

DESIGN OF AUTOMATIC TRUNK INJECTION MACHINE BASED ON TREE PEST CONTROL

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ABSTRACT

A trunk injection machine is designed, which integrates trunk drug injection, bottle insertion and drug spraying and realizes automatic control through MK60 single chip computer. It can quantitatively inject medicinal liquid, reduce the dosage of medicinal liquid and save a lot of manpower. The automation of trunk injection is realized. An effective solution for control of tree diseases and insect pests is provided.

Keywords: trunk injection, tree pest control, automatic control, multi-function

Introduction

With the improvement of people's awareness of environmental protection, the area of plantation becomes larger and larger, but the incidence of forest diseases and insect pests is increasing year by year. Serious insect pests may occur during the growth of trees if not managed. Drug spraying is not only wasteful but also has a great impact on the environment. Drugs residue in the soil greatly endanger the survival of other species and bring some resistance to the sustainable development of forest areas. There are many advantages in the prevention and control of diseases and insect pests, such as reducing the pollution of pesticides to the environment, only killing pests, protecting livestock safety, saving about 80% of drug use compared with spraying method, and saving a lot of manpower.

At present, forest trees are generally treated with drug injection to prevent and control diseases and insects. After drug injection, trees will not be affected by diseases and insects in one year or two. Under the condition of drug protection, forest trees can avoid the reproduction of diseases and insects and reduce the number of insect pests year by year. More importantly, it makes forest areas more convenient to maintain and greatly reduces the labor intensity of forest protection workers. However, different forest trees are suitable for different methods of prevention and control injection. At present, there is no multi-functional machinery which integrates perforation, injection and bottle insertion. This not only seriously affects the efficiency of operation, but also severely tests the health of forest protection workers who work for a long time. If the three functions of injection work are integrated into one, three functions can be switched arbitrarily to adapt to different requirements of trees, which greatly reduces the waste of drugs, significantly reduces the labor intensity of workers, and significantly improves the efficiency of operation.

1 Research status

In 1926, American scholar Muller published "Internal Therapy of Plants" and put forward the theory of tree injection control. Tree injection technology has been studied for nearly 100 years and has been developed for a long time ^[1]. However, as the technical basis of trunk injection equipment, it is far from meeting the needs of society. Many key technical problems, such as injection speed, damage to trees, intelligence and automation level, still need to be further studied. At present, there is still a need for higher performance injection machinery ^[2]. The

analysis of the working process and characteristics of dozens of tree injection and pesticide application machines developed in the past 70 years at home and abroad shows that these machines have developed six basic types: manual pneumatic type, manual hydraulic type, hand-supported direct pressure type, energy storage type and mechanical automatic type from the original natural transmission and injection type. Their main performance parameters are injection pressure and one-time injection quantity^[3]. The general trend of trunk injection machine is from low pressure, low concentration and low speed injection to high pressure and high concentration injection.

Shun G, Jian C and others put forward that different injection methods and time will produce effects on plants in 2012. Therefore, it is necessary to study the physiological status of plants and the best part of trunk injection^[4]. Because of the density of the trunk and the slow speed of drug absorption, how to achieve efficient absorption is also a major difficulty in current research. In order to improve drilling efficiency, the study of optimizing the bit and power drive part of the injection machine needs to be strengthened^[5].

In 2012, Shang Q and Liao K studied and analyzed the structure and sealing mechanism of the needle, analyzed the current structure and sealing mechanism of the needle, demonstrated the shortcomings of its sealing principle, and developed a trunk injector ring drill successfully. The shape of the needle is special. CMT5105 can be used to measure the jacking force of the needle. Because of the special shape of the needle, the needle has good sealing property in the cambium. When it enters the tree trunk, the diameter of the needle can be enlarged, but it will not crack. In the trunk injection test, the needle can inject a large amount of nutrient solution and achieve remarkable economic benefits. But it needs a lot of manpower, and cannot carry out a wide range of operations, and the punching part of the machine still needs the assistance of injection, in the direction of automatic injection still needs to be improved^[6].

2 Integral structure design

The purpose of this design and research is to solve the problem of tree pest control, enrich the function of trunk pest control drug injection equipment, improve the automation level of trunk injection machinery, reduce the degree of environmental pollution, and further realize energy saving, environmental protection and green operation.

The main function of automatic trunk injection machine is to flexibly switch three working modes, which is suitable for trunk injection of different trees. The injection machine has designed the mechanism of perforation, injection and bottle insertion, which can meet the injection requirements of different trunks of various trees, and the operation is efficient, accurate and stable. This new switching structure of three working modes makes the injection work not affected by the types of trees and different operating requirements.

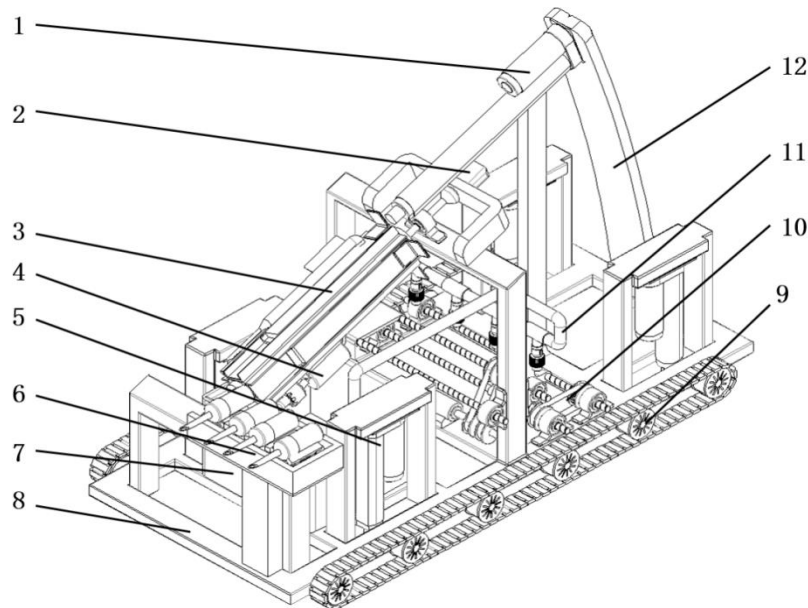


Fig. 1 Structural diagram of the whole machine

The overall structure of the automatic trunk injection machine is shown in Figure 1. In Figure 1, 1~12 is composed of main push rod motor, transposition steering gear, punch, injection, bottle inserting mechanism, electric drill, horizontal lifting mechanism, medicine bottle conveying mechanism, medicine box, chassis, driving track, synchronous wheel, spray rod, main body rack and so on. The main functions of the automatic trunk injection machine are walking, horizontal adjustment, perforation, injection, bottle insertion, drug spraying and so on. The crawler mechanism consists of track, driving wheel and bearing wheel. The crawler is set on the periphery of driving wheel and bearing wheel. The driving wheel and bearing wheel are fixed on the chassis. The driving wheel is driven by a motor, which drives the bearing wheel, track and frame to complete the moving function. When working, the injection machine first moves to the tree to be protected, and the chassis 7 is adjusted to the horizontal state through the horizontal adjusting mechanism. Then, the steering structure with electric drill 4 is rotated to the front end of the push rod by the displacement steering gear 2. Driven by a pair of push rods of the main motor, the drill bit is pushed into the tree trunk during the starting of the electric drill 4 to realize the drilling operation of the tree trunk. After drilling, the displacement steering gear 2 rotates the injection head to the front of the push rod, pushes the injection head into the hole, starts the first pumping pump, and realizes the drug injection operation. If it is necessary to insert bottles into trees, the displacement steering gear 2 rotates the bottle storage block to the front of the push rod, and the main push rod 1 drives the bottle storage block forward for a certain distance. Then the push motor on the delivery mechanism 6 pushes the bottle down, and the bottle falls into the groove of the bottle storage block. The main push rod 1 continues to push forward, inserting the bottle into the hole to realize the bottle insertion.

3 Key component design

3.1 Perforation, injection and bottle inserting mechanism

According to the functional requirements, the machine needs to have the functions of perforation, injection and bottle insertion. In order to meet the basic functional requirements, a comprehensive mechanism of perforation, injection and bottle insertion is designed and installed at the front end of the machine. The mechanism needs to switch freely among the three functions to meet the needs of different trunk injection operations. The whole mechanism is made of cold rolled steel to avoid the bending deformation of the mechanism. It is found that the injection depth required by most trees is between 20 and 30 mm, and the thrust required is generally between 800N and 1400N.

3.1.1 Perforation mechanism

The drilling mechanism is shown in Fig. 2. The top plate, slide way and 775 electric drill (shown in table 1) in Fig. 2 (1-3) are respectively locating at the rear part of the machine. After entering the working state, the push rod motor at the rear moves first, pushing the rear top plate and the slide rail forward together, and the 775 electric drill at the front of the slide rail moves forward together with the slide rail. When the electric drill is started at the predetermined working position, a hole with a depth of 20 mm-30 mm is drilled on the trunk, and then the push rod motor is recovered. The slide rail drives the motor to recover under the action of the spring, and the drilling work is completed.

Table1 775 Electric Drill Parameters

Technical index	Parameter	Technical index	Parameter	Technical index	Parameter
Rated voltage	12V	Step diameter	17.4mm	no-load power	20.4W
No-load current	12V, 1.7A	Installation aperture	M4	motor speed	3000(r/min)
Locked rotor current	4.7A	Motor length	67mm (excluding axes)	Motor shaft length	16mm
Bench height	5mm	Shaft diameter	5mm		
Motor diameter	45mm	Mounting hole spacing	About 29mm		

Through investigation and development, it is found that the injection depth required by most trees is between 20 and 30 mm, and the thrust force required is generally between 800 N and 1400 N. For this reason, the slideway is made of cold rolled steel with a length of 330 mm, a width of 48 mm and a thickness of 2.6 mm to meet the strength requirements.

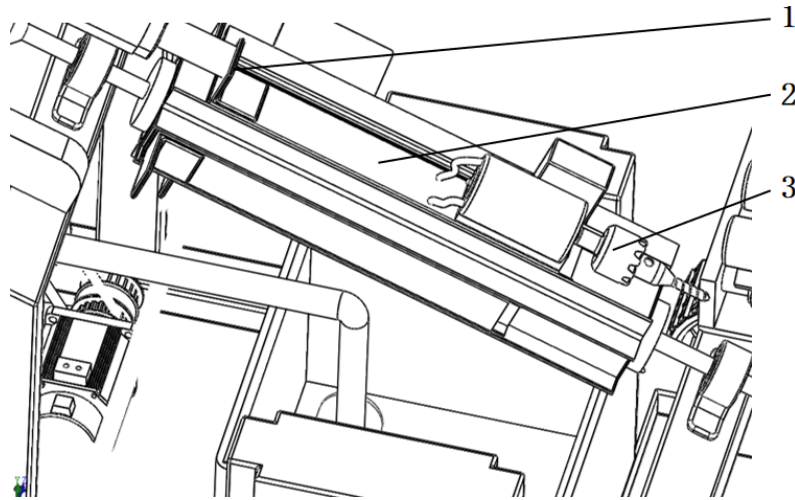


Figure2 Perforation mechanism

3.1.2 Injection mechanism

The injection mechanism is shown in Fig. 3. In Fig. 3, the sliding track, the rear top piece, the injection head, the medicament conveying pipe, the medicament box and the water pump are respectively shown in Fig.3 (1~ 6). The parameters of water pump are shown in table 2.

Table2 DC Pump Parameters

Technical index	Parameter	Technical index	Parameter
Voltage	12V	size	85 mm long * 50 mm wide * 65 mm high
power	18W	lift	4.8rice
flow	8L/min	Bearing temperature	60Within degrees
weight	200g		

When working, the steering gear conversion mechanism first acts to drive the rotating shaft to rotate, and the machine switches to the injection mode. Then the push rod motor works to push the rear top plate and slideway forward. The injection head located at the front end of the slide way moves forward along with the slide way. Under the control of MCU MK60, the injection head enters the hole that has been punched accurately. At this time, the water pump transfuses the medicine from the medicine box to the injection head. After the injection into the trunk, the push rod motor is retrieved, the whole mechanism is retrieved under the spring drive, and the injection work is completed.

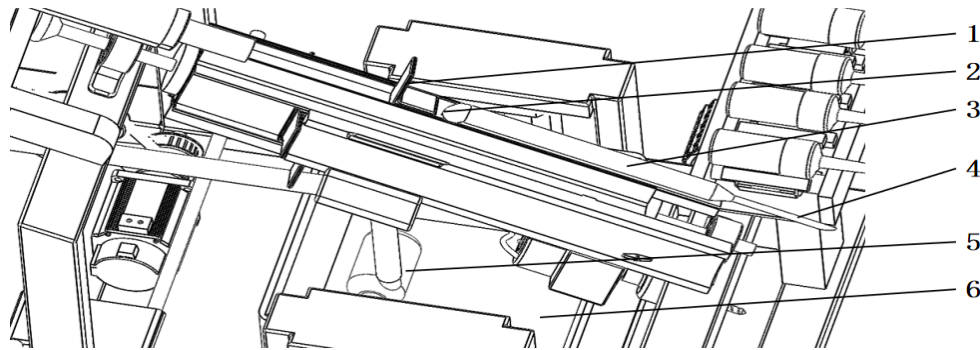


Figure 3 Injection mechanism

3.1.3 Bottle inserting mechanism

As shown in Fig. 4, the bottle inserting mechanism in Fig. 4 is composed of rear top plate, slide track, tightening steering gear and conveying mechanism of medicament bottle. When working, the steering gear switching mechanism first acts to drive the rotating shaft to rotate, and the machine switches to the working mode of bottle inserting. Then the push rod motor works to push the rear top plate and the slide rail forward. The chute on the slide rail moves forward along with the slide rail. After reaching the predetermined position, the conveyor mechanism of the upper part of the machine works, and the conveyor belt starts to move under the drive of the step motor to deliver the bottle. In the chute, when the bottle slides down to the bottom of the chute, the bottle is tightly inserted into the trunk for tightening the steering gear at the bottom. Subsequently, the whole mechanism was recovered, the transportation was stopped and the bottle insertion was completed.

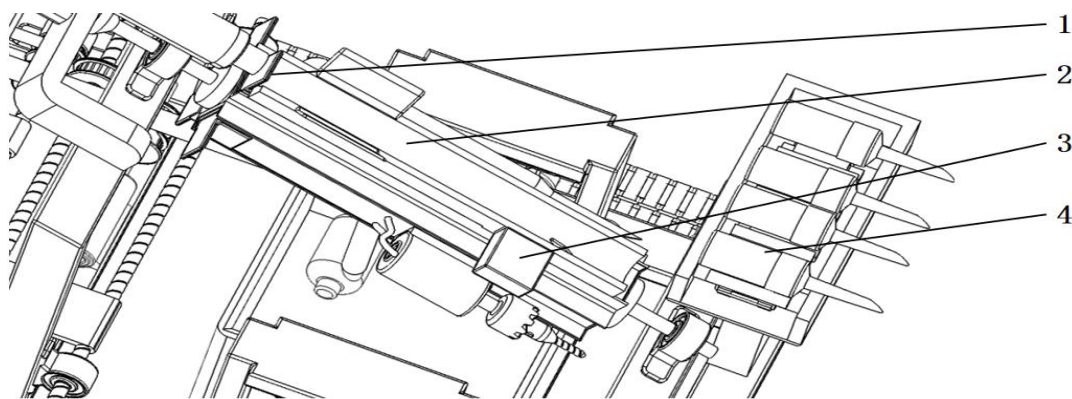


Figure 4 Bottling mechanism

3.2 Horizontal adjusting mechanism

The whole vehicle needs to maintain horizontal when it is working, so as to ensure the accuracy of the operation. The main function of the horizontal regulating mechanism is to maintain the horizontal of the machine. It consists of MMA8451 accelerometer, ENC-03RC gyroscope and

four push rod motors. When the machine reaches the working position, four push-rod motors work at the same time to raise the machine to a certain height. In this process, MMA8451 accelerometer and ENC-03RC gyroscope real-time monitor the horizontal of the machine and feedback the detection signal to MK60 MCU. The single chip computer controls the elongation of each push rod motor so that the machine is in a horizontal state.

3.3 Drug spraying system

The drug spray system is shown in Figure 5 as an auxiliary system of the machine. In Figure 5, 1~6 is medicine box, medicine delivery tube, spray rod, driving motor, synchronous wheel and synchronous belt. To achieve the function of spraying drugs, spraying drugs can kill pests in weeds around trees and improve the control effect. The number of synchronous gear teeth: 20 teeth, external diameter of teeth: 31.83 mm, outer diameter of shield: 35.5 mm, top wire hole: 2 M4, total height: 21 mm. The bandwidth of the synchronous belt is 10mm and it is made of the rubber material. The pitch is 5.08mm. Tooth shape: trapezoid, spacing: 5.08mm, width: 10mm, synchronous belt circumference: 203.2mm, teeth number 40. Spray head: adjustable and closed single outlet micro sprinkler 8mm three way barb. Drug conveyor pipe: 7*10 mm milky white silica gel pipe.

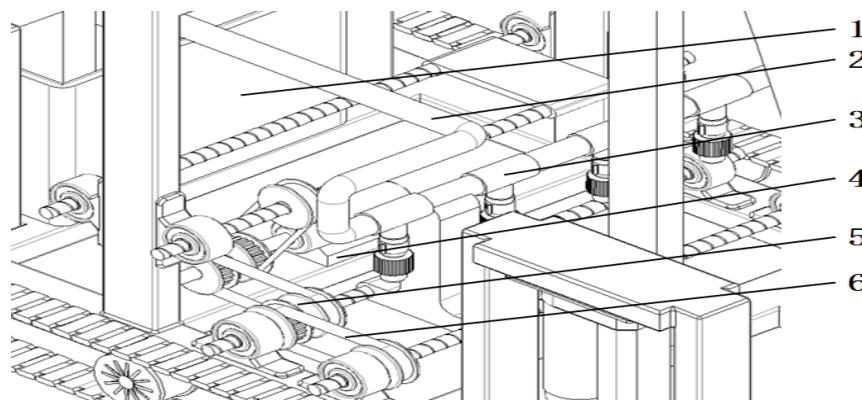


Figure5 Drug Spraying System

3.4 Vehicle Steering and Driving System

Vehicle driving system: In order to cope with complex road and woodland conditions, crawler is specially driven as shown in Figure 6. Its shape size is 900*320*300 mm, net weight is 2 kg, maximum torque is 1.2. The power is supplied by two 12V555 deceleration motors as shown in Fig. 7. The steering of the machine is realized by differential drive method.

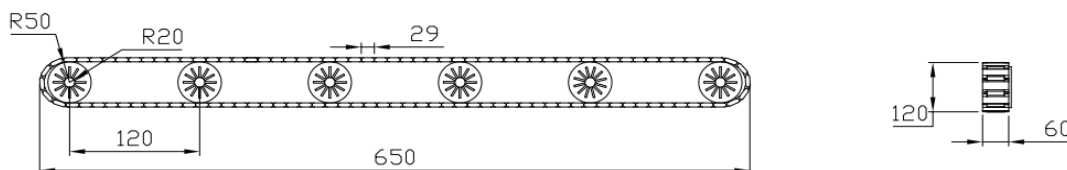


Figure6 track

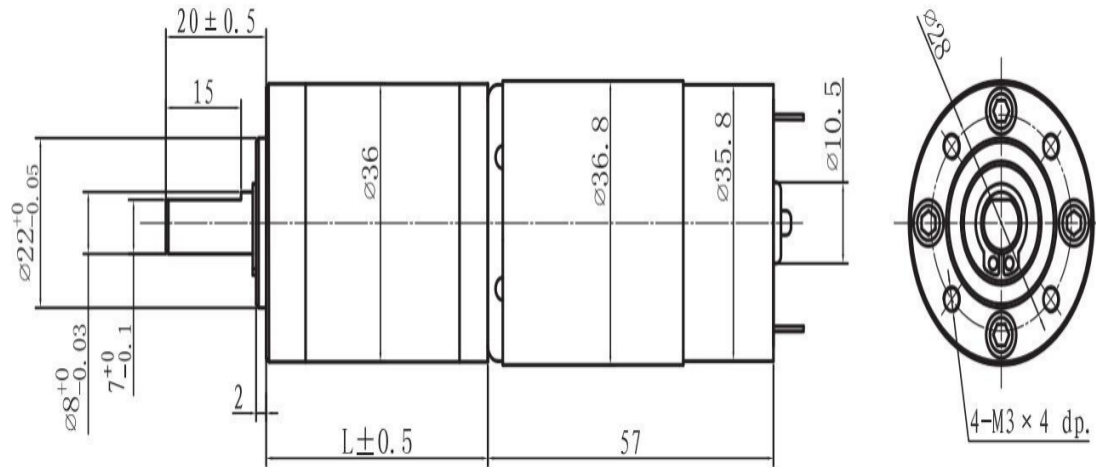


Figure7 555 deceleration motor

There are many advantages of the automatic trunk injection vehicle using tracked drive. The tracked drive makes the machine have a strong grip and can move freely between trees without being affected by the exposed roots and fallen branches and leaves of trees. Track drive has a large force area and a small pressure relative to the ground, so it is not easy to cause traps. And the track structure is simple, strong and durable, has excellent stability, can greatly increase the stability of the drive.^[7]

4 Control scheme design

In order to facilitate operation and improve automation, remote control handle is designed for remote operation. Operators can monitor the whole system in real time through the data displayed on the LCD screen. For example, when the machine arrives at the working position, the machine automatically adjusts the horizontal. By analyzing and calculating the feedback signals of MMA8451 accelerometer and ENC-03RC gyroscope, the MK60 single chip computer adjusts four push rod motors to keep the body horizontal, so as to facilitate the accurate completion of injection by perforation, injection and bottle insertion mechanism. If trunk injection is carried out, when the corresponding function key is pressed, the CPU will quickly process the relevant information, start the electrical components of relevant functions to drive the movement of relevant mechanical parts, and realize the function of trunk injection by automatically switching the steering gear between the workflow of punching, injection and bottle insertion; if the spraying function of drugs is turned on, the 555 motor will start and turn on. The synchronizing wheel, synchronous belt and ball screw transmission device make the spray stick slowly extend, and the liquid in the medicine box is sprayed out by the spray rod under the twitch of the small pump to achieve the function of spraying the medicine. The overall workflow of the control system is shown in Figure 8.

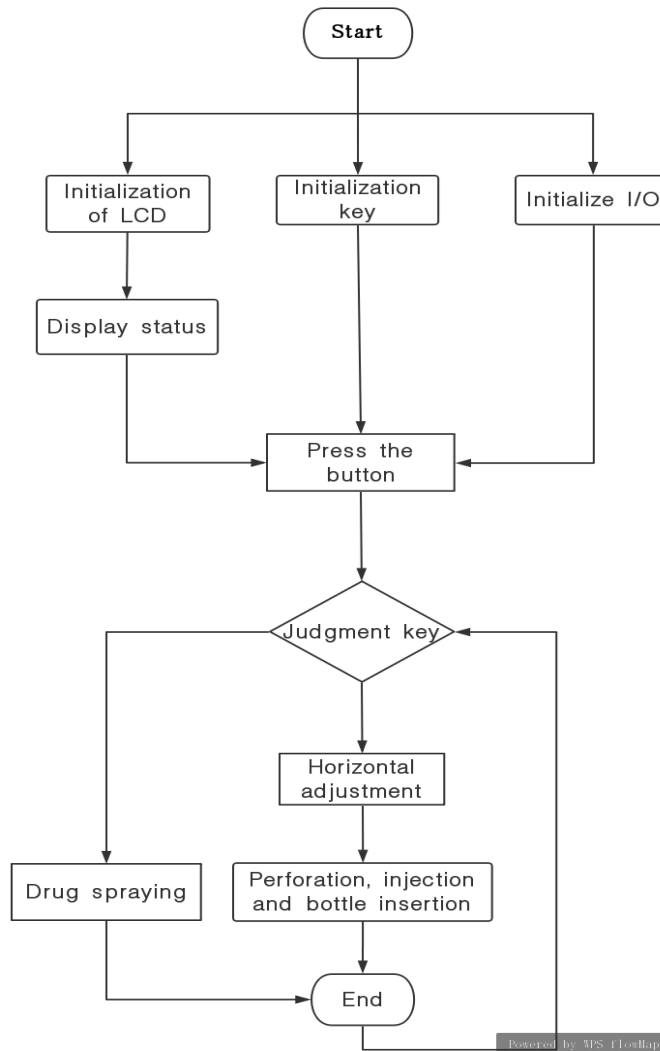


Figure8. Flow chart of control system

5 Whole machine performance

The trunk injection truck operates remotely through a remote control handle, and the operator can monitor the whole system in real time through the data displayed on the LCD screen. For example, when the machine arrives at the working position, it automatically adjusts the horizontal. By analyzing and calculating the feedback signals of MMA8451 accelerometer and ENC-03RC gyroscope, the MK60 single chip computer adjusts four push rod motors to keep the machine horizontal, so as to facilitate the accurate completion of injection by punching, injection and bottle insertion mechanism. If the trunk injection work reaches the designated position, the machine is erected by using the characteristics of the push rod motor, and the machine is kept horizontal by using the gyroscope, so as to ensure the stability of the machine in the working process, and the remote control is used to select the working mode after the adjustment is

completed. Mode 1: The main push rod motor works, so that the drill bit extends on the tree trunk to punch holes, the main push rod motor resets, the displacement steering gear works, the main push rod motor makes the dispensing device extend, injects the medicine into the tree trunk, and resets. Mode 2: The main push rod motor works to make the drill stick out and punch holes in the tree trunk, the main push rod motor resets, the displacement steering gear works, the main push rod motor makes the dispensing device extend, injects the medicine into the tree trunk, the main push rod motor resets, the displacement steering gear works, the main push rod motor makes the inserting device extend, the push bottle device pushes down, the tightening steering gear inserts the medicine bottle into the tree trunk, and resets. Mode 3: The main push rod motor works, so that the drill bit extends to punch holes on the tree trunk, the main push rod motor resets, the displacement steering gear works, the main push rod motor makes the bottle inserting device extend, the bottle pushing device pushes the bottle down, the tightening steering gear inserts the bottle into the tree trunk, and resets. If it is to open the spray function of medicine, the 555 type motor starts through the synchronous wheel, synchronous belt and ball screw transmission device to make the spray stick slowly extend, and the liquid in the medicine box is sprayed out by the spray rod under the pumping of the small pump to achieve the function of spraying the medicine. The performance parameters of the whole machine are shown in Table 3.^[8]

Table3 Performance Index Table of Automatic Trunk Injection Vehicle

Test items	Specifications	Test items	Specifications
Overall size	900mm*400mm*550m m	Main Push Rod Motor Travel	300mm
Slide length	310mm	Lifting Push-rod Motor Travel	100mm
Gross weight	20kg	Motor specifications	DC12V
Specification of steering gear	6V*3	Stepper motor	6V*1
Drilling depth	30mm-40mm	Bearing temperature	Less than 60 degrees centigrade
Body lift range	10mm-100mm	Maximum climbing angle	25Degree
Borehole diameter	4mm-8mm	Maximum operating speed	8 (km/h)
Maximum drilling speed	2000 (r/min)		

6 Popularization and application value

The automatic trunk injection vehicle has the following advantages:

- (1) Small and flexible: Compact mechanical design enable machine to operate in narrow terrain.
- (2) Full-featured: Automatic trunk injection truck is a practical machine which integrates perforation, injection, bottle insertion, drug spraying and other functions.
- (3) Energy-saving and environmental protection: The automatic trunk injection vehicle is driven by pure electric power, no noise, no pollution emission, clean and environmental protection, and low cost.

From the point of view of reducing manpower and improving operation efficiency, the designed automatic trunk injection truck aims at users' requirements and meets the national promotion policies. The automatic trunk injection truck adopts automatic control, which can reduce manpower and achieve a wide range of tree diseases and insect pest's control. It has good development prospect in future intelligent gardens.

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