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# Design of Portable Fruit Picking Device

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**Abstract.** In this paper, a portable and retractable high branch globular fruits (citrus, apple, etc.) picking device is designed for the current low degree of mechanization in fruit picking in China. The device is composed of telescopic mechanism, actuator, collection mechanism and controller, of which, the actuator includes steering gear, rudder arm, drawbar, movable blade, fixed blade and shearing handle. The operator can flexibly adjust the length of telescopic rod in the telescopic mechanism according to the position of the fruit. In the picking process, the controller of this device sends a control command to the actuator, and the actuator cuts off the fruit stem and causes the fruit to fall into the collection mechanism, thereby completing a complete fruit picking process. The experiment results show that the length of the telescopic rod can be adjusted from 1m to 2.2m, and the time of a complete picking is about 0.2s, the corresponds current is 2A, which shows that the device is simple and reliable, has high picking efficiency and a wide application prospect.

## 1. Introduction

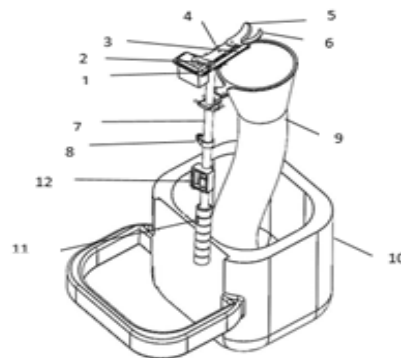
The fruit industry is one of China's important industries. Since the mid-1990s, China's fruit planting area and production have consistently ranked first in the world [1]. The fruit industry has a broad development prospect. By the end of 2015, the total fruit planting area in the country reached 15.3671 million hectares, an increase of 1,433,800 hectares, a total increase of 10.3% and an average annual growth rate of 1.6% from the beginning of the 12th Five-Year Plan period. Fruit picking is an important part of the fruit production process, it is characterized by strong seasonality, labor intensiveness and high cost. The labor required accounts for 35%-45% of the labor force in the whole production process [2-3]. At present, the picking of globular fruits on high branches is mainly done by hand, which is featured by high labor intensity, low picking efficiency, often needing tools such as ladders, and having certain potential safety hazards [4-7]. Therefore, mechanical picking will greatly reduce the labor intensity of the workers and ensure their personal safety while ensuring picking efficiency [8-9]. In this regard, this paper designed a portable fruit picking device, operator can adjust the length of the telescopic rod according to the position of fruit; it has a simple structure and convenient operation, and can be used in the picking of globular fruits on high branches.

## 2. Overall Structure and Working Principle

This device is composed of telescopic mechanism, actuator, collection mechanism and controller, the overall structure is shown in Fig.1. In Figure1, the telescopic mechanism comprises telescopic rod and C-shaped pipe clamp; the actuator is composed of steering gear, rudder arm, drawbar, movable blade,



fixed blade and shearing handle, in which, the rudder arm, drawbar, movable blade and shearing handle that constitute a four-connection rod mechanism, the steering gear is installed at the end of the shearing handle, the rudder arm is connected to the output shaft of the steering gear, the left and right ends of the drawbar are respectively connected with the rudder arm and the movable blade, and the movable blade and the fixed blade are hinged on the top end of the shear handle by the hexagon socket screw; the telescopic rod in the telescopic mechanism is installed in the middle of the shearing handle, and the C-shaped pipe clamp, the controller and the push button switch are mounted on the telescopic rod; the C-shaped pipe clamp can adjust the length of the telescopic rod from 1m to 2.2m; the collection mechanism includes soft fruit guiding bag and collection bag, of which, the shape of soft fruit guiding bag like a “funnel”, and its upper and lower diameters are respectively 112 mm and 80 mm.



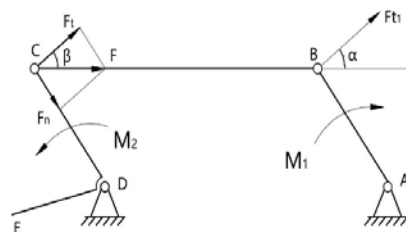
1. Steering gear 2. Rudder arm 3. Drawbar 4. Shear handle 5. Movable blade 6. Fixed blade  
7. Telescopic rod 8. C-shaped tube clamp 9. Soft fruit guiding bag 10. Collection bag 11. Button switch

**Figure 1.** Overall structure of the picking device

The working principle of this device is as follows: First, according to the position of the fruit, the operator adjusts the telescopic rod to the appropriate length through the C-shaped pipe clamp, and then turn on the button switch, the controller sends control command to the steering gear, and the rudder arm swings under the actuation of the steering gear to drive the drawbar to move, the drawbar pulls and rotates the movable blade to close it with the fixed blade and cut off the fruit stem, then the fruit falls along the soft fruit guiding bag into the collection bag to complete a complete picking process.

### 3. Fruit Stem Shearing Force Analysis

The four-bar linkage mechanism performs the picking action under the actuation action of the steering gear, and the force analysis of the fruit stem shearing is shown in Fig. 2.



**Figure2.** Force analysis diagram of the fruit stem shearing action by the four-bar linkage mechanism

In Fig. 2, AB is the rudder arm, BC is the drawbar, CD is the driven rocker bar, DE is the movable blade,  $M_1$  is the driving torque,  $M_2$  is the resistance torque;  $M_2$  is affected by the rotation angle of the rudder arm;  $\alpha$  and  $\beta$  are the pressure angle. The pulling force  $F_{t1}$  generated by the rudder arm is related to the steering gear torque and the rudder arm length. The calculation is as follows:

$$F_{t1} = \frac{T}{l_{AB}} \quad (1)$$

Where  $T$  is the steering gear torque of and  $l_{AB}$  is the rudder arm length.

By the swing of the rudder arm AB, the driving force  $F$  in the CB direction is generated on the driven rocker CD via the drawbar BC, which is calculated as follows:

$$F = F_{t1} \cos \alpha \quad (2)$$

Where  $F$  can be decomposed into the component force  $F_t$  along the velocity direction of the force application point C; and the component force  $F_n$  perpendicular to the force application point C.

$$F_t = F \cos \beta \quad (3)$$

Substitute equation (2) into equation (3) to yield:

$$F_t = F_{t1} \cos \alpha \cos \beta \quad (4)$$

So the resistance torque  $M_2$  is:

$$M_2 = F_t l_{CD} \quad (5)$$

As it can be seen from Figure2, the resistance torque  $M_2$  can also be regarded as the torque transmitted by the four-bar linkage mechanism. The shearing force  $F_s$  generated by the driven rocker bar CD under the actuation of  $M_2$  is calculated as follows:

$$F_s = \frac{M_2}{L_{ED}} \quad (6)$$

Substitute the formulas (1), (2), (4) and (5) into the formula (6), and obtain the shearing force  $F_s$ :

$$F_s = \frac{T l_{CD} \cos \alpha \cos \beta}{l_{AB} l_{ED}} \quad (7)$$

Where,  $l_{ED}$  is the distance from the fruit stem shearing point to the rotation axis D,  $l_{AB}$  is the length of the rudder arm and  $l_{CD}$  is the length of the driven rocker CD.

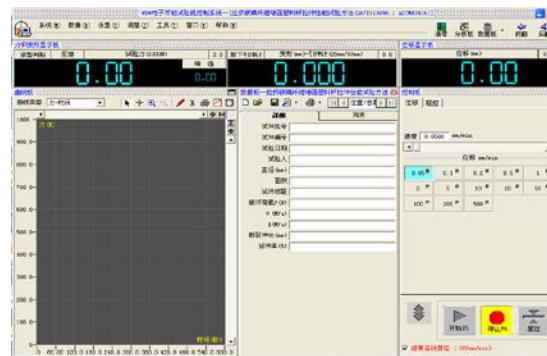
In this device, the lengths of  $l_{AB}$  and  $l_{CD}$  are equal, that is, the pressure angles  $\alpha$  and  $\beta$  are equal. Equation (7) can be simplified to:

$$F_s = \frac{T \cos^2 \alpha}{l_{ED}} \quad (8)$$

Where, the pressure angle  $\alpha$  is related to the rotation angle of the steering gear. In this device, the rotation angle of the steering gear is  $63^\circ \sim 90^\circ$ , that is, the corresponding pressure angle range is  $27^\circ \sim 0^\circ$ . When the pressure angle is  $27^\circ$ , the movable blade is opened to the maximum; when the pressure angle is  $0^\circ$ , the shearing force  $F_s$  is maximum and the movable blade and the fixed blade just close and cut off the fruit stem.

#### 4. Selection of Steering Gear

According to the above analysis of the fruit stem shearing force, the shearing tests for following four kinds of fruit stems were performed using this device, and the stem shearing force  $F_s$  were measured by static test machine and Max Test universal testing machine software. Max Test universal testing machine software analyzes the properties of different types of materials through the control and analysis of static testing machine and by setting different parameters. The software interface of Max Test universal testing machine is shown in Fig. 3.



**Figure3.** Interface of Max Test universal testing machine software

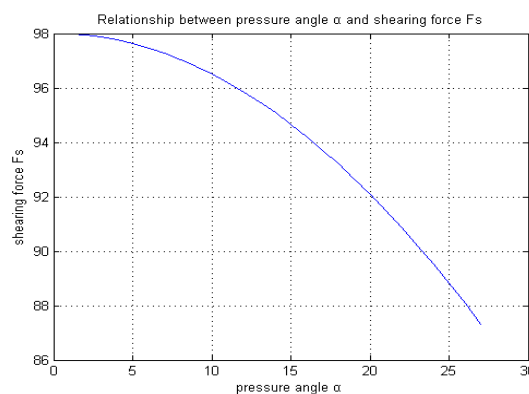
The measured shearing force  $F_s$  is brought into equation (8) to calculate the torque  $T$ , and then the steering gear suitable for the device can be selected according to the torque  $T$ . In the test, the pressure angle  $\alpha$  was chosen to be  $27^\circ$ ,  $l_{ED}=30\text{mm}$  and the results of the fruit stem cutting test are shown in Table 1.

**Table 1.** Fruit stem shearing test data

Type of Fruit stem	Diameter (mm)	Cross-sectional area	Shearing force	Torque T
Apple	4.04	12.82	54.03	1.62
Lychee	3.50	9.62	73.78	2.21
Pear	4.50	15.90	61.63	1.85
Loquat	5.01	19.64	44.3	1.33

It can be seen from the data in Table 1 that the selected steering gear torque should be greater than 2.21N.M (i.e. 22.58Kg.cm), so the digital metal steering gear actually selected in this paper has a torque of 30Kg.cm.

During the process of cutting off the fruit stem, the pressure angle  $\alpha$  ranges from  $27^\circ$  to  $0^\circ$ ,  $l_{ED}=30\text{mm}$  and the steering gear torque  $T=30\text{Kg.cm}$ , according to formula (8), the relationship between the shearing force  $F_s$  and pressure angle  $\alpha$  during the stem shearing process are obtained as shown in Fig.4.

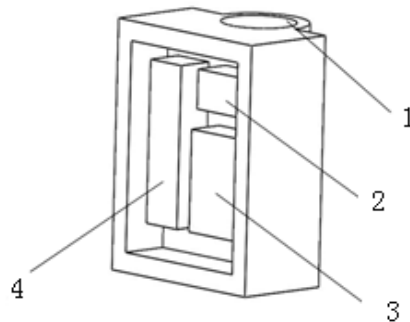


**Figure4.** Relationship between pressure angle  $\alpha$  and shearing force  $F_s$

In Fig.4, the shearing force  $F_s$  decreases as the pressure angle  $\alpha$  increases. When the pressure angle  $\alpha=0^\circ$ , the shearing force  $F_s$  is maximum; when the pressure angle  $\alpha=27^\circ$ , the shearing force  $F_s$  is minimum, the shearing force  $F_s$  range is from 87.32N to 98N, that is, in the fruit picking process, if the actual shearing force  $F_s$  is within the range, this device can effectively cut off the fruit stem and complete the fruit picking.

## 5. Design of Controller

The controller of this device is mounted on the telescopic rod and is composed of voltage stabilizing module, main control chip and power supply, and its structure is shown in Fig.5. In Fig.5, the voltage stabilizing module used is LM2596S DC-DC step-down module, this module integrates frequency compensation and fixed frequency generator, the switching frequency is 150KHz, it has filter circuit and output voltage indicator. The main control chip consists of The ATMEGA328P-AU microprocessor and its peripheral circuits. This processor is a high-performance, low-power consumption 8-bit AVR microprocessors with a flash memory capacity of 32KB; the power supply is 12V, 500mAh lithium battery, the positive and negative poles are respectively connected to the input end of the voltage stabilizing module, and the output voltage signal after being stepped down by the voltage stabilizing module is used as the power supply of the main control chip.



1 Telescopic rod 2 Power supply 3 Voltage stabilizing module 4 Main control chip

**Figure 5.** Structure Diagram of Controller

This paper uses Arduino IDE software to write the control program of this device, this software is featured by modular program, flexible program structure and wide applicability. The specific steps are as follows:

- (1) This device is initialized;
- (2) Check if the button switch is pressed, if yes, the controller works, if not, repeat action (2);
- (3) The controller sends control command to the steering gear, under the actuation of the steering gear, the rudder arm swings to drive the drawbar and then pulls the movable blade to rotate, so that the movable blade and the fixed blade are closed to cut off the fruit stem, and the fruit falls along the soft fruit guiding bag into the collection bag and completes a complete picking process;
- (4) Repeat the above steps to repeatedly pick fruits.

## 6 .Analysis of Test Results

Through the above design analysis, the design of this device is shown in Fig.6.



**Figure 6.** Structure of portable fruit picking device

To verify the picking reliability of this device, pickings tests of five fruits including apple, pear, loquat, lychee and orange were respectively performed; and the diameter of the fruit stem (mm) of

each fruit, the time of each picking (s), and the current for fruit stem shearing (A) and whether the fruit falls into the collection bag were recorded, the test results are shown in Table 2.

**Table 2.** Picking Test Data

Fruit type	Diameter of stem (mm)	Picking Time (s)	Stem shearing current (A)	Whether the fruit falls into the collection package
Apple	3.9	0.11	1.22	yes
Pear	3.8	0.13	1.07	yes
Loquat	5	0.15	1.75	yes
Lychee	4.4	0.20	1.30	yes
Orange	2.9	0.15	1.22	yes

It can be seen from the data in Table 2 that the picking time of this device does not exceed 0.2 s, the current used for cutting the fruit stem is within 2A, and all of the picked fruits falls smoothly into the collection bag to achieve successful picking.

## 7. Conclusion

The portable fruit picking device in this paper is designed with unique telescopic mechanism, actuator and collection mechanism. According to the position of the fruit, the length of the telescopic rod in the telescopic mechanism can be adjusted from 1m to 2.2m; the soft fruit guiding bag can reduce the impact between fruits; and the time of each picking is not more than 0.2s; the current required to cutting off the fruit stem is not more than 2A; and the selected power supply is 12V lithium battery. In summary, this device can perform high-efficient picking operations for a long time, it is featured convenient operation and novel structure; it can provide powerful technical guarantee for the fruit picking process, and has a broad market prospect.

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