An efficient portable fruit picker

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Abstract. In order to solve the problems of various fruit picking, such as large labor consumption, low efficiency, inconvenient picking machinery, we designed a low-cost and high-efficiency portable fruit picker. The cutting device of the fruit picker is composed of a fixed blade, a steel wire and a DC motor, and the control circuit drives the wire to cut the fruit handle by controlling the rotation of the DC motor. At the same time, we will also analyze the shear stress and system freedom of the fruit stem when the wire is cut. The highly efficient and portable fruit picker not only has high picking efficiency, small size, easy to carry, but also works stably and is suitable for picking a variety of fruits. The DC motor is powered by a 12V/15AH lithium battery and can operate continuously for 12h.

1. Introduction

As a fruit producing country, China produces more than 100 million tons of various fruits each year [1], and the entire production process requires a lot of labor. According to incomplete statistics, the labor required for orchard harvesting accounts for 35% to 45% of the entire fruit production process [2]. Its importance is self-evident, so it is of great practical significance to improve the level of mechanical picking in China and increase the degree of mechanical picking; these include liberating people from heavy picking labor, bringing China’s fruit production into an efficient stage, and promoting the optimization and reform of fruit planting structures. At present, the mechanical picking methods on the market are mainly divided into two types: mechanical assisted semi-automatic picking and mechanical automatic picking [1]. Both forms have their own advantages and disadvantages: the mechanical automatic picking of the mode 1 has the advantages of high efficiency and labor saving, but at the same time there is a problem that the position of the fruit cannot be accurately identified and the fruit is damaged. The equipment required for mechanical automatic picking is usually inconvenient to move. When the working environment is mountainous or hilly, this shortcoming is particularly prominent and even unable to work normally. The secondary system research and development is relatively high; in contrast, the mechanically assisted semi-automatic picking of mode 2 is not as good as that of mode 1, but its environmental adaptability is high, the picking precision is high, the fruit damage rate is low, and the volume is small and easy to carry. In contrast to the two methods, people are more willing to adopt mode 2 mechanically assisted semi-automatic picking. However, most of the mechanically assisted semi-automatic picking tools currently on the market have disadvantages such as poor versatility, poor adaptability, poor reliability and complicated operation [1]. The research was analyzed, optimized and innovated to design an efficient portable fruit picker. The fruit picker overcomes the shortcomings of versatility and poor adaptability, and can pick a variety of fruits such as apples, pears, and bayberry in different environments; the operation is very simple, and the picking can be completed by simply pressing the switch with one hand; The picker is also designed with a
buffer device to better protect the fruit during the collection work after the harvesting is completed. The above-mentioned, high-efficiency portable fruit picker is very suitable for the current fruit picking industry in China and it will play an important role in it.

2. Fruit picker basic composition
The fruit picker is composed of control system, power system, executing agency and gearing.

![Figure 1. Fruit picker basic composition](image)

3. Major component determination

3.1 Determination of the power plan
At present, the equipment that can provide power for machinery mainly includes electric motors, hydraulic equipment, pneumatic equipment, internal combustion engines, and the like. Different power equipments have their own advantages and disadvantages, but the power equipment for small mechanical tools such as pickers usually requires small size and light weight, so the internal combustion engine is generally not selected for power equipment. Therefore, the next step is to compare the working characteristics and performance of the motor, hydraulic equipment and pneumatic equipment, and select the power source that is most suitable for the efficient portable fruit picker power equipment.

|                             | Hydraulic equipment | Pneumatic equipment | Electric motor |
|-----------------------------|---------------------|---------------------|---------------|
| Output power                | Very large          | Large               | All have      |
| Reaction speed              | High                | Higher              | high          |
| Hidden danger               | Fire                | Explode             | Safety        |
| Structure                   | Simple              | Simple              | Complex       |
| Control                     | Steplessly regulated| Low                 | Accurate      |
| Environment                 | Oil stain           | Noise               | Nothing       |
| Cost                        | Higher              | Low                 | High          |
| Maintenance and use         | Convenience         | Convenience         | Complex       |
Efficient portable fruit pickers require simplicity, that is, the structure should not be too complicated, portable, and its quality and volume should not be too large, safe and minimize safety hazards, and the required power is not large, but it needs to work stably. The above selected motor is used as the power equipment.

3.2 Executive agency determination
At present, the actuators and picking heads of pickers on the market can be roughly divided into three types: scissor picking, gripping picking, and screwing picking. Different picking forms have different advantages and disadvantages, and the corresponding characteristics are selected according to their respective characteristics.

Scissor picking, scissor picking head is designed to mimic the working principle of scissors. It not only has good working performance, but also can cut the fruit stalk quickly and effectively. It is a traditional and stable cutting method. The structure is simple and the operation is simple. However, the picking needs to match the position of the handle and the picking head, and the smaller the stem is not conducive to positioning, which makes the picking work laborious and work inefficient.

Grab-type picking, grasping picking head imitates the working principle of the human hand, the work performance is good. When picking, picking the fruit with the picking head and pulling down the fruit to complete the picking simulation of the manual picking process, the work is stable and reliable and not easy to damage the fruit. However, when picking a fruit, it is necessary to put down the picker to collect the fruit and then carry out the second picking, which is inefficient; the size of the picking head limits the type of fruit picked, and the adaptability is poor; when the fruit handle is relatively firm, picking is very laborious.

Screw-type picking, the screwing picking head uses the rotation to generate shearing force to break the fruit stem to complete the picking. Although this method is stable in operation, the picking work can be completed, but the structure is complicated. When the fruit is picked, the picker is put down, and the fruit is collected and then picked twice, so that the work efficiency is low; the size of the picking head limits the type of fruit picked, and the adaptability is poor; it is very laborious to pick the relatively strong fruit handle; because the picking head needs to be rotated, the fruit will be damaged when the fruit is clamped.

Based on the above analysis, the design adopts an innovative picking method combining shear picking and gripping picking, and uses steel wire as the main tool for picking.

4. Principle and characteristics

4.1 Mechanical structure and principle of the scheme
As shown in Figure 2, the high-efficiency portable fruit picker is composed of a fruit storage basket 1, a small DC motor 2, a control switch 3, a steel wire 4, a fixed blade 5, a buffer device 6, a bracket 7, and a battery 8. During operation, the operator presses the control switch 3, the circuit is turned on, and the DC motor 2 rotates; the wire 4 is contracted by the DC motor to reduce the space between the wire 4 and the fixed blade 5 to cut the fruit handle; after the cutting is completed, the fruit falls into the basket through the buffer device 6 in the fruit storage basket 1, and at the same time, the inner wire of the picking head touches the power-off switch, so that the circuit is powered off; the steel wire returns to the original position under the action of the memory spring. One cut is completed.
Figure 2. Main structure diagram of picker, 1- fruit basket, 2- dc motor, 3- control switch, 4- steel wire, 5- fixed blade, 6- buffer device, 7- support, 8- battery.

4.2 Characteristics and innovation analysis
One of the innovations of this design is that instead of adopting the traditional cutting method. It adopts the innovative picking method combining shear picking and gripping picking, and uses steel wire as the main tool for picking. The advantages of this design are strong cutting adaptability, wide range of use (can pick a variety of fruits), low cost, small size and high efficiency; the biggest feature is that the motor is used as the power source without manual operation; secondly, the overall volume and quality are much smaller than the traditional picker and the parts can be freely disassembled for carrying, and the structure is simple and easy to operate; the picking machine has its own storage basket, and the basket is provided with a simple buffer device to prevent fruit damage.

5. Shear stress analysis and degree of freedom calculation

5.1 Analysis of shear stress
When the steel wire is cut, the fruit stem will be subjected to shear stress, and the force analysis of the fruit stem shows that:

$$\tau = \frac{F_s}{A} \quad (1)$$

$\tau$ is the shear stress; $F_s$ is the shear force; $A$ is the cross-sectional area.

The analysis of the fruit shank as a cylinder simplifies the analysis, so the area of the $A$ section can be approximated as a circular area of radius $r$, so the area of the $A$ section is:

$$A = \pi r^2 \quad (2)$$
A is the cross-sectional area; r is the radius.

The force on the stem is due to the shrinkage of the wire, and the shrinkage of the wire is caused by the rotation of the motor. Therefore, the shear force $F_s$ of the stem can be approximated as the torque provided by the motor, so:

$$F_s = \frac{M}{L} \quad (3)$$

$F_s$ is the shear force; $M$ is the torque of the motor; $L$ is the radius of the outer shaft of the motor. Substituting equations (2) and (3) into equation (1) to obtain the shear stress $\tau$ of the handle is:

$$\tau = \frac{M}{\pi d L r r} \quad (4)$$

$\tau$ is the shear stress; $M$ is the torque of the motor; $r$ is the radius; $L$ is the radius of the outer shaft of the motor.

5.2. Degree of freedom calculation

By the formula:

$$F = 3 \times n - (2P_l + P_h - P) - P_l \quad (5)$$

$F$ is the degree of freedom; $n$ is the number of components; $P_l$ is the low number; $P_h$ is the high number; $P$ is the virtual constraint; $P_l$ is the local degree of freedom.

Let $n=3$, $P_h=1$, $P_l=0$, $P=0$, and $P_1=0$ bring the degree of freedom of the mechanism (5):

$$F = 3 \times 1 - (2 \times 1 + 0 - 0) = 1$$

It can be seen that the institution has the only way to exercise and the plan is feasible.

6. Detail design

6.1. Buffer design of fruit basket

As shown in Figure 3, the buffer device consists of a fruit basket and a deceleration channel. The deceleration channel is made of elastic fabric, and the fruit is cut and falls in the deceleration channel, because the channel diameter is small and elastic, the fruit slowly falls down with the channel under the action of its own gravity, and finally falls into the fruit storage basket.

![Figure 3. Schematic diagram of the buffer device](image)

6.2 Steel wire return design

As shown in Figure 4, the process of the device is: the operator presses the control switch, the circuit is turned on, and the DC motor rotates; the memory spring that drives the wire in the bracket to move backward and is connected to the wire is tightened, when the picking is completed, the wire touches the power-off switch, so that the circuit is powered off; the wire returns to the original position under the action of the spring.
6.3 Cut design
During operation, the operator presses the control switch, the circuit is turned on, and the DC motor rotates; the wire is shrunk under the driving of the DC motor to reduce the space between the wire and the fixed blade to cut the fruit handle.

7. Conclusion
In this paper, the design idea and principle of the easy-to-carry fruit picking machine are discussed, and the shear stress of the steel wire when cutting the fruit stem is analyzed. The high-efficiency portable fruit picker has the characteristics of convenient carrying, simple operation, high work efficiency, and can be applied to different fruit picking; the picker has its own fruit storage basket, and a simple buffer device is arranged in the basket to prevent fruit damage; this design overcomes the shortcomings of low versatility and poor adaptability. It can pick a variety of fruits in different environments, such as apples, pears, bayberry. It is very simple to operate and even picking the control switch with one hand can complete the picking; the high-efficiency portable fruit picker is very suitable for the fruit picking industry in China at present, and has a good market prospect.

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