Optimization of Cutting Tool Structure for *Camellia oleifera* Weeding Device

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Abstract. Weeding is an important part of forest nurturing. A horizontal swing blade weeding mechanism was designed, and a Y-shaped swing blade model was designed using SolidWorks software to calculate the layout and quantity of swing blades.Modal analysis was conducted on the weeding blade to determine the natural frequencies and corresponding vibration modes of the first 6 constrained modes, resulting in the lowest natural frequency of 675.1Hz.Static analysis was conducted on the weeding blade, and the stress diagram and deformation distribution diagram of the tool were obtained. It can be concluded that the stress and deformation of the weeding blade during operation are within the allowable range.optimize the structure of the single row groove cutter.

Keywords: Weeding, blade swinging, modal analysis, optimization design.

1. Introduction

Camellia oleifera is one of the four major woody oil plants in the world and a very important woody oil tree species in China[1].Failure to carry out soil loosening, weeding, and irrigation operations in a timely manner has resulted in soil compaction and overgrown weeds and mixed irrigation in the *Camellia oleifera* forest, hindering the absorption of nutrients by *Camellia oleifera* and seriously affecting the quality of Camellia oleifera fruits, causing huge losses to the *Camellia oleifera* industry[2].The high-yield cultivation techniques for *Camellia oleifera* [3-4] indicate that removing weeds and shrubs, as well as loosening soil, can improve the environment of *Camellia oleifera* forests and increase their yield. Therefore, soil loosening, weeding, and irrigation in *Camellia oleifera* forests are extremely necessary. The problem of traditional rotary tillers being tangled by weeds and mixed irrigation roots can be solved by plowing or chiseling working parts[5-6].The common weeds and root systems of mixed irrigation in *Camellia oleifera* forests can be divided into two types based on their different configurations: taproot and fibrous root systems[7].Horizontal blades such as plow blades, horizontal disc blades, and vertical spiral plows are suitable for cutting vertical root systems[8-9].The plow blade has a low soil fragmentation rate, while the horizontal disc blade is only used for weeding and irrigating the upper part of the soil. The horizontal Y-shaped swing blade designed in this article serves as a component of the above-mentioned forest weeding equipment, with functions of weeding and loosening soil, meeting the needs of forest tending, improving work efficiency, and saving labor.

2. Design of horizontal Y-shaped swinging blade weeding device

According to the situation of weeds and shrubs in the forest land, for the operation area of the weeding device module, the swing blade weeding mode is selected for operation. The shape, size, and distribution of the swing blade have a great impact on the weeding effect and working life.

2.1 Layout of weed control device swing blade

The horizontal weeding device adopts a Y-shaped swing blade layout, which includes staggered balanced layout, single helix layout, double helix layout, symmetrical layout, etc. Due to the significant shaking of the single helix layout and double helix layout when the blade shaft rotates at high speed, they are not suitable for situations where the blade shaft is long. To ensure the balance of the swing blade weeding device during operation, this article will adopt the staggered balanced layout as the layout of the swing blade, as shown in the figure 1.

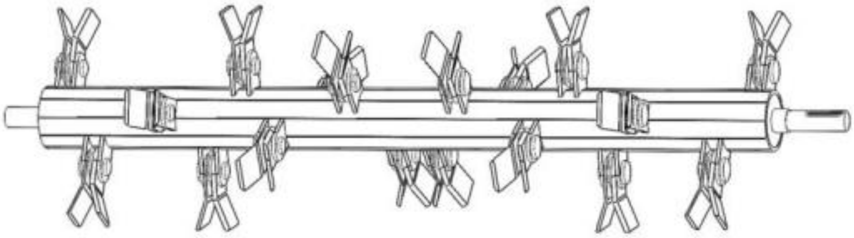

Figure 1. Swing knife layout

2.2 Confirm the number of swinging knives

The maximum weeding width of this design is 1.20m. The number of swinging blades in the swinging blade weeding device is related to the weeding width and density. If there are too many swinging blades, the weeding device will be too heavy, consume a lot of power, and there will be some collision between the blades, resulting in heavy cutting and low efficiency. If there are too few swinging blades, the weeds will not be completely removed, and there will be missed cutting, which will not achieve the goal of weeding. To ensure the rationality of the number of swinging knives, the number of swinging knives can be calculated using a formula(1).

$$N = C \times L \tag{1}$$

Where N is the total number of blades (pieces), C is the blade density (pieces/mm), L is the total weeding width of the weeding blade shaft (mm).

For different types of swinging knives, their density values are also different. The density value of Y-shaped swinging knives is 0.02 pieces/mm~0.04 pieces/mm, while that of straight knives is generally 0.05 pieces/mm~0.07 pieces/mm, and that of T-shaped knives is 0.01 pieces/mm [10]. Due to the effective weeding width of this swinging knife weed control device being 1.00m, the assembly method is to combine two sets of L-shaped improved swinging knives in reverse to form Y-shaped swinging knives. At the same time, to ensure lightweight design, the density value of swinging knives is 0.02 pieces/mm, and the total number of swinging knives obtained by solving is 24.

3. Design of weed cutting tools

There are many types of swinging knives, and currently the more mature ones include T-shaped swinging knives, Y-shaped swinging knives, L-shaped and improved swinging knives, straight knife swinging knives, hammer claw swinging knives, whip swinging knives, etc. Among them, Y-shaped swinging knives are generally treated with double-sided cutting, with the advantage of small size and wear resistance. When weeding, they cross contact with weed stems, tilt the incision, and reduce shear resistance. In order to conform to the concept of lightweight, high-efficiency, and low-power weed control, a Y-shaped improved swing blade with a serrated double-sided cutting edge is adopted. Two sets of blades are installed in reverse to form a Y-shaped shape as one set of cutting tools installed in one set of tool holders. Therefore, add a 5.0mm spacer between the two sets of blades. The blade thickness is 5.0mm, the length is 100.0mm, the width is 50mm, the height is 31.7mm, the center hole is 21mm, and the blade angle is 45 °. To improve the wear resistance of the cutting tool, the blade material is 65Mn steel sheet, and the installation method between the blade structure and the tool holder is shown in the figure 2.

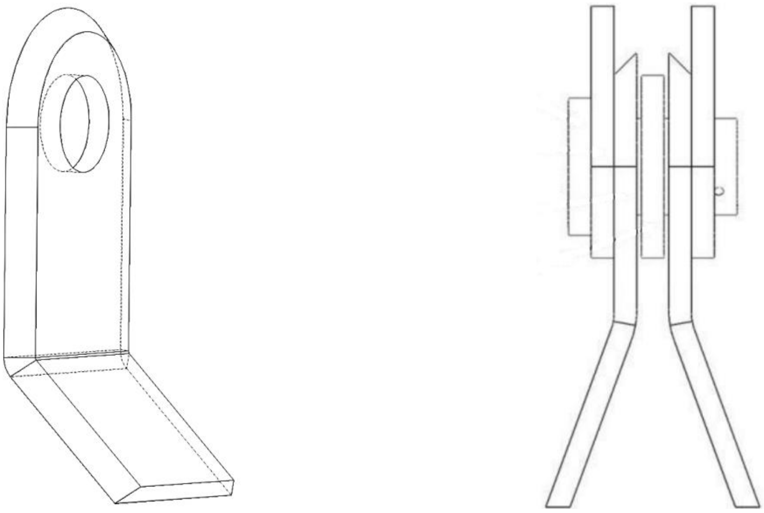

Figure 2. Blade structure and installation mode

4. Simulation Analysis

Perform modal analysis and static stress analysis on the solid model of the weeding blade in SolidWorks software.

4.1 Modal analysis

According to the operation process of the simulation interface, select a new example and perform the following steps:

1) Define material properties: The material of the single row groove cutter is alloy steel, with an elastic modulus of E=2.1×105MPa, Poisson's ratio u=0.28, and density ρ=7.7g/cm3. 2) Apply constraints: Select the installation hole position of the weed control tool and apply constraints. 3) Cell division: The model grid division adopts a program controlled free division method, with a unit edge size set to 1.41mm and grid Jacobian points of 16. The number of grid cells and nodes after division is 109077 and 71362, respectively, with a high grid quality level. 4) Modal order: On the frequency options page, set the frequency to 6 in the properties. 5) Solution: Right click and select Run.

By conducting modal analysis on the weeding blade, the modal analysis results of the first 6 orders were obtained, and their natural frequencies and vibration mode characteristics are shown in the table 1. The first order vibration mode diagram is shown in the figure 3.

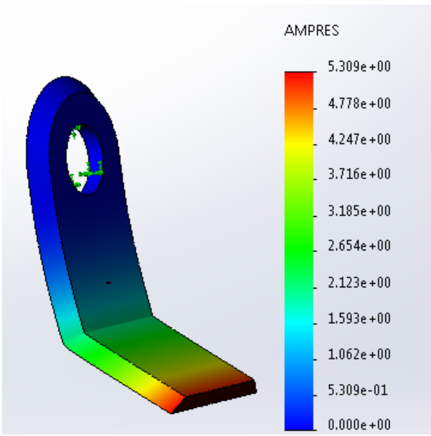

Figure 3. First order modal diagram of weeding knife

The natural frequency of the first 6 vibrations of the weeding blade increases with the order, and the higher the natural frequency, the more intense the vibration and the greater the damage to the structure. The lowest natural frequency value is 675.1Hz, so the excitation frequency of the external signal loaded on the trencher should be less than 675.1Hz to avoid resonance, which provides reference for the working conditions of the weed control device.

Table 1. The front 6 order natural frequencies

Order	Natural Frequencies/Hz	Order	Natural Frequencies/Hz
1	675.1	4	4328.7
2	1669.7	5	6897.4
3	3112.7	6	9964.5

4.2 Static stress analysis

The material selected for the weeding knife is alloy steel, with a yield limit of σ_s=620.4MPa and a strength limit of σ_b=723.8MPa. Apply a load F_r=90N on the surface of the soil cut by the trencher, and solve the stress diagram of the trencher as shown in Figure 4, and the deformation distribution diagram as shown in Figure 5.

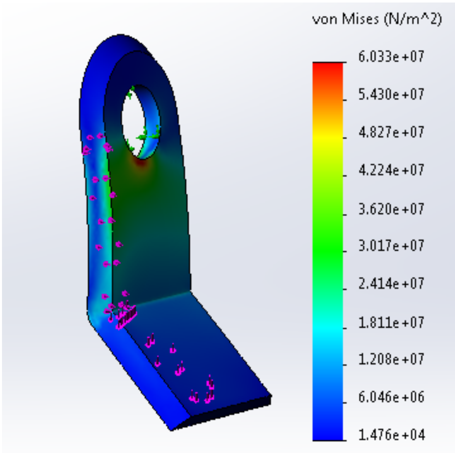

Figure 4. The stress diagram of weeding knife

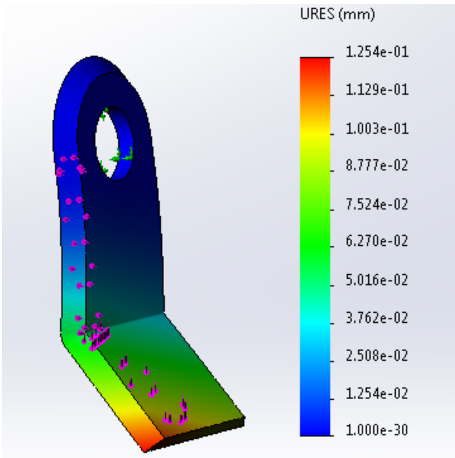

Figure 5. The deformation distribution diagram of weeding knife

From Figures 4 and 5, it can be seen that the position with the maximum deformation of the tool is at the tip, with a maximum deformation of 1.254 × 10-1mm, which is within the allowable deformation range; The position where the tool experiences the highest stress is at its mounting hole, with a maximum stress of 60.33MPa, which is within the allowable stress range of the material. The static stress analysis results of the grooving knife indicate that the tool operation is safe [11].

5. Conclusion

A horizontal Y-shaped weeding device has been developed to adapt to modern mechanized forestry tending, which can achieve weeding operations in *Camellia oleifera* forests and improve the efficiency and mechanization level of forestry tending. Through modal analysis of the weeding blade, it is found that the external excitation frequency of the horizontal weeding device should be less than 675.1Hz to avoid resonance; Static analysis was conducted on the weed killer blade, and it was found that the stress and deformation of the blade were within the allowable range.

Acknowledgements

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