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Research on Symmetrical Flexible Clamping Conveyor for Scallion Harvester

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Abstract

Aiming at the problems of low conveying efficiency, poor adaptability of conveying Scallion poles of different diameters, and little innovation of the mechanism that exist in the existing clamping conveyor device, a symmetrical flexible clamping conveyor device suitable for Scallion harvesting was innovatively designed. The design and analysis of the overall structure of the clamping conveyor, the clamping mechanism, the clamping pulley and other key mechanisms were carried out, and finally the finite element simulation analysis of the clamping conveyor was carried out, and the analysis of the deformation cloud and stress cloud showed that the designed clamping conveyor could meet the requirements of the working strength. The designed symmetric flexible clamping and conveying device can automatically adjust the clamping force according to the diameter of Scallion stalks to realize efficient and lossless clamping, which is more innovative than the existing clamping and conveying devices.

Keywords

Scallion Harvester; Symmetrical; Flexible; Clamping Conveyor.

1. Introduction

The scallion harvester is the key and core device for the full mechanization of the scallion industry. The clamping and conveying device is a key part of the scallion harvester. Its main function is to quickly pull up the scallion excavated by the excavation device from the soil and transport them stably. Its work performance directly affects the working efficiency of the scallion harvester [1-3].

Chinese scholars have conducted relevant research on clamping and conveying technology and devices. Shuai Peng [4] et al. designed a clamping and conveying device for a double-row scallion combine harvester, and analyzed the dimensional parameters of the clamping pulley and the spatial position of the clamping mechanism; Jie Xin [5] et al. designed the clamping and conveying device of garlic combine harvester, which mainly includes the driving part, the driven part, the clamping part and the tensioning part, etc. During operation, the adjacent flexible gears feed garlic into the clamping and conveying device through mutual meshing. Under the joint action of the clamping mechanism and the tensioning mechanism, the conveyer belt presents S-shaped conveying, making the garlic clamping reliable; Kaifeng Li [6] et al. developed a clamping and conveying device for carrot combine harvester, which mainly consists of main and driven wheels, clamping belt, main and driven wheel fixed frame, guiding beam and so on; Ranbing Yang [7] et al. developed a clamping and conveying device of peanut combine harvester, which realized stable peanut clamping and conveying by utilizing the overlapping area of a single belt and double belt, thereby compensating for the limitations associated with double belt clamping; Ruiming Yu [8] et al. designed the clamping and conveying device of cassava combine harvester, which adopts double-belt clamping as a whole.

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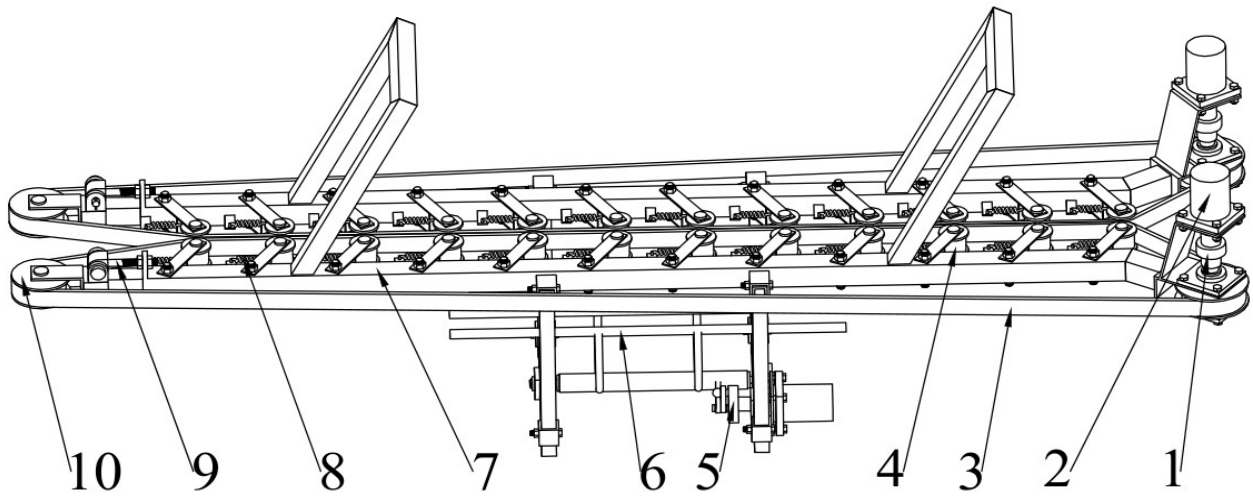
Two rows of clamping pulleys are arranged regularly, one row is fixed and the other row is movable. The movable side contains a tension spring, one end of which is fixed and the other end is movable, so that the elasticity of the tension spring can be fully used as the clamping force; Xiaoxiao Guo [9] et al. designed a clamping and conveying device for a vertical roller corn ear picking platform, which uses the three-point clamping principle, upper and lower chain plates and floating pressure bar to carry out three-point clamping for corn stalk in the process of conveying.

Through the analysis of the existing clamping and conveying technology and device research, although some progress has been made, there are few clamping and conveying devices for scallion harvest, and there are problems such as low conveying efficiency, poor adaptability to conveying scallions of different diameters, and little degree of innovation in the mechanism. In view of the problems existing in the existing clamping and conveying devices, this paper innovatively designs a symmetrical flexible clamping and conveying device suitable for scallion harvester, which can realize lossless firm clamping and stable conveying, and provides key technical support for the development of scallion combined harvester.

2. Principles of Overall Structural Design

The structural design of the clamping conveying device is shown in Figure 1. The overall structure adopts the double belt symmetrical design to ensure that the center line of the clamping conveying device coincides with the center line of the scallion planting. The scallion harvester adopts the working mode of digging first and pulling out later. First, the digging device loosens the soil at the root of the scallion, and lifts the scallion up to a certain height, and then feeds into the clamping conveying device. After the scallion enters the clamping conveying device, the clamping pulley squeezes the conveying belt under the action of the spring to clamp the scallion stalk, the hydraulic motor drives the conveying belt to rotate, so as to pull up the scallion and transport it back, and the soil is removed by the soil removal mechanism in the process of conveying. The tension degree of the conveying belt can be adjusted by adjusting the bolt, adjusting the horizontal relative distance between the tensioning pulley and the frame, so as to adjust the tension degree of the conveying belt according to the actual working conditions.



1. Coupling 2. Hydraulic motor 3. Conveyor belt 4. Clamping pulley 5. Eccentric pulley 6. Shaker 7. Frame 8. Spring 9. Adjusting bolt 10. Tensioning pulley

Figure 1. Structure of the clamping conveyor

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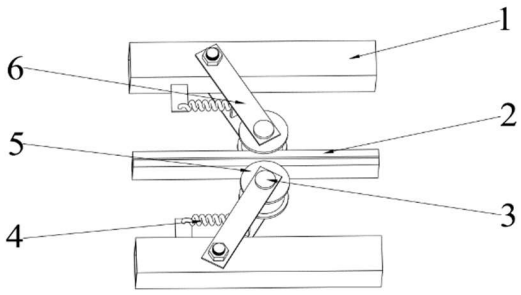
3. Key Mechanism Design and Analysis

3.1. Design and Analysis of Clamping Mechanism

3.1.1. Overall Design of Clamping Mechanism

The structure of the clamping mechanism is shown in Figure 2, which mainly includes springs, clamping pulleys, a rocker arm, a rocker arm shaft, a clamping pulley shaft, and a conveyor belt. The rocker arm is installed on the frame through the rocker arm shaft in a certain arrangement, the clamping pulley shaft is connected to the rocker arm through a bolt, the clamping pulley is mounted on the clamping pulley shaft and in contact with the conveyor belt, and the spring is connected at both ends to the rocker arm and the frame. The clamping pulley and the rocker arm can pivot relative to the frame's longitudinal beam. The clamping mechanism can automatically adjust the distance between the two conveyor belts according to the diameter of the scallion stem under the action of the spring, ensuring that the conveyor belt maintains close contact with the scallion stem, providing appropriate clamping force for scallions of different diameters, to ensure the reliability and continuity of the harvest.

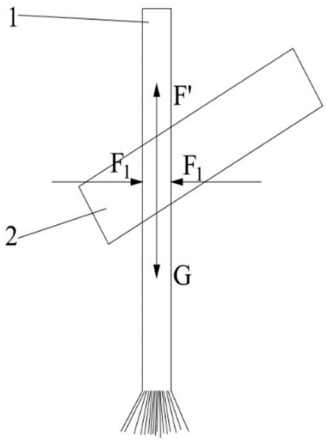


1. Frame 2. Conveyor belt 3. Clamping pulley shaft 4. Spring 5. Clamping pulley 6. Rocker arm

Figure 2. Structure of the clamping mechanism

3.1.2. Analysis of the Clamping and Conveying Force for Scallion

After the scallion is uprooted, it is transported backward by the action of the conveyor belt. During this stage, the scallion is completely detached from the soil, and the force it experiences is relatively simple. The scallion is only subjected to the clamping force of the conveyor belt and its own weight, with the weight of the soil adhering to the stem being negligible. Based on the motion characteristics of the scallion during transportation, a mechanical model is established as shown in Figure 3.



1. Scallion stem 2. Clamping and conveying device

Figure 3. Mechanical model for transport

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By conducting a force analysis through the transport mechanical model, we obtain:

$$F' = G. \tag{1}$$

$$F' = f_1 F_1. \tag{2}$$

In the equations, F1 represents the clamping force, in Newtons (N); F1 represents the frictional force between the conveyor belt and the scallion stem, in Newtons (N); G represents the weight of the scallion, in Newtons (N); and f1 represents the coefficient of friction between the scallion stem and the conveyor belt.

By solving the above two equations simultaneously, we find the clamping force:

$$F_1 = \frac{G}{f_1}. \tag{3}$$

Calculations show that the clamping force required for the clamping and conveying device to transport scallions is F1 = 21.28N.

By analyzing the clamping force in the two stages, it is found that the clamping force during uprooting is greater than during transportation. If the clamping and conveying device can successfully uproot the scallion, it can stably complete the transportation process.

3.2. Design of Clamping Pulley

The main function of the clamping pulley is to squeeze the conveyor belt to hold the scallion in place, preventing the scallion from falling off during the clamping and conveying process due to vibrations caused by the rotation of the pulley. Considering that the surface of the scallion stem is smooth without bumps or depressions, it can be approximated as a cylinder. Therefore, a full-segment clamping method is chosen, and the structure of the clamping pulley is shown in Figure 4. The full-segment clamping method provides a larger contact area between the scallion stem and the conveyor belt, which is beneficial for improving the stability of the clamping and conveying process.

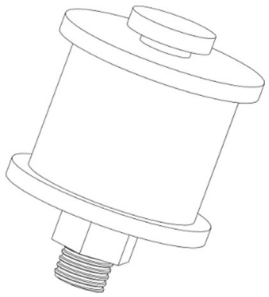

Figure 4. Structure of clamping pulley

3.3. Analysis of the Clamping and Conveying Device's Inclination Angle

The clamping and conveying device, when installed on the scallion harvester, will create a certain angle of inclination with the ground, known as the inclination angle of the clamping and conveying device. This angle is constant during the actual harvesting process and is crucial for the stable clamping and conveying of scallions. An inclination angle that is too large or too small will affect the harvesting efficiency. Referring to the "Agricultural Machinery Manufacturing Common Calculation Compendium" and considering the design of other root crop harvesters,

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the typical range for the inclination angle is 20-35°. Combining the actual harvesting experience of scallions, the inclination angle α for this clamping and conveying device design is set at 30°.

4. Finite Element Simulation Analysis of The Clamping and Conveying Device

Finite element simulation modeling and analysis were carried out for the new symmetric flexible clamping and conveying device. After importing the designed rack into ANSYS Workbench, the material of the rack is set as Q235 structural steel, density is 7850kg/m3, modulus of elasticity is 210GPa, Poisson's ratio is 0.29, and yield strength is 235MPa.To ensure the authenticity of the simulation, the clamping and conveying device is loaded and constrained according to the actual installation of the clamping and conveying device on the scallion harvester, and meshing is carried out by automatic meshing function, and the established finite element simulation model is shown in Figure 5. To ensure the authenticity of the simulation, the load and constraints are applied to the clamping conveyor according to the actual installation on the scallion harvester, and the automatic meshing function is used for meshing, and the finite element simulation model is shown in Figure 5:

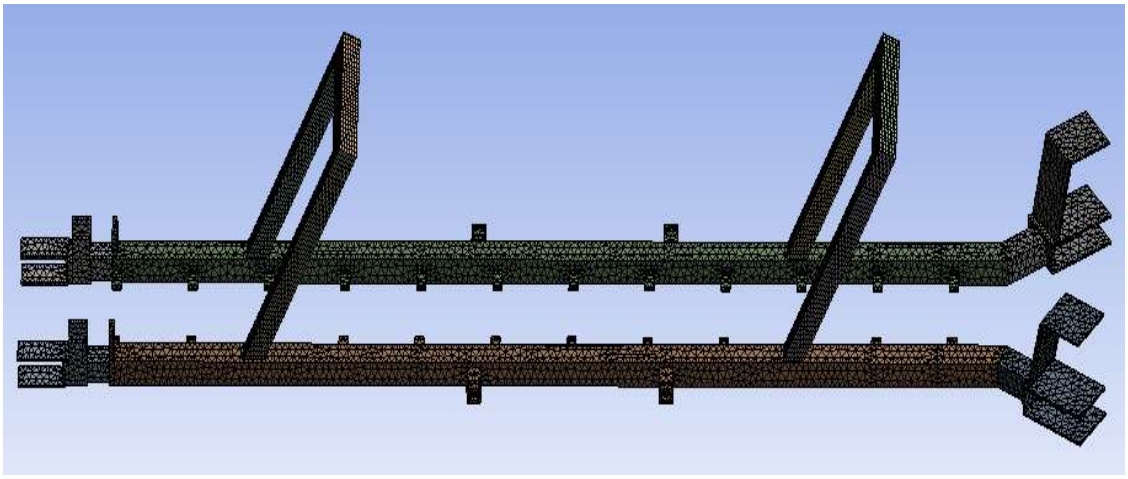

Figure 5. Finite element simulation model of clamping conveyor

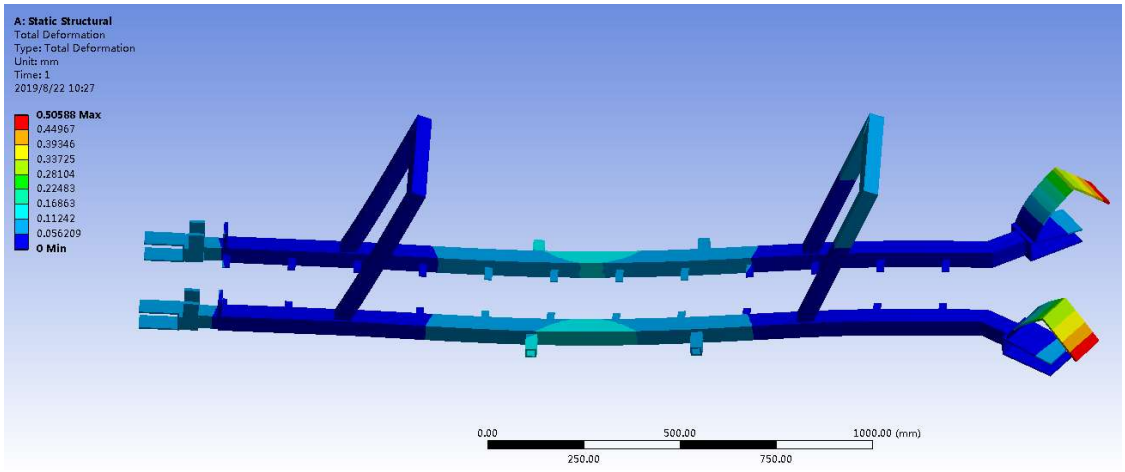

Figure 6. Clamping conveyor deformation cloud

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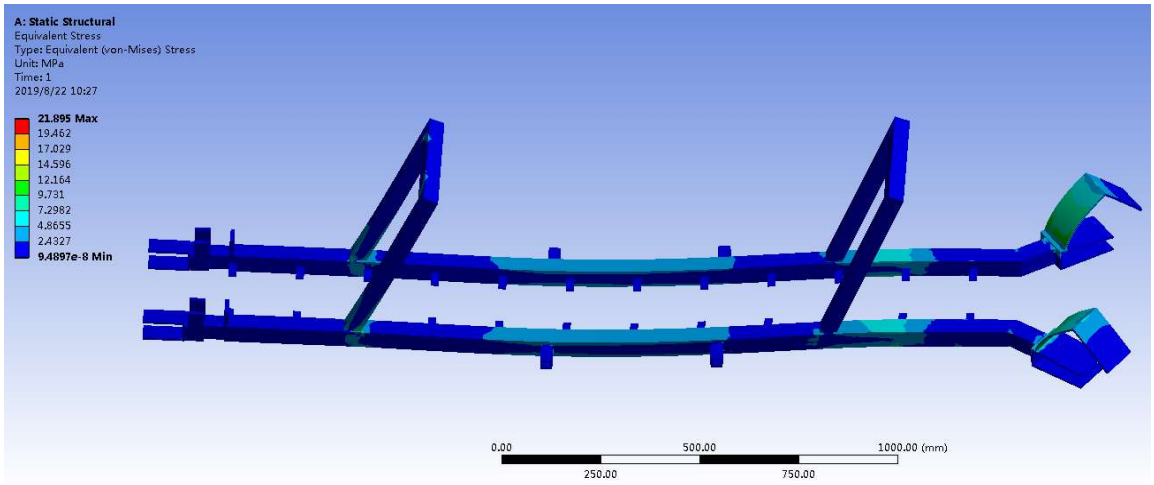

Figure 7. Clamping Conveyor Stress Cloud

Numerical calculation and analysis were carried out based on the finite element model, and the deformation cloud diagram and stress cloud diagram of the clamping and conveying device were obtained as shown in Figure 6 and 7, respectively. From the deformation cloud diagram, it can be seen that the deformation at the hydraulic motor bracket and the connecting longitudinal beam is more obvious, and the maximum deformation is 0.506mm, which occurs in the upper part of the hydraulic motor bracket; from the stress cloud diagram, it can be seen that the stress of the frame is mainly concentrated in the connecting longitudinal beam, which is mainly due to the gravity of the de-soiling mechanism, and the maximum stress is 21.895MPa, which occurs in the middle of the connecting longitudinal beam, and it is far less than the material yield limit of 235MPa. In summary, the clamping and conveying device can meet the strength requirements during operation.

5. Conclusion

(1) A new symmetrical flexible clamping and conveying device with double-belt clamping design is innovatively designed. The clamping and conveying device design principle is given. The clamping and conveying device was designed and analyzed, and a mathematical model of the clamping force of scallion conveying was established to provide a theoretical basis for the design of the clamping mechanism; the clamping pulley was further designed and the inclination angle of the clamping and conveying device was analyzed. Finally, the clamping and conveying device finite element simulation analysis, through the deformation cloud map and stress cloud map analysis, indicates that the designed clamping and conveying device can meet the requirements of the working strength.

(2) The clamping and conveying device can automatically adjust the size of the clamping force according to the diameter of the scallion stalks to achieve high efficiency and non-destructive clamping: to ensure that the clamping mechanism can always ensure that the conveyor belt and the scallion stalks are in close and non-destructive contact, which is more innovative than the existing clamping and conveying device.

(3) The clamping and conveying device is the key technology of root and tuber harvesters, the results of this research can provide a reference for the design of clamping and conveying devices of other root and tuber harvesters.

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