The Design of Peanut Seedling Cutting Test Bench

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Abstract: In order to solve the problems of the peanut harvester, such as unclean fruit picking and serious crushing, a peanut seedling cutting test bench is built. This paper starts with the selection and design of the components of the test bench, and then completes the design of the whole test bench, and finally completes the design of the peanut seedling cutting test scheme.

1. Introduction
As an important oil crop in China, the mechanized harvest degree of peanut will be higher and higher[1]. Although the research technology of peanut harvester has been very mature so far, there are still some shortcomings, such as low efficiency, unclean fruit picking and serious crushing.

For the peanut combine harvester, the seedling cutting device is an important part of the peanut combine harvester, and the cutting quality of the seedling root directly affects the peanut harvesting efficiency. During the operation of the existing peanut harvester, the peanut plant is lifted from the root by the grain lifter; the main root of the peanut is broken by the digger blade; the seedling is clamped up by the clamping chain; the fruit is picked by the fruit picking device, and then the seedling is transported out of the machine, which results in the final time-consuming and laborious treatment of the seedling. Therefore, we designed and tested the seedling removing device before picking in order to improve the pick up rate and reduce the breakage rate.

2. Overall design of the test bench
It is needed to feed, cut and collect the cutting data of peanut plants in the test bench. The test bench is mainly composed of a single disc cutting device, a motor, a clamping device and a torque sensor. The cutting device adopts the single disc cutting, which is powered by three-phase asynchronous motor. The speed of the motor is changed by the frequency converter to change the speed of the cutter. The cutting torque of the cutterhead spindle is measured by the torque sensor. The cutting length of peanut seedling is adjusted by the clamping device. The motor and the lower end of the torque sensor are respectively fixed on the test stand by bolts. Besides, the whole cutting device and the test stand are fixed on the workbench of B6050C shaper. At the same time, in order to prevent the root flying out when cutting, a protective net is covered around the cutter head to prevent the operator from being injured. The structure
of the cutting device in the disc peanut cutting test bench is shown in Figure 1.

![Figure 1 cutting device structural diagram](image)

1.motor, 2.coupling, 3.torque sensor, 4.coupling, 5.cutterhead spindle, 6.cutting cutter

### 3. Selection and design of key components

#### 3.1. Selection of motor and frequency converter

In this test bench, a 1.1KW model YVP 90s-4 three-phase asynchronous motor is selected to adjust the speed by changing the frequency. A 1.5KW frequency converter is selected for speed regulation and preset the required working frequency of the frequency converter, then connected the RS-485 communication cable with the computer for communication.

#### 3.2. Cutter selection

Cutter is an important part of the cutting device, which mainly has reciprocating type, swing knife type and disc type. At present, the existing cutter of the straw harvesting machine in China mainly adopts the single disc type. Compared with other cutters, the single disc type has the advantages of simple structure, convenient tool change, low energy consumption and no blockage in harvesting crops\(^2\). Therefore, in consideration of the actual need of peanut root cutting and the structure of the harvester, the single disc type is selected in the design of the device.

#### 3.3. Cutterhead selection

According to the size of peanut plant diameter, under the premise of ensuring good cutting efficiency, hard alloy steel is the blade material of the cutterhead. In order to get better cutting effect, three kinds of different diameters of cutter discs were selected for tests, which were 200mm, 255mm and 300mm respectively. However, the other parameters were the same: the thickness was 5mm, and the inner diameter was regular hexagon, and the number of teeth was 40. This not only prevents other factors from interfering with the test, but also simplifies the operation of the test. The most appropriate cutter head is determined by the cutting test.

As shown in Figure 2, in the process of turning the cutterhead, the cutter edge rotates at a high speed with the cutter head. At the moment before cutting, the serrated tooth tip contacts the peanut plant at a point, that is in the critical cutting state. The pressure generated by the serrated tooth can tear the peanut plant rapidly. After the plant teared, the cutter edge begins to cut, which is the linear contact. The continuous serrated tooth can effectively clamp the plant and reduce the cutting vibration. The cutting process is that the cutting edge gradually cuts in, and the cutting resistance changes from large to small, producing the cutting buffer effect\(^3\).
In the high-speed rotation of the cutterhead, in order to facilitate the analysis, the cutterhead is regarded as an approximate circle, and the rotation center is set as the origin of the coordinate system, and the x-axis direction is the forward direction of the machine. That is to say, the y-axis is vertical upward, opposite to the conveying direction of the plant. Taking the movement of a cutting point for analysis, the cutting point moves from A to B after a time, as shown in Figure 3.

The cutting point equations are following:

\[
x = V_m t + \cos(\beta + \omega t) - R \cos \beta \\
y = R \sin(\beta + \omega t) - R \sin \beta
\]

(1)

Where:
- \(V_m\) - seedling conveying speed, m/s
- \(R\) - Radius of disc cutter, m
- \(\beta\) - Angle between cutting point and X-axis when it is at a, (°)
- \(\omega\) - Angular velocity of disc cutter, rad/s

It can be seen that the rotation speed of the disc cutter is the main parameter affecting the cutting quality. Too low rotating speed of cutterhead causes the relative speed of cutterhead and plant seedlings becoming smaller, and the roots cannot be cut off, which will cause congestion; while too high rotating speed will cause excessive vibration of the device, affecting cutting quality and increasing energy consumption[4].

3.4. design of cutterhead spindle
Cutterhead spindle is the main part of connecting cutterhead and transmitting power. In order to simplify the design and ensure the cutting performance of the cutterhead, the length of the cutter head shaft is reduced and the spindle diameter is increased properly, so as to increase the stiffness of the shaft and reduce the torque on shaft[5], as shown in Figure 4.
3.5. Measuring device
The measuring device, of which a JN-DN dynamic torque sensor of 0 ~ 100N installed on the upper end of the cutter head drive shaft, is mainly used to measure the cutting torque. The sensor is connected with the motor output shaft and the cutter head main shaft respectively through the coupling, which is powered by an external power supply. The torque and frequency signals are transmitted to the power meter through the RS232 serial port line to display the torque value, speed and output power value.

4. Design of test scheme of cutting peanut seedling and root

4.1. Determination of cutting amount
The test materials were selected from some peanut plants with good growth in the test field. The yield per mu of peanut: 8000 plants, plant spacing: 200mm, row spacing: 300mm, ridge spacing: 800mm, ridge center spacing: 1000mm.

Relevant data of peanut harvester: 2 ridges at a time, working speed: 6 mu / h, 10 mu / h, 15 mu / h. In this test, the working speed is 10 mu / h.

Cutting frequency of seedlings:

\[
f = \frac{80000}{3600} = 22.2 \text{plants/s} \approx 23 \text{plants/s}
\]

In order to ensure the holding capacity of 23 peanut plants per second, a gear with the planning speed of 56 M / min was selected. In the later test, the feeding speed of the seedlings can be changed by changing the working gear of the shaping machine to compare the effect of different feeding speed on the cutting effect.

4.2. Test scheme
In order to research the cutting quality and cutting power of the test bench at different cutting line speeds, three groups of different rotating speeds of cutter head was selected for tests to confirm the optimal rotation. The test of peanut seedling root cutting was carried out by changing the cutter head with different diameters, and recording the cutting moment respectively to confirm the optimal cutter head diameter.

4.3. Test purpose
In order to study the influence of the structural parameters of the seedling cutting device on the cutting quality of the seedling root, the test of the seedling root cutting was carried out on the built test-bed, and the cutting torque was measured by the torque sensor. Three groups of optimal cutter head rotating speed and diameter were selected based on the test results, with the analysis of the influence of the cutting of peanut seedling, such as the rotating speed of the cutter head and the diameter.

4.4. Test method
Before the test, fix the peanut seedling on the 5-10cm at the upper end of the root stem joint of the clamping device; reserve a distance between the cutter head and the plant; connect the power supply to
start the motor; use the conveyor clamping device of the shaper to carry out the seedling root cutting test after the working state of the test bench is stable. After the cutting, close the switch to stop the power output of the motor and the cutter head. Count the number of cut and uncut peanut seedlings in the test, record the data on the torque sensor, and calculate the cutting rate and cutting power to evaluate the cutting quality and cutting power consumption. Several tests were carried out by changing the rotating speed and diameter of the cutter head. After the tests, compare the test data and analyze the relationship between each factor and the evaluation index to get the optimal parameter combination of root cutting, then the structure optimization of the seedling cutting test bench has been designed.

4.5. Test process
The tests of peanut seedling root cutting were carried out for many times. Firstly, under the working condition of 300 mm diameter of cutter head, the seedling roots were cut under the condition of 400 r/min, 560 r/min and 700 r/min rotating speed of cutter head respectively. After the cutting, the number of plants, such as cutting, tearing and skin abrasion, was calculated to get an optimal rotating speed; then set the rotating speed as the optimal parameters, undergo the cutting tests using the different diameters of 200 mm, 255 mm and 300 mm of Cutter heads. Count the number of plants, such as root cutting, tearing and skin abrasion to determine the diameter of cutter head with the best cutting quality and the lowest cutting power consumption. Finally, an optimal cutting device parameter was obtained.

5. Conclusion
In order to determine the optimal data of cutter size parameters and motion parameters, the test device of peanut seedling root cutting was designed. Thus the parameters can be applied to the prototype trial production of peanut harvester project (the cutter head in the prototype is driven by hydraulic motor). If the test is successful, it will have a good data support for the design of the peanut harvester seedling cutting device, so as to improve the efficiency of peanut harvest more efficiently and reasonably, which can improve the pick up rate and reduce the breakage rate.

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