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Mulberry Leaf Picking Device Design and Motion Simulation

Yingfu DENG[a], Bo WANG[a1], Yongyang DING[a], Licheng WANG[a], Zhijun LI[a], Jincheng ZHONG[a], Mengji CHEN[a], Peng LU[a], Zupeng ZHOU[b]

[a]*School of Artificial Intelligence and Smart Manufacturing, Hechi University, Yizhou 546300, China*

[b]*School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology, Guilin 541000, China*

Abstract. In recent years, with the development of the silkworm industry, the scale of silkworm breeding is increasing, and the mechanized picking of mulberry leaves has become an inevitable trend of development. Based on the research of various existing picking machines, this paper proposes and designs a comb-brush mulberry leaf picking device. According to the morphological parameters of the tree, the spacing between planting rows and the picking requirements, the design parameters of the mulberry leaf picking device are determined. The three-dimensional modeling and design of mulberry leaf picking device are carried out by three-dimensional software, and the static analysis of key parts is carried out. The results show that the maximum stress of the drum and brush bar is 0.363 Mpa, and the maximum deformation is 0.0074 mm. The analysis results meet the requirements. The three-dimensional model is imported into the motion simulation software ADAMS. The analysis shows that the travel speed of the machine is 250mm / s, the rotation speed of the drum is 130r / min, and the effective picking range is about 850mm. This design provides a certain reference for the development of mulberry leaf picking device.

Keywords. Silkworm; mulberry leaf picking; static analysis; motion simulation analysis

1. Introduction

Since 1978, remarkable progress has been made in the mechanization of mulberry cutting and mulberry leaf picking. Di Lei and his team [1] designed a new type of brush-type Camptotheca acuminata leaf picking and collecting machine, which can effectively solve the harvest problem in mountainous and hilly areas. Wang Zhongliu et al. [2] designed a pair of roller ginkgo leaf picking machine to meet the picking operation of ginkgo leaves at different heights. Sun Yujie et al. [3] designed a new type of high-branch leaf picking device to realize the picking and collection of leaves; cao Yongxiang et al. [4] invented a mulberry leaf picker, which is mainly composed of a fixed shell, a cutting blade, a collection box, a reminder device and a cutting device.

[1] Corresponding Author, Bo WANG, School of Artificial Intelligence and Smart Manufacturing, Hechi University, Yizhou 546300, China; E-mail: 64909240@qq.com.

Selsiya M S et al. [5] invented the automatic tea harvester system, through image processing to achieve selective picking of tea; praveena Gowda et al. [6] studied the application of mulberry field machinery to improve the efficiency of mulberry field operation, and developed a three-wheel moving mulberry branch cutting machine. Zhang S et al. [7] designed a ginkgo leaf picking device, which is mainly composed of a rod picking hand and a drum. By adjusting the inclination angle of the picking device and the motor speed, the theoretical analysis and calculation are carried out to verify the feasibility of the design, which provides a certain idea for the design of the mulberry picking machine.

Experts and scholars from all over the world have devoted a lot of energy and resources to the development and improvement of picking machinery, but there are still various problems in the invented device, such as complex operation process, low efficiency and imperfect collection device. Based on the previous design, this paper determines the appropriate picking mechanism and the collection device to establish a three-dimensional model, and then carries out static analysis and kinematics analysis of the important parts, which provides a theoretical basis for the subsequent development of a new mulberry leaf picking machine.

2. Mulberry leaf picking device design

2.1 Composition of the whole machine

Mulberry leaf picking machine is a kind of high-efficiency mechanical collecting tool, which is specially designed for mechanized picking and collecting mulberry leaves. Among them, the picking device is an important part of the machine, and the main components are the drum and the comb rod. By selecting a mulberry leaf picking mechanism, we can easily collect leaves from the plant without causing serious damage to the leaves. The composition of mulberry leaf picking machine mainly includes bearing seat, leaf collecting box, auxiliary positioning device, drum mechanism, leaf storage box and fan. The overall structure of mulberry leaf picking machine is shown in Figure 1.

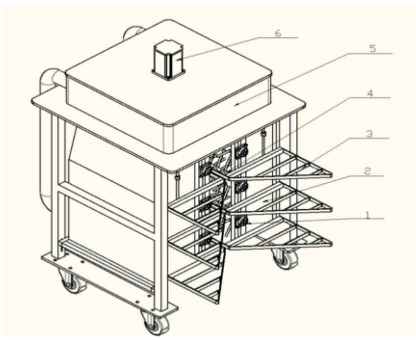


Figure 1. Overall structure diagram of mulberry leaf picking machine

1.bearing seat 2. leaf collecting box 3. auxiliary positioning device 4. roller mechanism 5. leaf storage box 6.fan

2.2 Working principle of the whole machine

When working, the mulberry leaf picking and collecting machine is first controlled to move to a suitable position, so that the mulberry branches to be picked are located between the three auxiliary mulberry branch positioning devices, and then the mulberry leaf picking and collecting machine is controlled to move forward. When the mulberry branch is located in the mulberry leaf picking device area, the comb brush rod rotates with the four drums. By using the function of the comb brush rod, the mulberry leaves on the mulberry branches can fall off, and the fallen mulberry leaves fall into the 2 leaf collecting box with inertia, and the mulberry leaves in the leaf collecting box are sucked into the 5 storage box located on the top of the mulberry leaf picking and collecting machine through the 6 fan.

2.3 Structure design of picking device

The main components of the picking device are drum and brush rod. The total length of the designed drum is 910 mm, and the comb brush rods are evenly distributed on the drum. Six rows of comb brush rods are distributed on the drum. In order to ensure the leaf picking rate in the picking process, it is necessary to arrange and fix the comb brush rods reasonably. On the left and right drums, the spacing of the picking rods is staggered. The design parameters of the drum and the comb rod are shown in table 1, and the three-dimensional model of the drum is shown in Figure 2.

Table 1. Structural parameters of the picking device

Serial number	Structure type	Size parameter
1	Roller length	910mm
2	The mulberry branch channel gap	21.1mm
3	Drum diameter	100mm
4	Length of brush bar	90mm
5	Brush rod diameter	15mm
6	Axial spacing of brush bar	78mm
7	Number of comb brush sticks (single drum)	72 or 66 roots

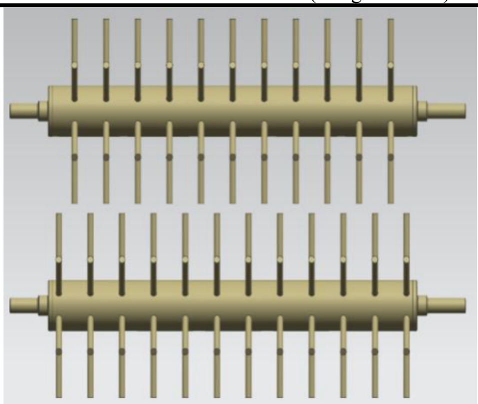
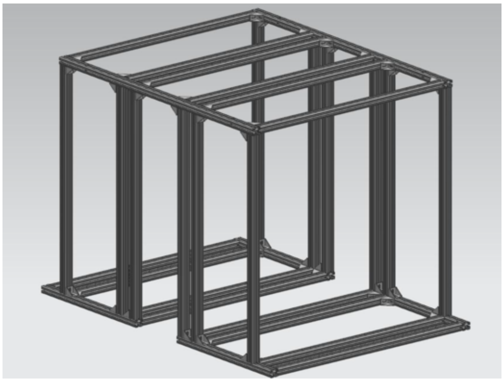


Figure 2. Picking mechanism model diagram

2.4 Design of picking device frame

The frame of the picking device is responsible for bearing the whole weight of the mulberry leaf picking device. The frame is assembled by 40 mm × 40 mm aluminum profile and aluminum alloy angle code through T-nut locking connection. The frame is mainly used for fixed drum picking mechanism, driving motor and leaf collecting box. The three-dimensional model is shown in Figure 3.



Figurge 3. Three-dimensional model of support frame

2.5 picking execution device design

The picking execution device is composed of a support frame, a bearing seat, a driving motor, a motor seat, a coupling, a drum structure (including a drum and a comb rod), a leaf collecting box and other components, which can effectively complete the picking task. The three-dimensional model of mulberry leaf picking device is shown in Figure 4.

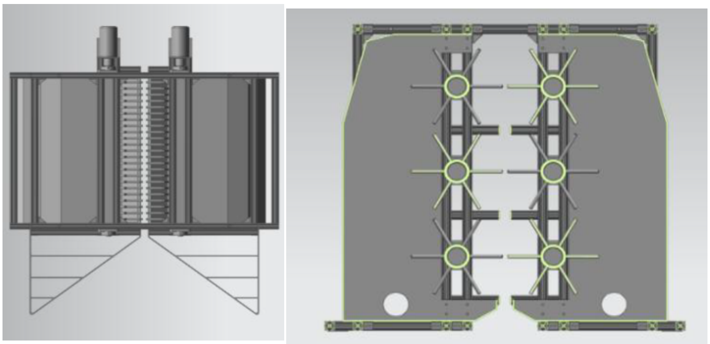


Figure 4. Picking device structure diagram

2.6 Interference checking of virtual prototype

After the construction of the three-dimensional model of the picking mechanism is completed, in order to ensure the rationality of the production process, the assembly interference inspection of its parts is carried out. Firstly, the three-dimensional modeling of each component is drawn, and then assembled to form a complete assembly. Then open the assembly of the mulberry leaf picking mechanism, click on ' gap analysis ', ' execution analysis ' and ' determination analysis ' in turn, and finally use SOLIDWORK software to perform automatic interference check. The interference results are shown in Figure 5.

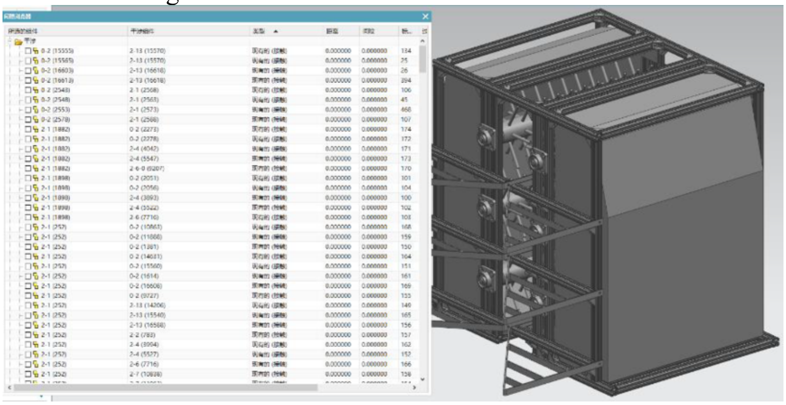


Figure 5. Interference inspection of picking mechanism

3. Statics simulation analysis of picking device

In the process of mulberry leaf picking, the drum and brush bar have a crucial impact on the reliability, picking efficiency and service life of the operation process. Therefore, static simulation analysis of these key components must be carried out to ensure the normal operation of the machine [8]. Using the three-dimensional model constructed by ANSYS Workbench and SOLIDWORK, the static simulation analysis of the drum and the brush rod is carried out to deeply understand its structural characteristics and performance.

3.1. Static simulation analysis of support frame

The three-dimensional model of the support frame is established. We import this model into ANSYS Workbench, and use tetrahedral mesh to divide it, and apply boundary conditions and loads. The equivalent stress and total deformation of the gantry frame model are obtained by post-processing, as shown in 6 and Figure 7.

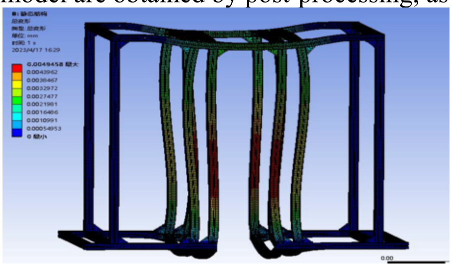


Figure 6. Overall deformation cloud diagram of support frame

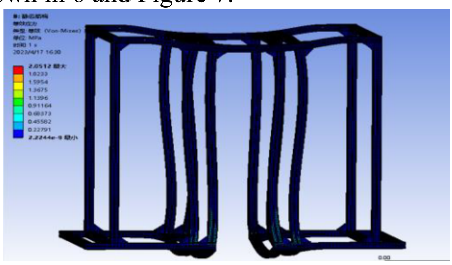


Figure 7. Equivalent stress deformation cloud diagram of support frame

By analyzing the deformation of the support frame, it is found that the maximum deformation occurs in the middle area of the support frame, and its value is as high as 0.005 mm. According to the equivalent stress deformation cloud map of the support frame, it can be seen that the bottom of the support frame bears the maximum stress, and the maximum stress is 2.05Mpa. The finite element analysis shows that the overall structure of the support frame meets the design requirements of strength and stiffness, and has high bearing capacity and good fatigue life.

3.2. Gantry frame statics simulation analysis

The three-dimensional model of gantry frame is established. We import this model into ANSYS Workbench. The tetrahedral mesh is used for division, boundary conditions and loads are applied, and the gantry frame model is post-processed to obtain its equivalent stress and total deformation, as shown in Figure 8 and Figure 9.

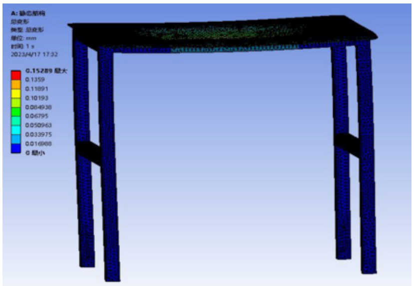


Figure 8. Overall deformation cloud diagram of gantry frame

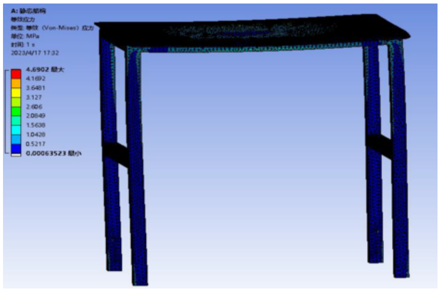


Figure 9. Equivalent stress deformation cloud diagram of gantry frame

From the overall deformation cloud map, it is known that the maximum deformation of the gantry frame is 0.15 mm, mainly concentrated in the middle of the storage platform. The structure is reinforced by welding process to ensure the overall strength and stiffness of the gantry. The maximum stress of the gantry frame is 4.69 Mpa, which is much lower than the yield limit of the material 355 Mpa. The design of the gantry frame has reached the standard of normal use in terms of overall deformation and equivalent stress, providing reliable support.

3.3. Statics simulation analysis of roller and picking round bar

Through ANSYS Workbench, the three-dimensional model of the drum and the picking rod is obtained, and the corresponding Poisson 's ratio, yield strength, elastic modulus and density are input for further analysis. The drum and picking rod are imported into the three-dimensional model and divided into tetrahedral grids. According to the optimal operating state of the drum and brush rod, constraints and loads are applied to the model. After the analysis and processing of the drum and brush rod, the equivalent stress, equivalent strain and overall deformation of the model can be obtained. As shown in Figure 10, Figure 11 and Figure 12.

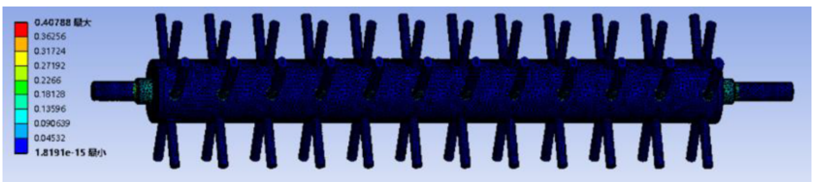


Figure 10. Equivalent stress cloud diagram of drum and picking rod

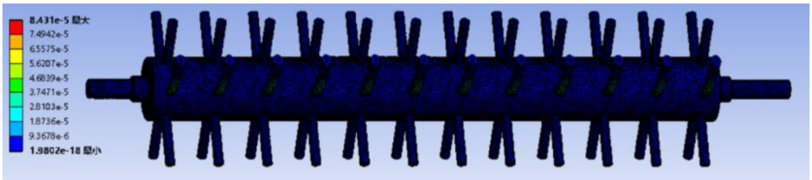


Figure 11. Equivalent strain cloud diagram of drum and picking rod

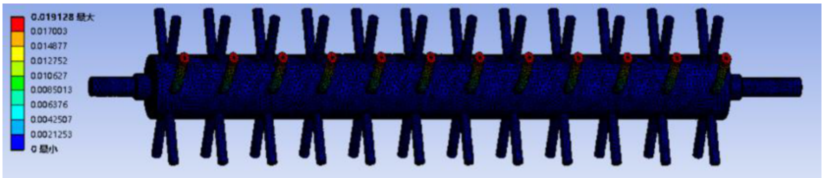


Figure 12. Overall deformation cloud diagram of drum and picking rod

It can be seen from the figure that the maximum stress value of the brush bar is 0.408 Mpa, which is far less than the yield strength of the plastic 27.44 Mpa, so the strength of the drum and the brush bar meets the operation requirements. The maximum deformation part is located at the top of the comb brush rod, and the maximum deformation is 0.0191 mm, which is within the allowable deformation range. Therefore, after the above analysis, the design of the drum and the comb brush rod is qualified.

4. Kinematics simulation analysis of picking device

The three-dimensional model of the picking and collecting device constructed in SOLIDWORK software is converted into STEP format file into X _ T format file, and finally imported into ADAMS software for solid modeling, as shown in Figure 13. For each part of the simulated three-dimensional model, the corresponding materials are selected in turn, and the parts that need to be set are selected in turn in the model tree. According to the nature of the movement of each mechanism of the mulberry leaf picking machine, the corresponding constraints are added, and the rotating pair is added at the position where there is relative rotation. The simulation time is set to 10 s, the number of simulation steps is 1000, and the operation cycle is 3 cycles.

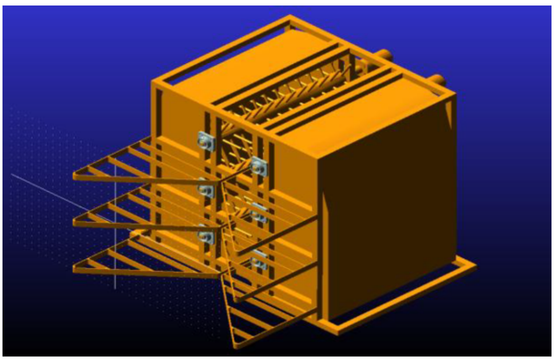


Figure 13. ADAMS simulation three-dimensional diagram

4.1. Motion simulation analysis of roller and comber rod

The motion simulation of the drum and the brush rod is carried out, and the Maker point is created at the end of the brush rod of the drum. According to the above parameters, the mulberry leaf picking and collecting machine is driven, and the motion trajectory of the drum mechanism can be seen. The ' Displays the Animation Control dialog ' command in the ' result ' is used to create the spatial motion trajectory of the Maker point. By continuously adjusting the rotation speed of the drum to observe the trajectory diagram, when the travel speed is 250mm / s and the rotation speed of the drum is 130r / min, the trajectory of the drum is the best, which ensures that the mulberry leaves on the mulberry branches can be picked clean during picking. The trajectory of the drum is shown in Figure 14.

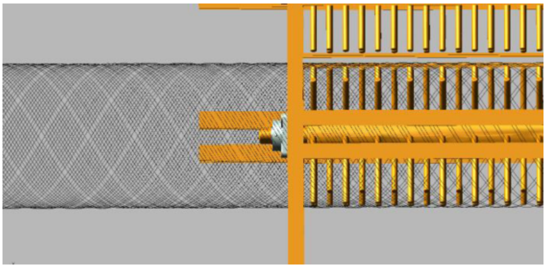


Figure 14. Trajectory of drum movement

After entering the ADAMS / Postprocessor post-processing module, the brush rod endpoint of the drum mechanism is taken as the research object. By using the above parameters, the Y-axis trajectory diagram and displacement diagram of the brush rod endpoint are obtained, as shown in Figure 15 and 16.

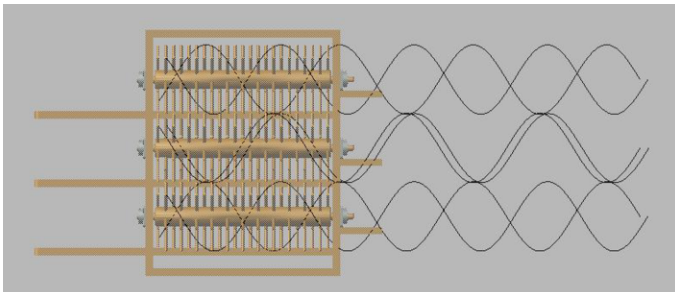


Figure 15. Y-axis trajectory

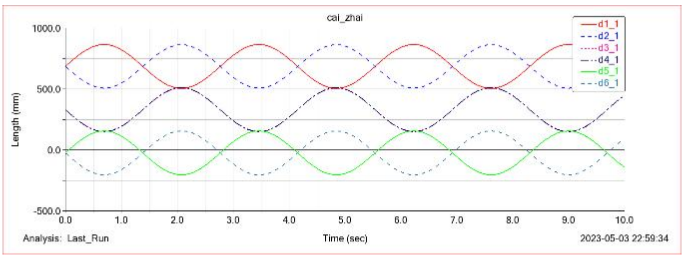


Figure 16. Y-axis displacement curve

As shown in Figures 15 and 16, the Y-axis trajectory diagram and the Y-axis displacement curve diagram of the brush rod endpoint are shown. Through the measurement in the diagram, it can be seen that the rotation of the drum mechanism takes about 2.75 s a week, and the whole mechanism moves forward by 687.5 mm. The effective picking range of the mulberry leaf picking machine is about 900 mm, which is basically consistent with the height of the mulberry branch.

5. Conclusion

In order to improve the picking efficiency and meet the large-scale mechanized collection and collection of mulberry leaves, this paper adopts a comb-brush picking scheme. In order to achieve efficient mulberry leaf collection, a scheme combining gravity drop and air-suction hybrid collection is adopted. This scheme not only ensures the compactness of the overall mechanical structure, but also provides a more convenient way for mulberry leaf collection. Through three-dimensional design, dynamic simulation, strength, stiffness and stability analysis, the rationality of the mechanism design is verified to provide an effective reference for the mechanized harvesting of mulberry leaves.

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