Research on a small rice car for Southwest China

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Abstract. According to the special terrain of terraced fields in the southwest, a small integrated rice cart is designed, which consists of rice cutting device, rotating guide device, transmission device, rice beating device and vibrating screen device. The whole device is coordinated and cooperated with each other, which integrates rice cutting, rice feeding, rice beating and rice collection, improves working efficiency, reduces labor intensity and saves manpower and material costs. Rice cutting device, rice beating device, etc. can complete the whole process of rice cutting and collection, and thresh directly, so as to avoid the loss of grains caused by too many intermediate steps. The design of triangular wheel treads makes the rice cart convenient for cross-floor operation and more suitable for terraced terrain. The whole integrated rice cart not only breaks through the constraints of environmental factors such as terrain, but also avoids the complicated process of manual rice harvesting. Moreover, the device is relatively small in size and quality, has strong adaptability, improves the efficiency of harvesting rice, reduces the labor intensity, avoids the loss of seeds caused by intermediate processes such as transportation operations and field operations, and has good energy saving and emission reduction benefits.

1. Project background and research significance

1.1. Project background
In agricultural production and life, farmers’ human resources gradually weaken, and modern agriculture pays more attention to the progress of planting technology and the change of planting methods. However, due to the specific environmental conditions, some terraced fields in Southwest China need to harvest rice by manpower.
Terraces are mainly distributed in hilly areas of south China, belonging to subtropical and tropical monsoon climate, with high temperature and rainy summer and mild and little rain in winter. They are mostly planted on sunny slopes with good soil quality and abundant water sources, mainly planting some crops such as rice. Because the geographical environment of terraced fields is not suitable for the existing large-scale machinery to work, and the current small-scale machinery for collecting rice has relatively weak functions, which can't work across floors and can't meet all functions in the harvesting process, and the machinery and equipment generally have the problem of high price, which makes the popularization of machinery difficult.

Based on the above background, we designed a small integrated rice cart for terraced fields in Southwest China. The small integrated rice cart is well adapted to the terrain of terraced fields. The rice cart is small in size, light in weight, strong in mobility, convenient for cross-layer operation, capable of better harvesting operations and improving the working efficiency of rice harvesting. The labor intensity is reduced, and more grain loss during transportation is avoided. Moreover, the device has relatively low cost and good market application value.

1.2. Research significance
Based on the above background, the project team designed a small integrated rice cart for terraced fields in Southwest China. Compared with the current harvesting method, the rice cart has the following advantages:

(1) the gap that the original machinery is difficult to work across floors is filled, and the working range of the rice cart is wider

(2) The device can integrate wheat cutting, wheat grabbing, wheat beating and wheat malting, so that the rice cart has stronger comprehensive performance, optimizes the functions of the original small machinery and makes up for the shortcomings of the original small machinery.

(3) Control the cost of the device, save the cost of manpower and material resources, and make the commercialization of rice more convenient.
This work has strong adaptability, can effectively harvest rice on terraced fields, save labor cost, provide basic parameter direction for rice harvesting in terraced fields, promote the upgrading of rice harvesting mode in southwest terraced fields, and make the commercialization of rice in southwest terraced fields more convenient.

2. Research contents and objectives of the project

2.1. Research content
(1) Compare and analyze the disadvantages of current manpower collection and why large machinery is not applicable, show the adaptability and flexibility of small machinery, reduce the cost of equipment and improve the user acceptance.
(2) According to the special geographical environment and existing collection methods of terraced fields in Southwest China, a suitable collection device is designed to realize the whole process of rotating collection, threshing guidance, threshing collection and secondary vibrating screen collection of the small integrated rice cart.
(3) The design of the internal structure of the device, how to realize the integration of rice cart functions and cross-layer collection, and complete the control module so that the device can realize the braking when jumping layer operation.

2.2. Research objectives
(1) Rice harvesting and collection can be realized through the flow of the whole device;
(2) Cross-layer operation of the device is realized by designing the walking mode of the device;
(3) The device can realize the corresponding functions of rice cutting, threshing and storage.
(4) The cost of the device is reduced, so that the device has better market application value and wide market acceptance.

3. The implementation plan of project research and the research methods and technical routes to be adopted

3.1. Overall scheme
The whole rice cart is composed of rice cutting device, rotating guide device, transmission device, threshing device and vibrating screen device. First, the rice is cut by the rice cutting device, then guided to the transmission device by the rotating guide device, and then transported to the threshing device by the transmission device. The high-speed rotating metal cylinder strikes the rice, which makes the rice fall off well, and takes the remaining rice stalks out of the threshing device itself, and the vibrating screen device vibrates again to improve the collection rate. The design of triangular crawler wheels can greatly improve the ability of the rice cart to walk on flat ground or climb across floors. The modules of the whole device cooperate with each other to realize the functional integration of the rice cart, improve the harvesting efficiency and have good benefits.

Figure 3. Overall schematic diagram of device
The work flow is shown in the figure

![Figure 4. Overall work flow](image)

First, the rice is cut by the cutting device, and the rotating guiding device can guide the rice to the conveying device, and then the conveyor belt conveys the rice to the threshing device for threshing, collecting the beaten rice grains for the first time, and vibrating the discharged rice straw, so as to collect some rice grains remaining due to splashing and other reasons for the second time. Collect twice to ensure a higher collection rate and avoid waste.

3.2. Research methods and technical routes

3.2.1. Rice cutting device. The rice cutting device is mainly composed of a moving knife part and a fixed knife part. In the fixed knife part, the blade is fixed to the beam by bolts. In the moving knife part, the moving blade is riveted to the knife bar by rivets, and the rice is cut by the reciprocating movement of the moving knife. When the moving knife and the fixed knife are not in the same plane, the fixed knife connected by bolts can be leveled by adding shims, so that the fixed knife and the moving knife are in the same plane. In a working cycle, the moving range of the moving knife is between the fixed knives on both sides, which makes the knife surfaces move on a plane, protects the knife, ensures a larger working space for the cutting knife, and improves the harvesting rate.
3.2.2. Rotating guide device. The rotating wheel is used for guiding the cut paddy to the transmission device by rotating after the paddy is cut by the cutting device. It is important to adjust the height, front and back of the rotating wheel. If the reel is too high, it will cause the grain to fall off and increase the blow loss. If the reel is too low, it will cause the reel to belt or twine.

3.2.3. Transmission device. The newly cut rice is carried on the conveyor belt due to inertia and directly transported to the upper part of the threshing device through the conveyor belt, so that rice ears and rice stalks are fully separated when passing through the threshing cylinder. Due to the continuous rotation of the threshing device, the threshed rice stalks will not stay too much, but will be taken out of the device, and the rice stalks will be output by the following modules, thus providing space for the next rice to be threshed and realizing the continuity of rice threshing.

3.2.4. Padding device. Introduction of rice threshing device. The rice threshing device is mainly composed of a rice threshing device, a protective shell, a motor and the like, wherein the rice threshing device is a cylindrical working surface with a fixed tooth shape to repeatedly impact and rub rice, the protective shell can prevent rice grains from splashing, collect more efficiently and improve the collection rate, and the motor mainly provides certain power.

3.2.5. Rice beating process. Its working principle is that in a working space with certain technical requirements on the inner surface, the rice grains are hit by a metal cylinder rotating at high speed, so that the rice grains repeatedly collide and rub with the tooth-shaped working surface fixed on the cylinder surface, thus causing the rice grains to fall off from the rice straw. There is a shell on it, which can prevent the splash of rice grains and make them better collected. After threshing the rice in the working space, the continuous movement of the conveyor belt and the continuous rotation of the
threshing device will make the rice straw continue to advance and be discharged through the vibrating sieve, while the beaten rice grains will flow down into the detachable storage box.

3.2.6. Vibrating screen device. The vibrating screen module is aimed at threshed rice straw. However, some rice grains are splashed or threshed insufficiently. Under the action of the vibrating screen conveyor belt, some left rice grains can be collected while the rice straw is discharged, which improves the collection rate of rice grains and the collection efficiency of the whole device.

3.3. Exercise device

3.3.1. Walking scheme design.

According to the practical conditions that the land on the terrace surface is very soft and uneven, the designed triangular wheel shoe can adapt to the complex and changeable environment of the terrace, realize the efficient and stable operation of the rice cart, and improve the moving speed of the rice cart; On the other hand, when encountering a large pit or slope, the lunar rover can switch modes freely, so that the crawler stops immediately, and the motor provides a large force to realize a series of obstacle-crossing actions, such as turning over and crossing the slope, with the help of human beings, which can make the rice rover have better climbing ability when working on terraces.

3.3.2. Cross-layer principle. The middle motor is used to provide greater horsepower for the rice cart. When the rice cart encounters a large slope, the crawler stops at random under the control of the control module, locking the transmission shaft, forcing the triangle wheel to turn over and cross the slope, which can realize the upward or downward layer changing work of the rice cart and greatly improve the ability of the rice cart to cross the slope.

3.3.3. Comparison of obstacle crossing modes. At present, there are two main moving modes of rice cart: crawler movement and wheeled movement.

Crawler-type mobile system has good obstacle-surmounting performance, strong adaptability and long service life. Crawler-type mobile system has extremely low requirements for obstacle-surmounting, strong obstacle-surmounting ability, good climbing performance, and is suitable for driving on rugged ground, with wide adaptability and high movement efficiency. Its disadvantages are poor flexibility and adaptability, the mechanism of crawler-type mobile system may be complex, and motion analysis and control may be difficult.

The wheeled mobile system has considerable advantages in relatively flat terrain, and its control is simpler than that of the legged mobile system. At present, most of the mobile systems of planetary exploration vehicles tend to be designed as wheeled mechanisms. Wheeled mobile movement is fast and stable. Although it is suitable for gentle environment and has poor obstacle-crossing ability, a suitable suspension system needs ingenious design to adapt it to uneven terrain. Compared with other obstacle-surmounting methods, wheeled obstacle-surmounting has the advantage of high efficiency, but it has a big defect of poor adaptability and high requirements for environment.
3.3.4. **Damping design.**

![Spring damping device](image)

**Figure 9. Spring damping device**

The shock absorption module adopts spring shock absorber, in order to reduce the vibration and impact of the rice cart on the road during the movement and ensure the stability of the car body and its working device. The shock absorber is assembled on four wheel shoes, and springs are used to achieve shock absorption.

3.3.5. **Control module.** This control device is mainly used when the whole rice cart needs to go up a step, because there are some stone walls or soil ridges at the edge of terraced fields to prevent soil erosion, so when the rice cart needs to change floors, the control module can judge and lock the triangle wheel shoe to turn the rice cart up, thus realizing the more convenient change of floors without destroying the original design for water and soil conservation.

In order to meet the design requirements, the control module consists of a single chip microcomputer and an external detection circuit. The module detects the working current of the motor by designing a circuit, judges whether the triangle wheel encounters great resistance when working, and feeds back the working state of the triangle wheel to the MCU system by external interruption. As shown in fig. 10, U1A is an LM358 operational amplifier, which is used as a voltage comparator in the detection circuit to detect the voltage drop Ur on the current sensing resistor r connected in series with the motor. R1, LED1 and 5K multi-turn precision trimming resistor R3 constitute a voltage reference circuit. Before the rice cart works, the resistance value of R3 can be adjusted by knob to change the action sensitivity of the detection circuit. D1 and reset switch K1 form a self-locking circuit to ensure that the motor can stop working reliably; 4. J1 is a 12V small DC relay, driven by SS8550 medium power PNP triode, which is used to isolate the control circuit from the working circuit of the motor, and to control the on-off of the motor.

![External detection circuit](image)

**Figure 10. Schematic diagram of external detection circuit**
When the 12V motor in the triangle wheel can't continue to run due to great obstacles, the current in the circuit will increase obviously, which will lead to an increase in the voltage drop on the current sensing resistor, and make the LM358 output high level to turn off the SS8550 and disconnect the relay. At the same time, the rising edge signal generated when LM358 outputs high level is captured by the single chip microcomputer, which enables the motor to brake. After the triangle wheel passes through the obstacle, the microcontroller switches on the reset switch again to restart the motor.

4. Innovation of the project
This project has the following innovations:
(1) The design of triangular crawler wheel makes the rice cart have better environmental adaptability, which can improve the movement ability and climbing ability of the rice cart at work;
(2) The overall structure of the rice cart is reasonable, each module can be coordinated with each other, which is more suitable for intensive production. It can integrate rice cutting, transmission, threshing and collection, so that the rice cart has stronger comprehensive performance;
(3) The device improves the working efficiency of rice harvesting, reduces the labor intensity, avoids more grain loss in the process of transportation, makes the commercialization of rice more convenient, and fills the gap of the small-scale device of terraced fields in the southwest;

5. Research basis and feasibility analysis of the project

5.1. Research Foundation

| Parameter               | Harvest/mu | Comparison of advantages and disadvantages                  |
|-------------------------|------------|-------------------------------------------------------------|
| Small integrated rice   | 20-40      | High efficiency and strong adaptability to terrain          |
| cart                    |            |                                                             |
| Large harvester         | 100        | High efficiency, large harvest, but more energy consumption |
| Manual harvesting       | 4          | Low efficiency, not in line with the trend of mechanization |

For some large harvesters, the harvesting efficiency is high, but the disadvantages are that they are large in volume and mass, not suitable for the terraced terrain in Southwest China, and the large machinery consumes high energy, and the working frequency is relatively less. Although the manual collection method is the most flexible and consumes less energy, it is too inefficient, which does not conform to the trend of mechanization and intensification, and is not conducive to the commercialization of rice. However, the small integrated rice cart has certain flexibility, can change floors conveniently, and has strong adaptability to terrace terrain. Compared with the manual harvesting method, the efficiency is improved more. Moreover, the device can realize the integration of harvesting and threshing rice, and has strong comprehensiveness.

5.2. Feasibility analysis
For 100 mu of rice, the oil consumption of large machinery is about 30 liters a day, and the calorific value of diesel oil is $3.3 \times 10^7$ J/L, so the total energy consumption

$$W = qV = 30 \times 3.3 \times 10^7 = 9.9 \times 10^8 J$$

For the small integrated rice cart, it takes about 2.5 days for the same amount of rice, and the power consumption is 5.5kw/h, and the actual energy consumption is about
Because of the loss of energy transmission and the conversion efficiency of 20% to 30%, the conversion rate is 25%, so the total energy consumption

\[ W_{\text{Energyconsumption}} = Pt = 5.5 \times 10^3 \times 2.5 \times 10 = 1.375 \times 10^5 J \]  

\[ W = W_{\text{Energyconsumption}} \div k = 5.5 \times 10^5 \]  

Through calculation, it can be concluded that the small rice cart consumes less energy and has higher benefit.

The device has no complicated mechanical structure, can have a long life cycle, and has better interchangeability, which makes the use of the device more convenient and reliable, and all parts of the whole device can realize effective cooperation and functional integration. The device is mainly based on mechanical structure, supplemented by related circuit control system. The machining methods of mechanical parts are welding, riveting, bolt connection, etc., and the overall structure is firm, which can achieve stable working effect.

![Figure 11. Investigation on price expectation of rice harvester](image)

The device improves the rice harvesting efficiency, reduces the labor intensity of farmers, has strong comprehensive performance, avoids more grain loss during transportation, and has important significance for the development of terraced fields in Southwest China and the protection of ecological environment. This small integrated rice cart overcomes the disadvantages of inconvenient manual collection and interference of large collection machines to ecological environment in the past, and fits the current development trend. Generally speaking, for the ecological environment of farmers and terraced fields in Southwest China, this work has very valuable value, considerable social benefits and can achieve the expected results.

5.3. Stress analysis

5.3.1. Body analysis. The car body is the most stressed support, so the force analysis of the car body is carried out

According to a certain proportion, the working load of the car body is set to be 1000N, and its various stress states are analyzed.
As shown in fig. 12, it can be seen from the analysis results that when the natural frequency reaches the maximum, the stress in the corresponding direction can meet the requirements.

5.3.2. **Automobile spindle analysis.**

As shown in fig. 13, the types and sizes of allowable loads on automobile spindles are also different, generally there are three types, namely static load force, static torque and dynamic torque, and the maximum stress in XY and -XY directions is 35.49MPa.
5.3.3. Axle analysis.

As shown in fig. 14, the maximum stress of the axle in the y direction is 26.55MPa, and the strain values in all directions are at low values.

5.3.4. Shock absorber analysis. Stress analysis is carried out when the shock absorber is under static stress. The stress mainly comes from the impact force and body gravity when the rice cart moves. Now, stress analysis is carried out in all directions of the shock absorber.

According to the data analysis of stress and contact pressure of shock absorber under normal working pressure, the changes are small and in a reasonable state, so the shock absorber structure can bear the load and reduce the vibration amplitude.

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