Structure design of furrow fertilizer machine in apple orchard

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Abstract. China now most areas of the orchard mechanization level is low, fruit trees during the growth and development of artificial fertilization, the economic efficiency is low. Aiming at the problems of poor furrowing effect and poor fertilization quality, this paper designs an Apple Orchard Ditching fertilizer machine, which is composed of a rotary tillage device, a furrowing device, a fertilization device, a soil covering device and a transmission system. In this paper, based on the agronomic requirements of apple tree furrowing and fertilization and the physical and mechanical properties of soil and fertilizer, the dynamic simulation of the operation process was carried out by using CAD software. The stress and movement process of soil and fertilizer were analyzed, and the key structure and operation parameters of orchard ditching and fertilization machine were optimized. The equipment can realize the furrowing depth of 100 *mm*~250 *mm*, the fertilization depth of 100 *mm*~250 *mm*, and the furrowing depth of 100 *mm*~250 *mm*. The working efficiency can meet the requirements of 0.2 *ha / h*. It can effectively reduce the labor intensity of workers and improve the quality of fertilization, and has a certain application prospect.

Keywords: Apple orchard, Rotary tillage device, Ditching device, Fertilization device, Soil-covering device

1 INTRODUCTION

As a common fruit, apple plays an important role in our daily life. How to improve the efficiency and quality of apple operations, so that it can increase production and income, is a particularly important problem[1]. At present, the mechanization level of orchards in most areas of China. At present, Ditch opening and fertilization equipment can only perform ditching and fertilization operations independently. Although they have been gradually intelligent, they are expensive and not suitable for most orchard operations, and it is difficult to popularize them in China. The purpose of this paper is to design a suitable furrowing and fertilization mechanism for apple orchard, which saves labor, improves the efficiency of topdressing and improves the quality of fertilization through machine application of compound fertilizer, so that farmers can obtain greater benefits.

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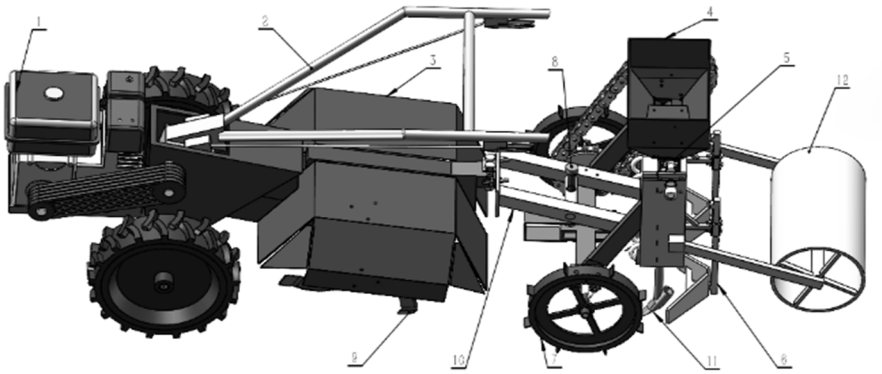
2 The overall structure design and working principle of the furrow fertilization machine for apple orchard

2.1 Structural composition

The structure of apple furrow fertilizing machine is mainly composed of rotary tillage device, furrow device, fertilization device, soil covering device and transmission system. As shown in Figure 1.



1. Diesel engine 2. Handrail 3. Retaining plate 4. Fertilization box 5. External groove wheel fertilizer applicator 6. Soil-covering device7. Ground wheel 8. Screw 9. Rotary tillage knife 10. Frame 11. Ditching knife 12. Suppression wheel

Fig. 1. 3D design of the structure of the furrowing and fertilizing machine in apple orchard

2.2 Principle of operation

The whole machine is driven by the walking tractor, the diesel engine is driven by the belt drive, through the rotary tillage assembly, the power is transmitted to the rotary tillage knife shaft, the knife shaft then drives the rotary tillage knife to complete the rotary tillage operation, the land after rotary tillage is ditched by the ditching knife, the fertilization part is driven by the ground wheel through the chain drive external groove wheel fertilizer remover rotation, so that the fertilizer falls from the fertilizer transmission pipe to complete the fertilization operation. Finally, the land is leveled by the soil covering device, and the suppression wheel compaction to complete all operations.

2.3 Overall parameters of prototype

The technical parameters of the prototype are shown in Table 1.

Table 1. Overall parameters of prototype

Working parameter	numerical value
Ditching depth	100 *mm*-250 *mm*
Depth of fertilization	100 *mm*-250 *mm*
Running speed	0.5*m/s*
Work efficiency	0.2 *ha / h*
Machine size (length × width × height)	2300 *mm*×940 *mm*×1100 *mm*
Fertilizer type	Granular compound fertilizer

3 Design of key components

3.1 Design of rotary tillage device

The rotary tillage device mainly drives the knife shaft of the rotary tillage device to rotate through the power output of the diesel engine, and then the rotary tillage knife shaft drives the rotary tillage knife to rotate accordingly at a fixed speed, and the hard soil becomes soft. The rotary tillage reduces the soil resistance, reduces the difficulty of fertilization, and improves the quality of operation[2]. The structure of the rotary tillage device is shown in Figure 2.

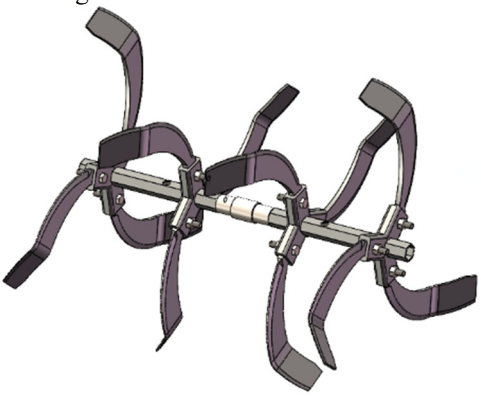


Fig. 2. 3D design diagram of rotary tillage device

Rotary tillage device blade selection scimitar, scimitar has good sliding cutting performance, and the performance of throwing is excellent, not easy to wrap the grass. According to the relevant literature, it can be known that the working depth and speed ratio λ of rotary tiller can meet the following formula[3]:

$$H < R\left(1 - 1/\lambda\right) \tag{1}$$

Among them, λ has a significant impact on the performance requirements of rotary tillage work, and there are many conditions that affect the value of λ . At present, the

speed ratio λ is ranges from 4 to 10 is commonly used in production. When the maximum tillage depth H=250mm is brought in, the minimum radius *R* of rotary tillage knife required is 278 *mm*, and the model of rotary tiller blade selected is IS285.

The knife shaft rotates once, the time interval of the blade is, at this time, the relationship is as[4]:

$$S = v_m t = \frac{2\pi v_m}{z\omega} = \frac{2\pi R}{z\lambda} = \frac{60 v_m}{zn} \tag{2}$$

In the formula, S is the pitch of soil cutting, which is taken as 10~12 cm；

n is the tool shaft speed, 230 r/min;

z is the number of blades, number;

λ is the speed ratio, with a value of 4-10;

v_m is the maximum forward speed of the machine, which is 0.5 m/s.;

The calculated value of z ranges from 1.24 to 4.47. Considering comprehensively, the number of blades is 3.

3.2 The design of the ditching device

Refer to the relevant information[5], the recommended particle size of the fertilizer is 2-4*mm*, so in order to ensure that the fertilizer can fall evenly, the diameter of the fertilizer transfer hole above the ditching knife is 30mm to prevent fertilizer blockage.

According to the suitable growth environment of apples, a ditching plough suitable for apple ditching operation is designed. The ditching plough has simple structure, easy manufacture and easy disassembly. The ditching width of the ditching plough is 40mm, and its structure is simple and easy to maintain. In order to make it easier to put into the soil, the Angle of 60° is selected. The structure is shown in Figure 3.

According to the growing environment of the crop, the appropriate material is selected for production, and the material is 35 steel. The ditching knife mainly exerts resistance on its front blade when ditching. The finite element analysis of its structure is carried out, and the analysis result is shown in Figure 4.

Fig. 3. 3D diagram of the furrow opener

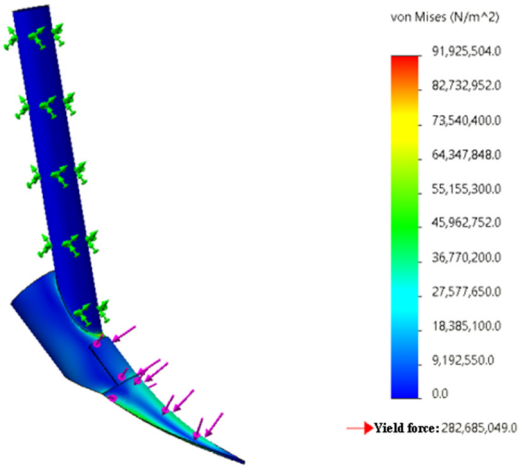


Fig. 4. Finite element analysis of the ditching cutter

It can be seen that the yield strength of the furrow opener is 9.19×10^7 N/m^2, and the maximum yield force that the furrow opener can withstand is 2.83×10^8 N/m^2. Therefore, the furrow opener can withstand the resistance of 9.19×10^7 N/m^2, and the strength of the furrow cutter meets the working requirements.

3.3 Design of the fertilization box

Every 100 *kg* apple needs to absorb 0.8-2 *kg* of pure nitrogen, 0.6-1.2*kg* of P_2O_5, 0.8-1.8kg of K_2O [6]. The size of the fertilizer box on the top plane is 420 *mm*×260 *mm*, the bottom surface is 320 *mm*×100 *mm*, and the depth is 130 *mm*. It is roughly calculated that the total volume of the fertilizer box is 20190 cm^3, and the density of the compound fertilizer is roughly 1.5 g/cm^3. Therefore, the maximum amount of fertilizer in the fertilizer box is about 30 *kg*, which meets the requirements of fertilization. The structure is shown in Figure 5.

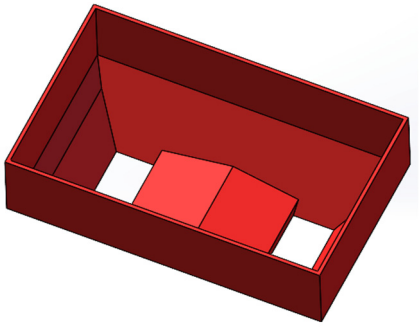


Fig. 5. 3D diagram of the fertilization box

3.4 Design of the fertilization device

The fertilization device is mainly composed of fertilizer box, fertilizer conveying pipe, and fertilizer discharging device. The external trough wheel type fertilizer applicator is selected. The structure of this kind of fertilizer application device is relatively simple, and it has good application performance for composite fertilizer, uniform fertilization and easy to use. The external groove wheel type fertilization device is mainly composed of a fertilizer shell, an external groove wheel, and an inner and outer retaining ring. When the device works, the fertilizer falls to the exhaust shell due to gravity, the walking wheel drives the driving shaft to rotate, and the fertilizer falls into the fertilizer pipeline due to gravity and the centrifugal force generated by the tank wheel to complete the fertilization work. The radius of the external groove wheel is 25 mm, and the radius of the groove is 9 mm. When the number of grooves is small, the fertilization uniformity is poor. When the number of grooves is large, the displacement will be reduced and the fertilization will be hindered, so the number of grooves is 6[7]. The Angle between the grooves is w = 60°, so the pitch Angle is 50°.Its groove cross-sectional area S is calculated using the following formula:

$$S = \frac{\omega}{360}\pi R^2 - \cot\left(\frac{\omega}{2}\right)r^2 + \left(\frac{1}{2} - \frac{\omega}{360}\right)\pi r^2 \tag{3}$$

Where r is the radius of the groove, which is 9 mm;

R is the radius of the groove wheel, which is 25 *mm*.

Calculate S = 271.571 mm^2. With the area *S*×section length, the size of the groove wheel is calculated to be 16.294 cm^3. The fertilizer density is brought into the amount of fertilizer in each groove is 24.44 *g*. The structure is shown in Figure 6.

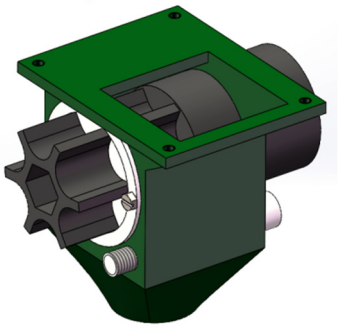


Fig. 6. 3D diagram of the outer groove wheel fertilizer applicator

3.5 Design of the soil-covering device

The soil covering device should ensure that the soil is smooth after the work is completed. This design uses a figue-eight baffle, whose bottom Angle is 100°[8], the bottom length of the baffle is 200 *mm*, and the minimum height is 67.43 *mm*. The total working

range is greater than 600 *mm*, which meets the requirements of soil covering. The device can adjust the height by adjusting the position of the fixed bolt to adapt to the operation of different depths of ditching[9]. Its structure is shown in Figure 7.

After the overlaying device, a suppression device is added. There are many forms of suppression wheels[10]. In this project, cylindrical suppression wheels are selected, with a structural diameter of 300 *mm* and a working width of 520 *mm*.

$$n = \frac{v}{2\pi r} \tag{4}$$

Where n is the rotational speed;

v is the forward speed of the machine, 0.5 *m/s*;

r is the radius of the suppression wheel, and it is taken as 150 *mm;*

It is calculated that the speed of the suppression wheel is 0.53 *r/s*, that is, 32 *r/min*. Its structure is shown in Figure 8.

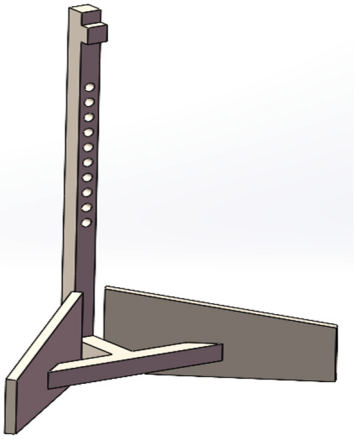


Fig. 7. 3D diagram of the overburden

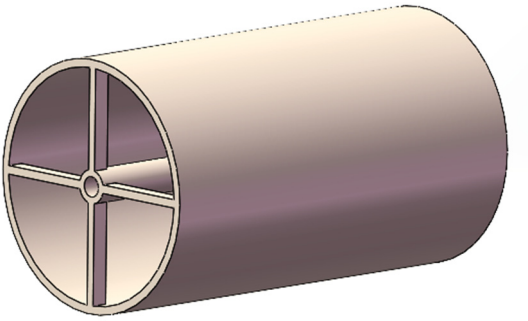


Fig. 8. 3D diagram of suppression wheel

4 Conclusion

In In order to solve the problems of time-consuming and laborious traditional fertilization method, poor furrowing effect of existing domestic mechanical devices and poor fertilization effect, this paper designed a furrowing fertilization machine for apple orchard. In order to improve the quality of furrowing and fertilization, the rotary tillage device, furrowing device and fertilization device are designed. According to the working efficiency of 0.2 *ha / h*, the power is selected, so that the operation efficiency is greatly improved. At the same time, the ground wheel is designed, which can adjust the depth of fertilization according to different situations. It provides a certain reference for the design of this kind of furrow fertilization machinery.

References

1. WANG Guochuan. Application status and development suggestions of orchard agriculture mechanization in Shanxi Province [J]. Journal of Fruit Tree Resources,3(04):85-86(2022).
2. Liu Yu, Liu Yuping, Zhang Tuo. Load analysis of Rotary tilling tool shaft of Micro-cultivator based on discrete element and multi-body dynamics [J]. China Journal of Agricultural Science and Technology,22(11):79-86（2019).
3. Sun Kui-Jun, Sun Xin-Wei, WANG Xiao-kai, Liu Hong-Lei, Yu Jun-ping. Investigation on current situation of apple production mechanization [J]. Shandong Agricultural Mechanization,4(06):44-45(2022).
4. Sun Xinwei, Liu Honglei, Chen Shenping, Yu Junping, WANG Xiaokai, Sun Guijun. Mechanization technology of apple field production management [J]. Yantai Fruit Trees,5(01):51-53(2023).
5. WANG H R. Development status and countermeasures of full mechanization of apple orchards in Xiangfen County [J]. Agricultural Development and Equipment,4(09):31-32(2022).
6. Cao Fangting, Yang Jianxin. Bagging cultivation technology of Red Fuji apple with high quality and high yield [J]. Journal of Fruit Resources,3(05):57-59(2022).
7. ZHANG Hongjian, Xu Chunbao, Liu Shuangxi, Jiang Hao, ZHANG Chengfu, Wang Jinxing. Design and experiment of Double-row trench applicator for orchard with automatic depth Regulation [J]. Transactions of the Chinese Society for Agricultural Machinery,52(01):62-72(2021).
8. Lin Yuexiang, Shang Shuqi, Wang Dongwei, Song Laiqi, Zhang Jingguo. Development of continuous trenching and spacing planter for apple trees with low anvil dense planting [J]. Transactions of the Chinese Society of Agricultural Engineering,35(01):23-30(2019).
9. Sun Maosen, Jiang Xiumei. Design of deep ditching fertilizer applicator for orchard [J]. Agricultural Machinery, (09):143-144(2014).
10. Wang Tianli. Application points of compound fertilizer in apple production [J]. Rural Baizhi, (04):39-40(2012).