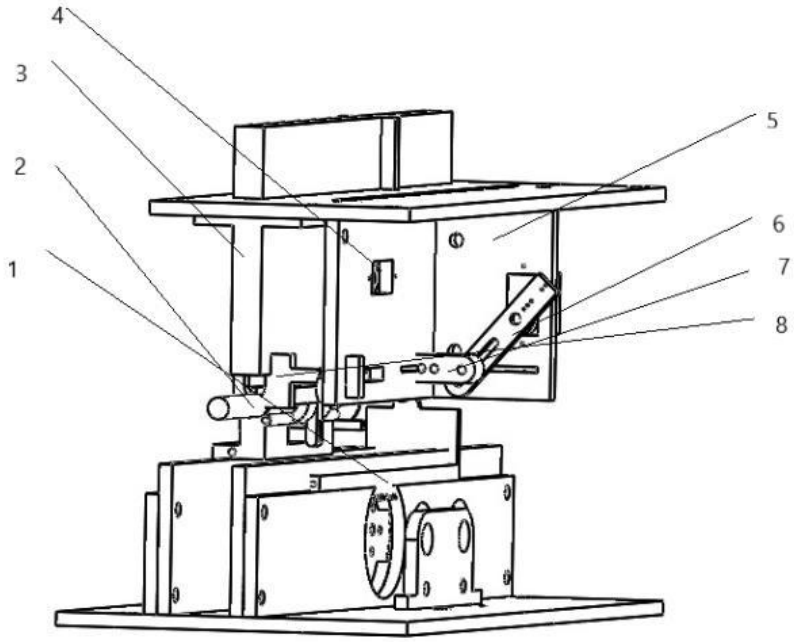


Figure 2.4

3. Working principle

An automatic vaccine injection device its working principle is based on the reality medical staff vaccination a series of vaccine operation process: hold the arm-disinfectant, select injection-needle injection, reasonable recovery, its module simulation, mainly injection module, blessing module, disinfection module, feeding module and intelligent voice broadcast system and electronic display module (main mechanical structure as shown in Figure 3)..1



In the diagram:
1-rack, 2-injection, 3-vaccine box, 4-steering gear, 5-position plate, 6-steering gear, 7-link, 8-lateral rod

3.1 Injection module

When the stepping motor is turning, one side is an incomplete gear through contact with the rack and the other side with the needle handle. When the stepping motor is reversed, the two sets of gears can also drive the movement of the needle handle and needle pipe. Due to the existence of incomplete gear, the continuous action of needle ligation and injection can be completed.

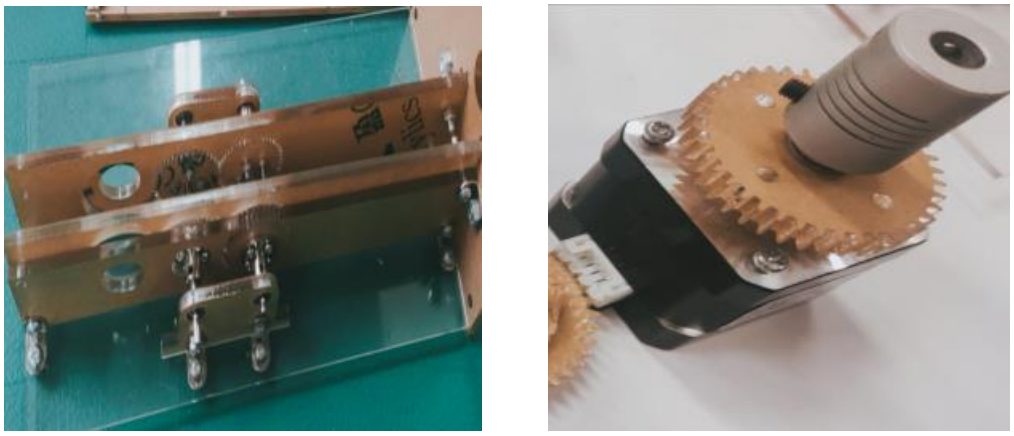


Figure 3.1 Electric Motor and Gear Set

3.2 Holding module

When the user presses the deltoid muscle area of the arm close to the hole of the arm cylinder, the arm will buckle and the buckle will pull the wire. The two meniscal plates contained in the arm cylinder will be close to each other under the action of the powerful spring, and then achieve the effect of shrinking and fixing the arm. The aim is to prevent the shaking of the arm during the injection, and the damage of the vaccine needle causes lower injection accuracy. Half moon uses flexible rubber material, and the outside is covered with thin rubber, which is easy to hold the arm and bring comfort and security to users.

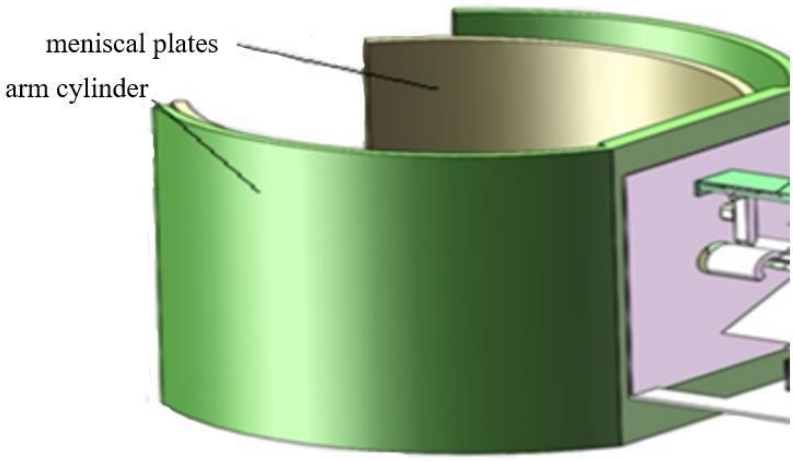


Figure 3.2 Simulation diagram

3.3 Disinfection module

When receiving the confirmation information instruction, the atomized tablets (As shown in the figure3.3) begin to work and spray disinfectant. According to the set power-on time, to achieve a small dose of disinfectant injection, so as to achieve disinfection and sanitation treatment.

Figure 3.3 atomized tablets

3.4 Feed feeding module

According to the principle of the crank shake rod mechanism, the servo rudder machine begins to turn, which will cause the longitudinal propulsion of the push rod, forcing the preinjection position below to fall. After the servo turns again, causing the pullback, the upper vaccine will enter the pre-injection position below (As shown in the figure3.4).

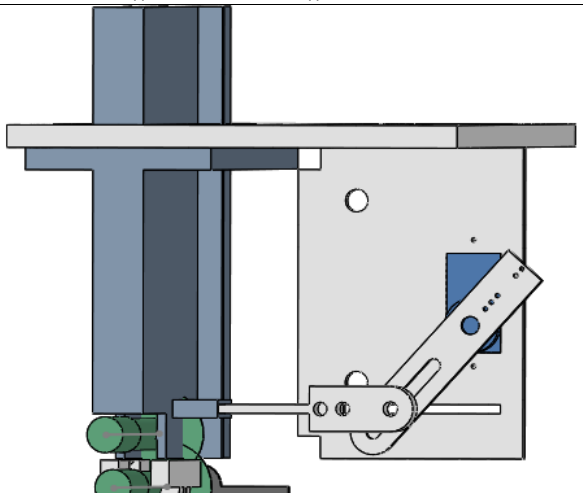


Figure 3.4 feeding simulation diagram

3.5 Intelligent voice broadcasting system and electronic display module

For vaccinators, there are intelligent display screen and voice broadcast function, which can provide users to confirm personal information before vaccination. The display will show the user's name, ID number, contact information, type, capacity and batch of the vaccine. The user operates according to the intelligent display information and voice broadcast information on the device. After confirming the personal information, the arm to be vaccinated is extended. After the inoculation, the voice broadcast will indicate that the inoculation has been successful and can leave for 30 minutes without abnormality.

Figure 3.5 Display screen and player

4. Design and Calculation

4.1 Gear design and calculation under the gear mechanism

Generally speaking, the operation steps of artificial vaccine injection can be roughly divided into three processes: needle insertion, injection of vaccine, and needle extraction. The process time of needle insertion is 1 to 2 seconds, vaccine injection process time is 5 to 8 seconds, and needle extraction process time is 1 to 2 seconds.

This module accordingly uses the gear set mechanism accordingly to complete the design purpose. The main parts are active gear, left rack fastener, right rack fastener, driven complete gear, driven incomplete gear. The components have a stepping motor and a reducer.

According to the size measurement of each part of the needle, the design needle pipe needs to move 60mm distance, while the needle handle needs 120mm distance. Considering the substitutability of the standard parts and the rationality of the transmission process efficiency, we choose the gear and rack with modulus m=1.

According to the above theory, the theoretical number of the rack is 40, the actual number of the rack is 48 (considering the engagement of the gear and the rack) only p=3.14mm, we set the transmission ratio is 1, so according to the number of Figure 2.4, z=40, the number of incomplete gear z=20 (symmetrical distribution).The formed gears and rack are shown in Figure 4.1.

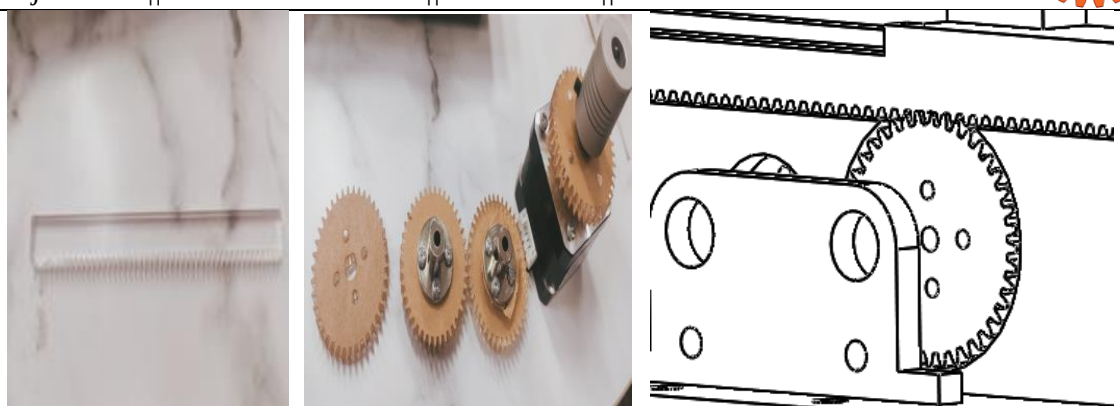


Figure 4.1 Gear and rack chart

Tie the needle: the stepping motor is turning, and the reducer reduces the rotation to 15~30r / min. The active gear is correctly engaged between the gears. The front gear set, the left side is driven incomplete gear, the tooth part and the left rack fastener engagement, the left rack fastener drives the needle tube joint movement 62.8mm, the speed is 31.4~62.8mm/s; the right side is the driven full gear, through engaging with the right rack member, the right rack member drives the needle handle common motion 62.8mm, the speed of 31.4~62.8mm/s. The needle cylinder moves synchronously with the needle cylinder. The depth of the needle into the human body is 5~8mm, and the outlet can be set at 57.8~54.8mm.Thus, the purpose of inserting the needle is completed.

Injection Vaccine: Stepper motor is turning forward, reducing the number of revolutions to 3.75 to 6 r / min. The active gear is correctly engaged between the gears. Front gear set, the left side is driven incomplete gear, the less part does not engage with the left rack fastener, the left rack fastener and needle stop movement, the stop time is 5~8s; the right side is the driven full gear, engaging with the right rack member, the needle handle common motion 62.8mm, the speed of 7.85~12.56mm/s. The needle handle slowly injects the vaccine into the body, achieving the purpose of the injection.

Pull out the needle: The stepping motor reverses, and the reducer reduces the revolutions to 30~60r / m in. The active gear is correctly engaged between the gears. Front gear group, the left side is driven incomplete gear, the first toothless part does not engage with the left rack fastener, the left rack fastener and the needle tube first stop movement, the stop time is 0~1s, then the tooth part with the left rack fastener, the left rack fastener drives the needle joint movement 62.8mm, speed is 62.8~125.6mm/s; the right side is the driven full gear, by engaging with the right rack member, the right rack member movement 125.6mm, the speed is 62.8~125.6mm/s. The needle handle is separated from the right rack member, and its movement state follows the syringe. This completes the purpose of pulling out the needle.

The system processing variable speed time of the three process intervals is 1s.The total time to run once is from 9 to 14s.The running time mode can be switched according to the inoculum.

4.2 Selection of electric motors

According to experience, the doctor's needle is generally "two fast and one slow" that is, the needle and pull needle speed, the speed of injection is slow, according to the experience and the moment of the speed should be 30-50 cm/s. The speed of the injection is generally 20 cm/s.

$$V = \omega r \quad (1)$$
$$\omega = 2\pi n \quad (2)$$
$$T = 9550P/n \quad (3)$$

The rack speed is about 0.4 m/s, and the motor speed is about 3 rpm; the rack speed is 0m / s, and the motor speed is about 1 rpm..2.2.6

When the rated 24w stepping motor, the torque is 1.12N · m and 2.4N · m

According to the design, the space size of the motor shall not exceed 0.6m*0.6m*0.6m.The initiation reaction time was t <2s

After calculation, meet the parameters required for the design function:

The excitation mode is 2 phase excitation (2 phase four beat operation), with positive and negative rotation; rated current (single phase) is 1.5A (DC); power supply voltage is in the range of 12~36V; working environment is adapted to 10~50°C; rotational inertia is 50~60g.cm2. Meet the parameters required for the design optimization function (low noise, low heating, low loss): no-load starting frequency f 2000pps, no-load operating frequency f 8000pps.

Our group members selected three motors whose high sales volume on the market met the design requirements (Figure 4.2):

Table 1 Comparison table of step-forward motor types

Step motor type	price	quality	power
Type T step motor	Y50	0.5kg	20W
ST trapezoidal straight guide rail slide table	Y80	2.5kg	24W
Electric light push rod motor	Y100	1.8kg	20W

Considering the economic and energy saving factors, the team chose the T-type linear wire rod stepping motor.

Figure 4.2 Various types of motors

4.3 Determination of the rocker mechanism size

Since the stroke of the push rod is 20mm, during the movement of the connecting rod mechanism, the size of the remote rod is tentatively 10 mm, and the size of the connecting rod is 20 mm. When the crank rotates continuously, the connecting rod will drive the push rod to reciprocate.

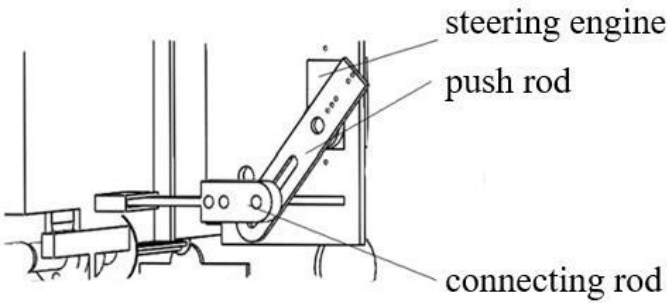


Figure 4. Schematic diagram of the linkage mechanism

4.4 Design and calculation of relevant electronic control operation scheme

This product to achieve more multifunctional, so the need for more electrical parts, resulting in more input and output variables.

The electronic control core control board adopts UNO R3 control board with high development efficiency, stability and good compatibility. Each functional module component is controlled separately through the control board, and three-way adc signal is input through the joystick to control three steering gear, among which two steering gear control rods.

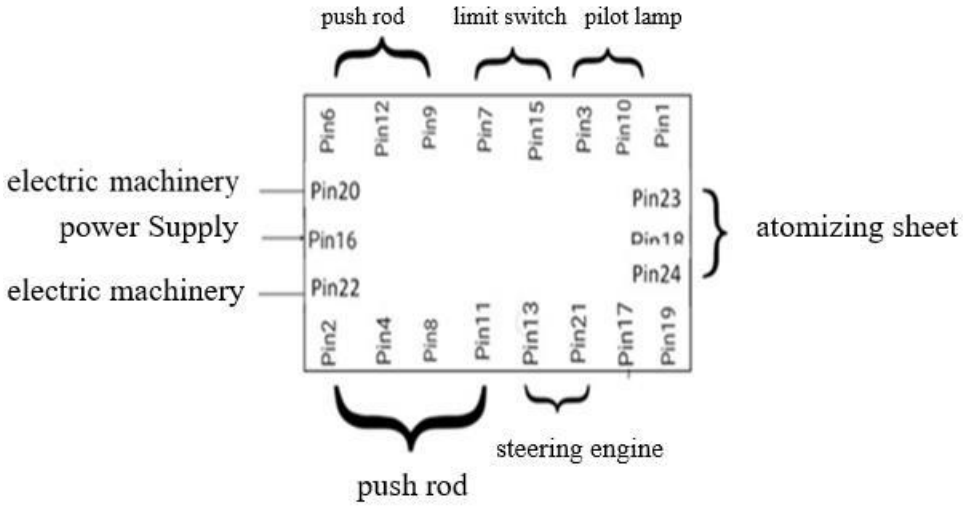


Figure 4.4 Schematic diagram of the control principle of the electronic control components

Figure 4.5 Electric control board

4.4.1 Mechanical control design

Due to the working strength of each module, we choose MG90S metal steering gear and its accessories, and with indicator lights, you can view the working status of each module. as shown in the figure.

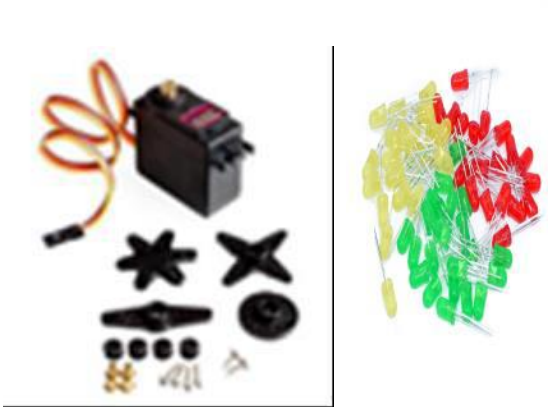


Figure 4.6 Steering gear and led indicator lamp

4.4.2 Disinfection device setting

As the hospital disinfected with iodine tincture (iodine), dip a cotton swab each time, smear the injection area, about 15cm * 2, and measure about 5ml.Therefore, we consulted the online medical data and found that the existing universal disinfection was a small dose injection at that time, so we sprayed it with atomized tablets (Fig. 4.6), with the power of 10ml / minute and the injection range of 90 degrees wide Angle. The atomization film meets the design requirements according to the simulation.

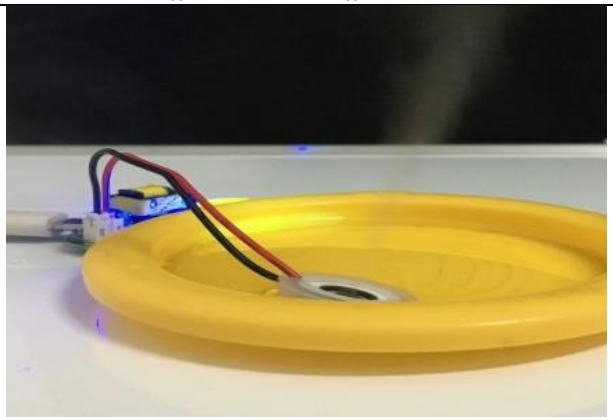


Figure 4.7 atomization film

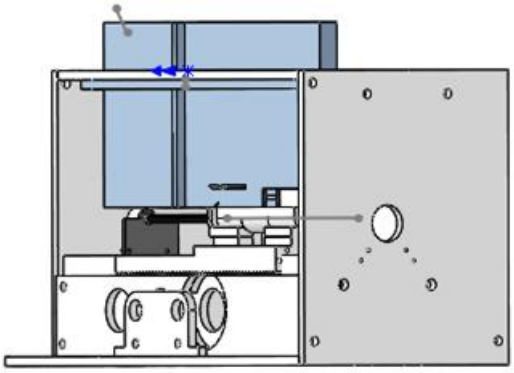
5. Main innovation points

(1) Through the combination of incomplete gear and complete gear and tooth rack, the continuous action of vaccine injection needle and injection is achieved.
(2) Through the application of the crank rod mechanism, the intermittent drop of vaccine injection one by one.
(3) Through the combination of electronic display and announcer, the intelligent experience of users is improved.
(4) The disinfection module is composed of atomized tablets, peristaltic pumps and other instruments to realize the function of small-dose injection disinfection.

6. Future planning

In the future, the product is not only limited to the scope of vaccination, but also to improve the injection, no type, more intelligent networking with medical big data, people can scan with medical insurance card or ID card or QR code.

Work picture



Summary

Automated vaccine injection devices are targeted not only for the COVID-19 vaccine, but also for mass vaccination of a similar nature. The overall structure of the device is simple, relatively low cost, with strong versatility and operability. After preliminary experiments, users can get a good vaccination experience. As an emergency medical device, the vaccine injection of mass epidemic diseases, such as COVID-19 and influenza, can complete the vaccination task to people with high efficiency and high quality, program the non-core injection work, and effectively reduce the workload of medical staff, which has great promotion and application value. However, due to the lack of physical production experience and short time, there are still some defects in appearance and function. I hope to have the opportunity to show the optimized second-generation products in the subsequent competition site. Hasty written, inevitably have a lot of shortcomings, please criticize and correct the experts!

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