DESIGN AND EXPERIMENT OF SELF-PROPELLED MULTIFUNCTIONAL TRENCHING AND FERTILIZING MACHINE

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自走式多功能开沟施肥机的设计与实验

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ABSTRACT

In orchard management, trenching operations are labor-intensive and have low efficiency, and mechanization is of crucial importance for the development of the fruit industry in China. In view of the many deficiencies of the existing chain-type and disc-type trenching machinery, this paper designs a self-propelled multifunctional orchard trenching machine. Its core component, the double-disc trenching disc, is an innovative design. Compared with the traditional single-disc trenching disc, it effectively reduces the trenching power consumption while ensuring the trenching depth and width, and significantly improves the operation efficiency. The trenching machine is composed of a frame, a gearbox, a double-disc trenching disc, a trenching knife, a soil retaining plate, etc. Field tests show that the operation speed reaches 1.2 kilometers per hour, the trenching depth is 31.2 cm, the width is 30.5 cm, and the stability coefficient of the trenching depth is 97.2%. Its power consumption is in a relatively good parameter group. When the cutter roller speed is 400 r/min, the forward speed is 0.8 km/s, and the trenching depth is 0.3 m, the average power consumption value of the trenching component is measured to be approximately 7.63 kW, with an 11.18% reduction in power consumption compared with the current trenching machines. And it meets the requirements of orchard agronomy and industry standards. In terms of improving productivity, its high-efficiency operation performance can greatly shorten the trenching operation time in the orchard, enabling fruit growers to arrange production more reasonably and increase fruit output. In reducing labor costs, mechanization replaces manpower, reduces manpower input, reduces labor cost expenditures, and at the same time avoids the instability of manpower operations. For the sustainability of orchard operations, the precise and stable trenching operation helps to optimize the utilization of land resources, ensure the quality of orchard agronomy, maintain the long-term production capacity of the orchard, promote the sustainable development of the orchard, and inject new impetus into the mechanization process of the fruit industry.

摘要

果园管理中开沟作业劳动密集且效率低，机械化对中国果业发展至关重要。鉴于现有链式、盘式开沟机械存在诸多不足，本文设计了一种自走式多功能果园开沟机。其核心部件双盘开沟盘为创新设计，相比传统单盘式开沟盘，在保证开沟深度和宽度的同时，有效降低了开沟功耗，显著提升了作业效率。该开沟机由机架、变速箱、双盘开沟盘、开沟刀和挡土板等组成，田间试验表明，作业速度达 1.2 公里 / 小时，开沟深度为 31.2 cm，宽度为 30.5 cm，深度稳定性系数为 97.2%，其功耗较优参数组，刀辊转速为 400 r/min，前进速度为 0.8 km/s，开沟深度为 0.3 m，测得此时开沟部件平均功耗值约为 7.63 kW，较目前开沟机相比功耗降低 11.18%。且符合果园农艺和行业标准要求。在提高生产力方面，其高效作业性能可大幅缩短果园开沟作业时间，使果农能更合理安排生产，提升水果产量。降低劳动力成本上，机械化替代人力，减少了人力投入，降低人力成本支出，同时避免人力作业的不稳定性。对于果园运营可持续性，精准稳定的开沟作业有助于优化土地资源利用，保证果园农艺质量，维持果园长期生产能力，推动果园可持续发展，为水果行业机械化进程注入新动力。

INTRODUCTION

China is the world's largest fruit producer, with the planting area and output of fruit varieties ranking first in the world. It has become the third largest agricultural planting industry after food and vegetables *(Yinghong, 2019)*.

The fruit industry is a labor-intensive industry. With the increase in fruit orchard planting area and labor costs in recent years, labor shortages have become one of the important reasons hindering the development of China's fruit industry *(Jianhui, 2012)*. The operation of trenching and fertilizing is the most important part of orchard management. Reasonable trenching and fertilizing operations are important ways to increase fruit yield and improve fruit quality. The current trenching and fertilizing operation in domestic orchards mainly relies on manual completion, with high intensity, low efficiency, low standardization, and easy to delay farming time, severely affecting the development process of China's fruit industry. Therefore, mechanized trenching operation has become an inevitable trend in large-scale orchard trenching and fertilizing operations.

Currently, domestic research scholars have conducted a series of research on orchard trenching machines. *Yichuan et al., (2015)*, designed the 2FK-40 orchard trenching and fertilizing machine, with a disc-type trenching blade design, maximum trenching depth of 40 cm, adjustable depth, and trenching distance of 50-80 cm from the crop roots. The machine can complete trenching, fertilizing, and covering soil operations at one time without damaging the crop roots. *Ruihua et al., (2018)*, developed a grape trenching and fertilizing machine, which can complete trenching, fertilizing, and covering soil at one time, and the trenching depth can meet the agronomic requirements of the grape orchard. *Zhou et al., (2023)*, designed and developed a deep organic fertilizer trenching device suitable for fruit planting modes such as grapes and jujubes in Xinjiang, which achieves mechanized trenching operation and meets the requirements of deep organic fertilizer application, with the characteristics of simple structure and stable performance.

The above research has to some extent alleviated the problem of high labor intensity in orchards, but there are still some shortcomings in meeting the agronomic requirements of orchards, as well as the reliability and energy consumption of the machinery.

Based on this, this paper comprehensively considers the requirements of orchard planting modes, agronomy, and energy conservation, that is, the trenching depth and width should be greater than 30 cm, and the structural design should minimize power consumption while ensuring compliance with agronomic requirements. A self-propelled multifunctional orchard trenching machine is developed to realize mechanized trenching operation.

Overall structure and working principles

A rotary tillage blade assembly is installed at each end of the trenching power output shaft. The rotary tillage blade assembly is welded with a rotary tillage blade seat and equipped with a rotary tillage blade. During trenching and fertilization, the trenching and fertilization guide cover guides and throws the soil thrown out during trenching, fills the trench, and simultaneously applies fertilizer. The machine is composed of a track chassis, matching power, gearbox, additional reducer, working chain, tool, spiral soil discharger, hydraulic cylinder, etc., and has the characteristics of compact structure, flexible rotation, and excellent trenching quality, as shown in figure 1.

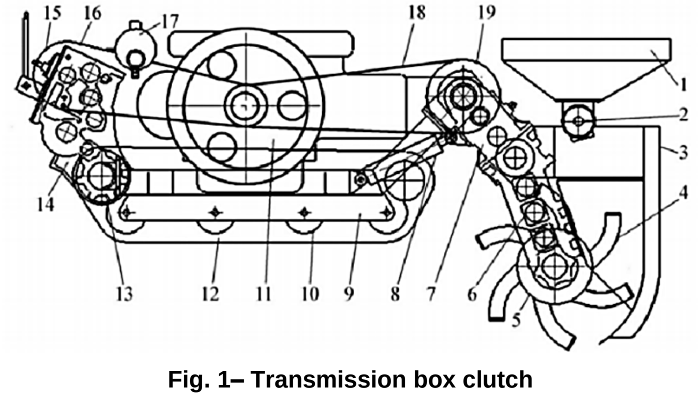

Fig. 1– Transmission box clutch

1. Fertilizer box; 2. Manure spreader; 3. Cultivator hood; 4. Rotary tiller blade; 5. Rotary tiller blade mounting bracket; 6. Trenching transmission box; 7. Transmission box; 8. Hydraulic cylinder; 9. Frame; 10. Track support wheel; 11. Diesel engine; 12. Track; 13. Track drive wheel; 14. Gearbox; 15. Gearbox clutch; 16. V-belt; 17. Hydraulic oil tank; 18. Transmission box V-belt

The self-propelled multi-functional trenching and fertilizing machine developed in this study uses 65Mn steel for the tool material. It has the characteristic of good rigidity, which enables the trenching cutter to maintain good shape stability during the operation process and is not easy to deform, thus ensuring the accuracy and continuity of the trenching operation and ensuring that the trenching depth, width, etc. meet the requirements. Moreover, due to its high tensile strength and wear resistance, during the trenching operation, the trenching cutter can withstand large tensile forces.

Especially when cutting hard soil or encountering obstacles in the soil, the high tensile strength of 65Mn steel can ensure that the trenching cutter is not easy to break, extend its service life, reduce the downtime for maintenance caused by cutter damage, and improve the operation efficiency *(Qi, 2023)*. The wear resistance of 65Mn steel can effectively reduce the wear rate of the cutter, enabling it to maintain good cutting performance after long-term use, reducing the frequency of cutter replacement, saving costs, and also helping to ensure the stability of the trenching quality. In addition, the double-disc trenching cutter can make the soil receive more reasonable forces during the trenching process. When the cutter discs rotate, the two discs work together to optimize the cutting and ejecting angles of the soil. For example, compared with a single disc, the double discs can eject the soil from different angles, making the soil more evenly distributed on both sides of the trench, effectively preventing the soil from piling up in the trench and affecting the trenching quality. This good soil ejecting effect provides convenient conditions for subsequent operations such as fertilizing and back filling. If the soil cannot be well ejected from the trench, the efficiency of subsequent fertilizing and back filling will be affected, and the double-disc cutter discs can better solve this problem. During the rotation of the double-disc cutter discs, due to their symmetrical structure, the stability of the entire trenching machine during work is enhanced. The two cutter discs share the resistance during the trenching process, reducing unstable situations such as machine shaking caused by excessive unilateral force. In terms of power consumption, the double-disc cutter discs can more evenly distribute power while ensuring the trenching effect. Compared with the single-disc cutter discs, the double-disc cutter discs can make more efficient use of power, reducing the overall power consumption of the trenching operation to a certain extent, which is beneficial to energy conservation and reducing operation costs *(Miao et al., 2022)*.

During the working process, start the crawler multifunctional working machine, and control the power output, rotation speed and steering of the orchard crawler multifunctional working machine by operating the handle. The power of the multifunctional working machine is output through the rear power output shaft, transmitted to the gearbox at the right rear end of the frame via the universal shaft, and the gearbox transmits the power to the trenching cutter disc. The rotation of the trenching cutter disc drives the trenching cutter to rotate for trenching operation. When the rotation speed of the trenching cutter disc reaches the requirement, the driver controls the hydraulic system to lower the frame according to the trenching depth requirement until the required trenching depth is achieved. When the trenching machine is working, the soil cut by the trenching cutter disc is thrown to the right side of the trench under the action of the soil deflector, and the trenching machine completes the trenching operation. The performance parameters of the machine are shown in Table 1.

Table 1

Main technical parameter of the orchard trencher

Parameter	Numeric value
Supporting power / kW	≥18
The size of the whole machine (Length*width*height) / (m*m*m)	1.1*0.9*1.02
Maximum speed of output shaft / $(r \cdot min^{-1})$	540
Trench width / (m)	0.3
Trenching depth / (m)	0.35
Speed of work/ $(km \cdot h^{-1})$	0.8~1.5

Key component design

The trenching disc is an important component of the trenching assembly, and the structural design parameters of the trenching disc determine the trenching depth and width, while also significantly affecting the power consumption and stability of the trenching process. Currently, in the design of trenching discs that can meet the requirements for trenching depth, single discs are mostly used, which makes it difficult to ensure the trenching width. Therefore, based on the single-disc trenching disc, a dual-disc trenching disc has been designed, which can better meet the requirements for trenching width and effectively achieve soil ejection *(Pingyuan et al.,2017)*. The main design parameter is the diameter D of the trenching disc.

The disc diameter D is the main parameter of the trenching machine's trenching disc, which has a significant impact on the soil ejection distance, power consumption, transmission form, and overall machine size of the trenching machine. Currently, in China, the general empirical formula for the design of the size of the rotating trenching machine disc is based on literature *(Xue et al., 2018)*.

The diameter of the trenching machine disc is:

$$D = (1.2 \sim 1.4)H \tag{1}$$

where:

D—Cutterhead diameter, [mm];

H—Trenching depth, [mm].

Based on the working requirements for deep fertilization trenching in orchards and the design requirements of the project, the minimum trenching depth is about 30 cm, and the maximum is about 40 cm. According to formula (1), the range of the disc diameter is 360 mm to 560 mm.

The diameter of the trenching disc has a significant impact on the power consumption of trenching. Under the premise of meeting the minimum trenching depth of 30 cm, the smaller the diameter D of the trenching disc, the less power is consumed for trenching. Therefore, to ensure that the trenching disc cuts the soil evenly and can throw the cut soil blocks onto the trench surface with less power consumption, the trenching disc is designed as a double-disc type. The diameter of the designed trenching disc is selected to be 430 mm. To reduce the mass of the trenching disc and lower the overall power consumption, the trenching disc is processed into a circular ring shape, as shown in Figure 2.

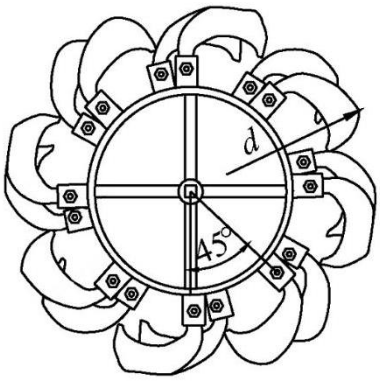

Fig. 2 –Structure diagram of stepped trenching cutter

The structure and arrangement of the trenching blades have a significant impact on the performance of the trenching machine. Currently, the main structural forms of trenching blades used for trenching are chisel blades, right-angle blades, and curved blades. The selected trenching curved blades have a wider cutting face width than the standard rotary tilling curved blades of the national standard, which can effectively carry soil and have good soil ejection performance. To ensure the stability of the trenching machine and the continuity of soil cutting, each layer of the double-disc trenching blade disc is evenly equipped with 8 trenching blades. The installation positions of the trenching blades on adjacent discs are staggered by 45°. This stepped trenching blade disc is equipped with a total of 16 trenching blades, which are fixed to the blade seats on the edge of the trenching blade disc by bolts. After the installation of the trenching blades, the rotating radius R of the blade disc with the trenching blades installed is determined to be 385 mm.

The JC-28 self-propelled small orchard trenching machine of Jingchi brand consumes a power of 6.98 KW when the trenching rotational speed is 500 r·min^{-1}, the forward speed is 1.0 km/h, and the trench depth is 0.15 m. In contrast, under the same working requirements, the designed self-propelled multi-functional trenching and fertilizing machine consumes a power of 5.96 KW, saving 14.6% of the power consumption. However, considering the differences in the experimental environment, the specific values may deviate.

Three-position design and strength analysis of the tool

First, a 3D scanner is used to scan the rotary tilling blade to establish an accurate model of the rotary tilling blade, as shown in Figure 4. The camera resolution of the 3D scanner is 1280×1024 pixels, with a scanning accuracy of 20 micrometers and a scanning speed of 1.3 seconds per frame. The front and back sides of the rotary tilling blade are scanned to obtain the models of both sides, as shown in Figure 5. The scanned models of both sides are imported into the software Geomagic Studio 12 for model stitching and merged into the final complete model, as shown in Figure 6.

Fig. 4 – Scanning Process with COM1M-12 Type Grating 3D Scanner

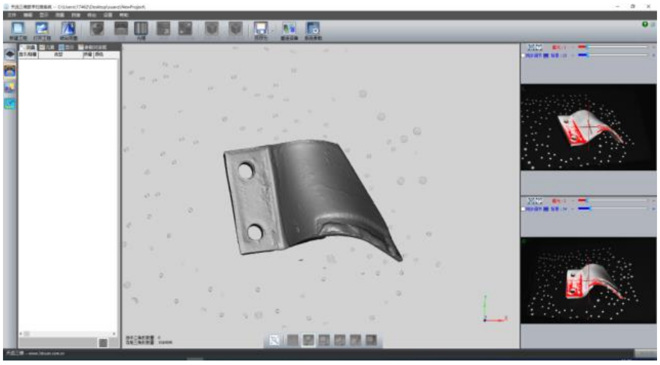

Fig. 5 – Scanned Single-Sided Model

The 3D model of the rotary tilling blade merged by Geomagic Studio 12 is preprocessed using SolidWorks 3D software. In the Start menu, execute the "ANSYS21.0—Workbench" command. The working load of the rotary tilling blade can be determined according to literature (*Mariem, 2018*), with the load magnitude being 500 N. Based on the above force analysis, the load is uniformly applied to the rotary tilling blade. A new material is added in the engineering data properties, and the new material name "65Mn" is entered. The specific material parameters are shown in Table 2. Then, meshing is carried out. The mapping meshing method is adopted to mesh the irregular rotary tilling blade model. The meshing situation of the rotary tilling blade is shown in Figure 6. Since the blade edge of the rotary tilling blade is the first to be subjected to force, it is necessary to check whether the deformation and stress of the rotary tilling blade meet the design requirements, providing a reference for subsequent optimization and improvement.

Table 2

Simulation Experiment Parameters of 65Mn Steel

Material Properties	Numeric value
Elastic Modulus / (kPa)	$2*10^8$
Poisson's ratio / %	0.3

Soil moisture content / %	16
Yield strength / (kPa)	$7.85*10^5$
Tensile strength / (kPa)	$9.8*10^5$
Mass density / (kg*m³)	$7.81*10^3$

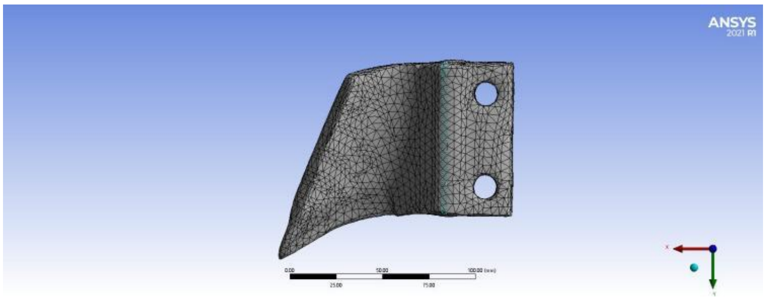

Fig. 6 – Mesh Division of Rotary Tilling Blade

As shown in Figure 7, it is the strength cloud map of the rotary tilling blade.

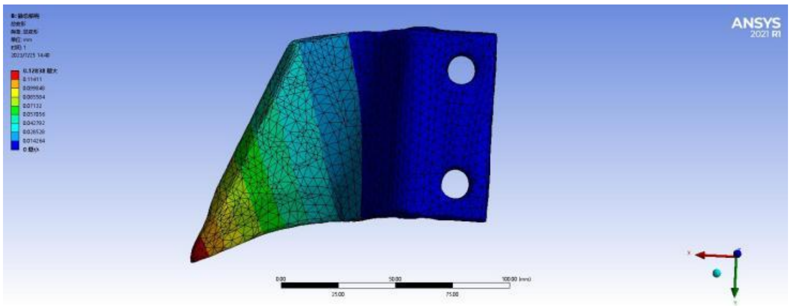

Fig. 7 – Stress Cloud Map of the Rotary Tilling Blade

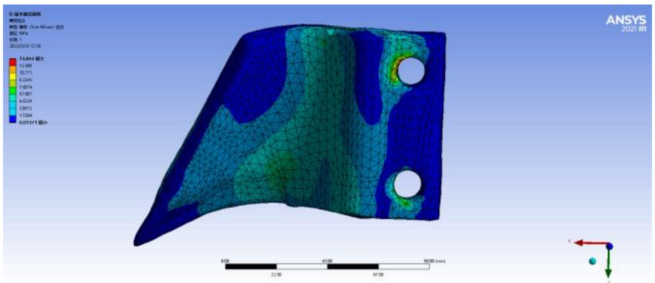

Fig. 8 – Displacement Variation of the Rotary Tilling Blade

From Figure 7, it can be seen that the maximum stress of the rotary tilling blade is 55.48 MPa, which is located at the lower edge of the blade. The reason for this is that the lower edge of the rotary tilling blade is the first to come into contact with the soil. In addition, significant stress also occurs at the mounting hole and the position of the secondary cutting edge, with an average stress of 30 MPa, which is less than the allowable stress of 300 MPa for 65Mn steel. The displacement variation at the mounting hole and the handle of the rotary tilling blade also leads to relatively large deformation, and the average deformation meets the requirements. The maximum displacement of the rotary tilling blade occurs at the blade edge and the upper half, with the maximum displacement being 0.4 mm. There is also obvious deformation at the mounting hole and the handle position, which is due to the stress concentration at the mounting hole, and the average deformation is 0.38 mm. Based on the above analysis, the rotary tilling blade meets the design requirements.

The primary function of the soil deflector plate is to arrange the soil thrown up by the trenching blades in an orderly manner on the right side of the trench, preventing the soil from re-entering the trench and affecting the quality of the trenching. The soil deflector plate mainly consists of an arc plate, side straight plate, flexible plate, and fixed installation square tube, as shown in Figure 3. When the trenching blade disc cuts the soil, the soil is thrown up at a certain speed along with the rotation of the disc. At this moment, the soil strikes the arc plate, and further breaks and falls under the impact of the arc plate. To ensure that the soil is arranged in an orderly manner on the right side of the trench and to reduce the overall weight of the machine, a flexible plate is installed on the right side of the arc plate.

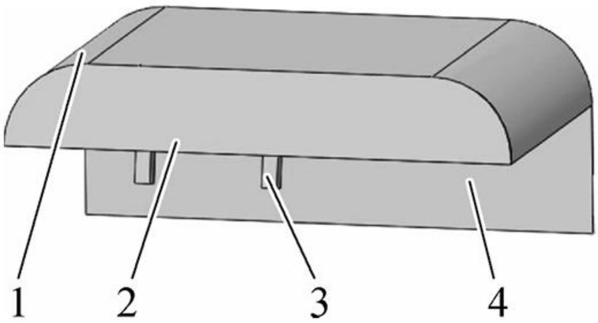

Fig. 3 – Structure diagram of diversion cover
1. Arc Plate; 2. Side Straight Plate; 3. Fixed Installation Square Tube; 4. Flexible Plate

Field experiments and analysis of results

Based on the relevant agronomic requirements for trenching in orchards, this paper designed a double-disc trenching device and carried out relevant simulation experiments. To verify whether the prototype can meet the agronomic requirements for trenching in orchards, trenching tests were conducted at Shandong University of Technology in 2023. On the day of the test, the weather was sunny with a light breeze, and the temperature was 16°C. A relatively flat area was selected at the test site for the trenching test. During the test process, the blade thickness was 6 mm, the depth of cut was 30 mm, and the cutting speed of the blade was 7.7 m/s. The test mainly involved equipment such as tape measures, speedometers, computer data acquisition systems, TJSD 750 firmness meters, and cutting rings. The test conditions are shown in Table 3.

Table 3

Test conditions

parameter	numeric value
Test site（Length * Width）/（m*m）	50*40
Test the terrain of the site in terms of slope	flat
Soil moisture content/%	16
Ambient temperature/℃	17
Soil density / (kg*m³)	2190
Soil compactness / (kPa)	1342

During the trial process, the self-propelled multi-functional orchard trencher is suspended on the orchard crawler multi-functional machine. The operation is stable and the work is safe and reliable during the trenching project, which allows for better trenching and soil-throwing operations. At the same time, the trencher can be raised and lowered by manipulating the orchard crawler multi-functional machine to meet the depth requirements for trenching. As shown in Figure 8.

Fig. 9 – Field Experiment

To inspect the stability of the trenching depth of the trencher, measurements were taken at five points along the direction of travel during two cycles of the machine's operation, as shown in Figure 10. The test data for the trenching depth are presented in Table 4.

Table 4

Measurement results of trenching depth

Depth/m	Test point 1	Test point 2	Test point 3	Test point 4	Test point 5	Average depth
Itinerary 1	0.304	0.325	0.318	0.329	0.316	0.317
Itinerary 2	0.321	0.318	0.305	0.309	0.327	

Fig. 10 – Trenching depth measurement

Both the trenching width and the trenching depth were measured at the same measuring point. The distance between the two sides of the trench was measured with a ruler, and this distance was the trench width, as shown in Figure 11. The measurement results of the trenching width are presented in Table 5.

Fig. 11 – Trenching width measurement

Table 5

Measurement results of trenching width

Width/m	Test point 1	Test point 2	Test point 3	Test point 4	Test point 5	Average width
Itinerary 1	0.305	0.304	0.304	0.308	0.306	0.307
Itinerary 2	0.307	0.308	0.306	0.308	0.310	

The formula for the trench - depth stability coefficient is:

$$S = \sqrt{\frac{\sum_{i=1}^{n}(h_i - h)^2}{N-1}} \tag{2}$$

$$V = \frac{s}{h} \times 100\% \tag{3}$$

$$U = 1 - V \tag{4}$$

In the formula:

h_i—represents the trenching depth at the ith measuring point, in mm;
N—represents the total number of measuring points within the travel distance, and N = 10;
h—represents the average value of the trenching depth, in mm;
s—represents the standard deviation of the trenching depth, in mm;
V—represents the coefficient of variation of the trenching depth, in %;
U—represents the stability coefficient of the trenching depth, in %;

The calculated stability coefficient of the trenching depth U = 97.2%.

To further verify the working performance of the trencher, the main performance indicators of the trencher, including trench width, depth, and operating speed, were measured according to the Chinese agricultural industry standard "NY/T740—2003 Field Trenching Machinery Operation Quality"*(Liufang and Peng, 2007)*. The results are shown in Table 6. The calculated stability coefficient for the trenching depth is 97.2%, which complies with the Chinese agricultural industry standard that the stability coefficient for trenching depth should not be less than 80%, indicating good trenching quality.

Table 6

Experimental performance result

parameter	Design values	Test results
Trenching depth/m	≥0.3	0.317
Trench width/m	≥0.3	0.307
Speed of work/（km·h^{-1}）	0.8~1.5	1.2

Based on Table 5 and the experiment, the trencher, operating at a forward speed of 1.2 km/h, achieved a trench depth of 31.27 cm and a width of 30.5 cm. Both the depth and width of the trench, as well as the operating speed, meet the design requirements. Additionally, the depth of the trench can be controlled by the hydraulic lifting device of the orchard multi-functional machine, which can be adjusted according to actual needs. This can effectively satisfy both the design requirements and the horticultural demands of the orchard *(Jiqiang et al., 2021)*.

Control experiment design

Experimental analysis was carried out by comparing with the existing trenching machines *(Kang, 2017)*. After field tests, the comparison results of the power consumption of the double-disc trenching knives and the trench depth stability are shown in Table 7. Compared with the existing trenching machines, the specific productivity and the trenching stability coefficient of the existing trenching machines are 0.45 kJ/kg and 84% - 85% respectively. The specific productivity is the energy consumed for excavating a unit mass of soil within a unit time. For the trenching machine described in this paper, the specific productivity is 0.35 kJ/kg and the trenching stability coefficient is 95.69%. They are respectively reduced by 22.22% and increased by 11.2% - 12.5% compared with those of the existing trenching machines.

Table 7

Comparative test data

Trenching speed / ($r \cdot min^{-1}$)	Forward speed / (km·h-1)	Ditch depth/m	Power consumption / kW		Reduced value / %	Stability coefficient / %		Added value / %
			Existing trenching machines	The designed trenching machine		Existing trenching machines	The designed trenching machine	
400	0.8	0.15	4.95	4.24	14.34	87.73	94.26	6.53
		0.20	6.24	5.51	11.69	88.82	95.34	6.62
		0.25	7.04	6.34	9.94	89.21	96.01	6.80
		0.30	8.59	7.63	11.18	92.10	97.11	5.01
		0.35	10.99	9.98	9.19	92.45	95.75	3.30
Average value			7.562	6.738	11.268	90.062	95.694	5.652

Limiting factors in the field experiment

1) The experimental site was selected in a relatively flat area of Shandong University of Technology. However, the actual orchard terrain is complex and diverse, with different degrees of slopes, differences in soil compaction, and the presence of obstacles. This experimental site cannot fully represent the actual terrain conditions of all orchards, which may lead to certain deviations in the performance of the machine when it is actually applied in different orchards compared to the experimental results. For example, in orchards with larger slopes, the stability of the machine and the control of trenching depth may face greater challenges, and this factor was not fully considered in the experiment.

2) Although the operating speed of the machine reached 1.2 kilometers per hour, the trenching depth was 31.2 cm, the width was 30.5 cm, and the trench depth stability coefficient was 97.2% in the experiment, these performance indicators were measured under specific conditions such as the cutter roller speed (e.g., 400 r/min), forward speed (0.8 km/s), and trenching depth (0.3 m). When these working conditions change, the performance of the machine may be affected. The experiment did not conduct in-depth research on the performance changes of the machine under long-term continuous operation.

In the field experiment of the self-propelled multifunctional trenching and fertilizing machine, although certain achievements have been made, due to the limitations of the experimental site, soil conditions, and other factors, as well as the fact that the changes in machine performance under different working conditions have not been fully clarified, further testing and optimization in a wider range of actual application scenarios are needed to comprehensively evaluate the performance and applicability of the machine.

CONCLUSIONS

1) In response to the development needs of orchard mechanization and the deficiencies of existing trenching machinery, a self-propelled multifunctional orchard trenching machine has been successfully developed. The innovative design of its double-disc trenching disc effectively reduces power consumption while ensuring the trenching depth (reaching 31.2 cm) and width (reaching 30.5 cm), significantly improving the operation efficiency. The operation speed reaches 1.2 kilometers per hour, meeting the requirements of orchard agronomy and industry standards, and strongly promoting the process of orchard mechanization, fulfilling the demand for efficient trenching machinery mentioned in the introduction.

2) The finite element analysis of the rotary tillage knife shows that the maximum stress is 13.84 MPa and the average deformation is 0.01 mm. The location and causes of the maximum deformation are identified, which provides a reference for the selection of tool materials and the improvement of the structure. It ensures the accuracy and continuity of trenching, improves the trenching quality, and guarantees the sustainable operation of the orchard.

3) Field tests show that the performance indicators of the trencher are good. The trench depth stability coefficient reaches 97.2%, meeting the standard requirements. And it performs excellently under specific working conditions, fully verifying the rationality of the design. The high-efficiency operation performance can shorten the trenching time in the orchard, help fruit growers arrange production reasonably, increase fruit output, achieve the research goals of improving orchard productivity and promoting the sustainable development of the orchard, and provide strong support for the development of orchard mechanization.

4) The control experiment comparing with the existing trenching machines shows that the specific productivity of the designed trenching machine is reduced by 22.22%, and the trenching stability coefficient is increased by 11.2% - 12.5%. This further proves its advantages in energy conservation and operation stability,

provides a better choice for orchard mechanized operations, and helps to improve the overall management level and economic benefits of the orchard.

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