Semi-automatic Leek Harvester Based on Multi-angle Adjustment

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Abstract

The team is committed to solving the domestic leek harvesting process of excessive human input, high cost, intelligence, low level of mechanization, to provide users with a diversified range of high-performance semi-automatic leek harvester equipment and solutions, which can make the leek production safer, time-saving, labor-saving. The team independently researched and developed leek harvester which can walk independently and harvest automatically, adopting new adjustable mechanical structure, artificial intelligence algorithm and human-computer interaction software application, which makes the domestic automatic harvesting gradually become possible.

*Keywords:*leek harvesting, intelligent, mechanical innovation, self-propelled

1. Introduction

This product from the farm planting leek growers of the actual problem, in-depth for their leek harvesting for labor intensive, high cost problems, to understand their real needs, and then determine the leek harvester design positioning. After sufficient market research, after analyzing and comparing several typical leek harvesters on the market, we chose the multi-angle adjustment; through ergonomic analysis to determine the main body size of the harvester, and then carried out the selection of materials, structural design, parts design and strength check; through the button operation start-stop worm gear DC gear motor control machine forward, DC gear motor drive synchronous toothed belt transmission, and 3D printing is used to slope the design for the grain support device.[1,2]

The rest of the paper is organized as follows. Part II presents the overall mechanical design. Part III presents the light source following system design. Part IV gives the finite element analysis to verify the effectiveness of the designed mechanism. Part V summarizes the main points of this paper.

2. Overall Mechanical Design

This product is an intelligent leek harvesting robot based on multi-angle adjustment. It can harvest accurately, and the stubble height level is controlled within 3% error, and the whole machine movement speed is 0.3m/s, the speed is smooth, and it can meet the requirements of leek planting with row spacing of 30-40cm and plant spacing of 15-20cm. The whole machine size in length × width × height = 1670mm × 470mm × 470mm, the total quality of 65kg, by the transmission mechanism, supporting Harvesting institutions, harvesting institutions, the three main institutions. The overall organizational structure and physical diagram is shown in Fig.1.

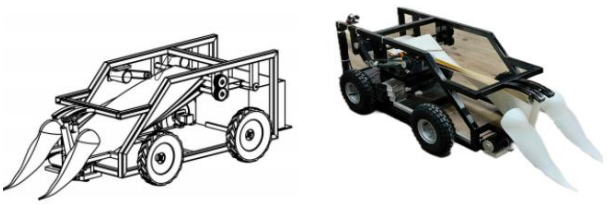
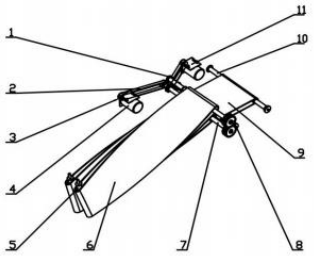


Fig.1 Overall organizational structure and physical map

2.1. Delivery mechanism

In order to complete the recycling of leeks after harvesting,so that leeks fall into the collection device in a smooth and orderly manner,we utilize a rotary conveyor belt and a horizontal buffer conveyor belt to form a conveyor belt group,and the degree of wrapping reaches 90%.

The mechanism includes mechanical components such as shafts,gears,pulleys,DC motors,motor drives,buttons,and so on.The conveyor mechanism is shown in Fig.2.

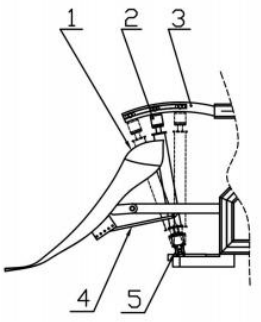


1—driven pulley；2—synchronous belt；3—drive pulley；4—DC motor；5—Vertical follower shaft；6—Sponge Conveyor Belt；7—Horizontal with main shaft；8—spur gear；9—horizontal conveyor belt；10—Horizontal follower shaft；11—Motor connection plate

Fig. 2. Conveyor mechanism

2.2. Fuhe organization

The product of the Harvest Supporting Device is symmetrical setting, Harvest Supporting Plate operation is a continuous progressive process, the lowest end is almost in contact with the ground and parallel to the ground, the height from the ground is less than 2cm, and the vibration error is controlled at 6.3%. The shape of the cross-section of the Harvest Supporting Device is based on the progressive smooth arc shape of the plant with minimum force and less mechanical damage, the front end is 10mm wide, the back end is 100mm wide, showing a progressive trend, preventing the Harvest Supporting Angle for different kinds of leeks is different, and the organization can adjust the position of the connecting rod to make a small degree of angular adjustment. The composition of the mechanism is shown in Fig.3.[3]



1—propane；2—upper connection；3—indexing bar；
4—connection bar；5—bottom bracket
Fig.3. Harvest support mechanism

The mechanism can adjust the angle of the connecting rod corresponds to a number of holes, and then adjust the angle of the Harvest Board, in addition to adjusting the upper and lower connectors to adjust the clamping angle, the connecting rod mechanism schematic diagram shown in Fig.4.

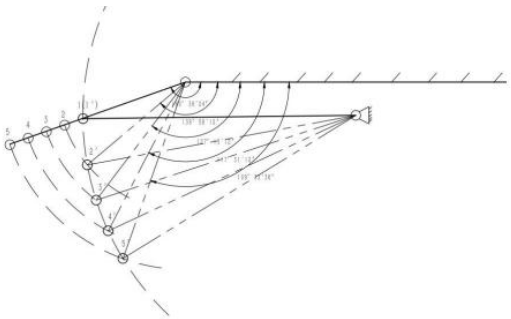


Fig.4.Schematic diagram of connecting rod mechanism

2.3. Harvesting mechanism

This harvester is single row harvesting, compact structural space arrangement, and leeks in the clamping assistance to complete the cutting, so the choice of disc cutter. The disk cutter is shown in Fig.5.

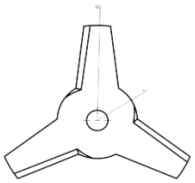
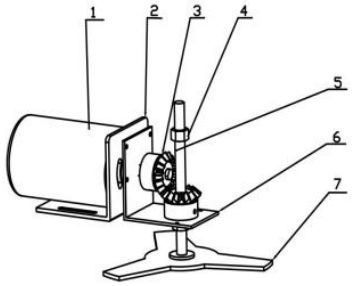


Fig.5. STM32F103ZET6 chip

The whole structure of the cutting device is shown in Fig.6, which consists of cutting motor, rotating shaft of the cutter, bevel gear, relaxation nut, etc. The cutting device can be adjusted by adjusting the height of the rotating shaft to ensure the cutting of leeks. Cutting device by adjusting the height of the rotary axis to ensure that the stubble height. The cutting disk is a one-piece disk knife, and each side edge cuts the leek.Blade parameters are shown in Table 1.

Table 1. Blade parameters

makings	edge angle	InnerBore Diameter	rotary diameter	Base circle
65Mn	17°	16mm	120mm	67mm



1—DC motor；2—Motor Bracket；3—pinion gear；
4—Loosen the screws.；
5—cutter shaft；6—Gear connection plate；7—fretting knife
Fig. 6 Cutter mechanism

3. Dual-axis light source following system

In order to solve the problem of insufficient power generation efficiency of traditional solar panels, the team has developed a multi-functional two-dimensional tracking solar power generation system especially for the possible power shortage of the harvester, which is capable of tracking intelligently according to the intensity of light and the sun's altitude angle, so as to significantly improve the power generation efficiency, and the physical object is as shown in Fig. 7.

Fig. 7 Physical solar charging system

The control system is composed of an Arduino microcontroller L298N motor drive module and a solar panel with four built-in analog photoresistors to ensure the smooth operation of the system.

3.1. Principle of operation

When the sun's light intensity changes, the built-in photoresistor of the solar panel will automatically recognize the light intensity, after reading the data will be fed back to the Arduino microcontroller for processing, and finally the high and low levels will be output by the L298N motor driver module, so as to control the motor, in order to achieve the effect of adjusting the angle of the two directions, horizontally and vertically.

In order to guarantee the stable operation of the system as well as the energy saving and environmental protection indexes, the horizontal and vertical angle change rates during the operation of the mechanism are 15° per second and 10° per second, respectively, and at the same time, the program compiled inside the microcontroller system has additional limitations, so that the system is activated to run only when the difference in the intensity of the sensed light reaches a certain level.

4. Finite element analysis and verification

Modal analysis is an efficient way to study the structural vibration characteristics, mainly applied to analyze whether the machine structure design is reasonable, through modal analysis, can determine the cutter's intrinsic frequency, vibration pattern and vibration mode and other information, so as to derive the structural strength and stability of the cutter, as well as to predict possible resonance phenomenon, resonance can be avoided, to provide theoretical guidance for the design and improvement of the later stage.

According to the results of modal analysis, the vibration frequency of the cutter can be obtained in the range of 201.55~320.13 HZ, and the vibration pattern is mainly concentrated in the position of the cutting teeth. The maximum amplitude of the cutter is 162.3mm in the 4th order, and the vibration pattern mainly shows the twisting and deformation of the cutting edge of the cutting teeth. According to the requirements of the machine production operation cutter speed up to 1800r/min, its resonance frequency is about 28.66Hz, through the modal analysis of the cutter, the minimum frequency of the cutter is 201.55Hz, so the cutter will not resonate in the process of the work and the phenomenon of local early destruction, to meet the cutter in the work of the safety and stability requirements. The modal analysis is shown in Fig.8.

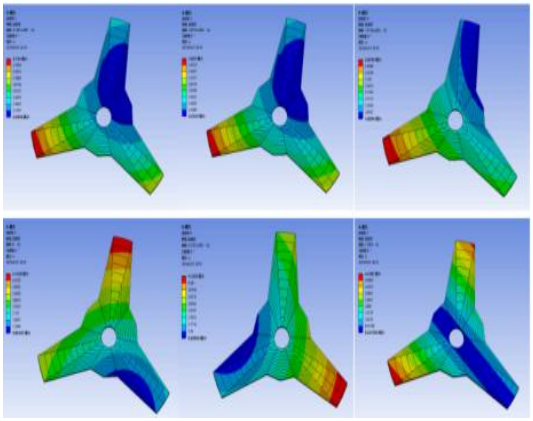


Fig. 8 Sixth order modes of cutter

5. Conclusion

Based on the high labor cost and low efficiency problems faced by leek growers, this paper designs and develops an intelligent leek harvester, which systematically solves a number of pain points existing in the traditional harvesting process. Through market research and demand analysis, this paper establishes the design concept of multi-angle adjustment as the core, specifically including the modular design of the transmission mechanism, the harvesting mechanism and the harvesting mechanism. Among them, the transmission mechanism adopts the combination of rotary conveyor belt and horizontal buffer conveyor belt, which improves the stability and efficiency of leek collection; the harvesting mechanism effectively reduces the plant damage by adjusting the angle of the connecting rod and optimizing the clamping angle; and the harvesting mechanism uses disc cutter, which, combined with the compact structural layout, ensures the precise control of the harvesting height. The whole machine is designed to achieve a stable movement speed of 0.3m/s and meets the requirements of row spacing and plant spacing for leek planting, providing users with an efficient and reliable mechanization solution.

In addition, in order to solve the problem of insufficient power that may occur when the equipment runs for a long time, this paper innovatively designs a dual-axis light source following system. It provides a reference for the subsequent application of solar energy in agricultural machinery.

The strength and stability of the cutter and other key components are verified through finite element modal analysis to ensure that the equipment will not resonate or be partially damaged under high-frequency operating conditions.

With intelligence, energy saving and high efficiency as the core, this design explores the new path of leek harvesting mechanization and provides new technical solutions and innovative ideas for the development of agricultural mechanization and intelligence.

References

1. ZHANG Wendong,YANG Xuelan,GUO Hong'en,et al. Design and test of tracked self-propelled leek harvester[J]. *Agricultural Equipment and Vehicle Engineering*,2024,62(11):1-6+13.
2. ZHANG Xuming,YANG Ying,ZHANG Hao,et al. Experimental study on the application of electric leek harvester[J]. *Agricultural Machinery Quality and Supervision*,2024,(08):18+20.
3. LI Jiwei,BIAN Lina,ZHAI Joy,et al. Technology and development of new device for supporting harvesting device of leek harvester[J]. *Anhui Agricultural Science*,2021,49(21):223-226+230.

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