Design and analysis of the hand-held transplanter riding mechanism

Lu Guang-Hua 1,4,*, Huang Ting-Bo 2, Liu Yan 1, Zhang Rong-Shan 3, Chen Xia 1, Shen Yao-Qi 1

1 Taizhou Institute of Science and Technology of NUST, Taizhou 225300, China
2 Jiangsu Airship Co., Ltd., Taizhou Jiangsu 225300, China
3 Jiangsu Fuma High-tech Power Machinery Co., Ltd., Taizhou Jiangsu, 225300, China
4 Taizhou Continental Zhizi Intelligent Technology Co., Ltd., Taizhou Jiangsu, 225300, China

*Corresponding author’s e-mail: 304853621@qq.com

Abstract: With the scale and mechanization of agricultural planting, rice transplanter is an important mechanical tool in the agricultural field. This design is based on the hand-held rice transplanter as the prototype, designing the riding mechanism of the rice transplanter, and carrying out finite element analysis and design. It achieved good results.

1. Introduction
China is a big agricultural country, and rice is the main food product of China. Rice planting production technology is complex, seasonal changes are large, and labor is huge, but it is also the most important link in rice planting production. For hundreds of years, China has been mainly based on artificial breeding. The urgent demands of the broad masses of peasants are freed from this cumbersome manual labor[1]. With the vigorous development of agricultural mechanization, there are many types of hand-held rice transplanters in China, but most of them do not consider the standing position and comfort of people when they work randomly in the field. In recent years, with the introduction and in-depth study of ergonomics, people have put forward a lot of requirements for the comfort of machine use[2]. In this paper, the structure of the existing hand-held rice transplanter has been improved and optimized, and the ride-up device has been added, which has achieved good results.

2. Structural design of the rice transplanter
The initial structural design of the walk-behind rice transplanter is shown in Figure 1. The entire rice transplanter is not designed to stand for the staff to stand. For machines operating in the field, it is necessary to have a suitable, secure and comfortable ride.
The present invention relates to a stand-up hand-held transplanter riding device, comprising a hooking assembly and an riding mechanism, wherein the hooking assembly is connected with the riding mechanism, the hooking assembly comprises a hanging rod and a floating plate; One end of the rod is fixed on the prior art hand-held rice transplanter[i], and the other end of the hook rod is provided with a hanging pin; the floating plate is fixed on the hanging rod to increase the buoyancy effect; the riding mechanism includes a hanging rod two protruding threads are arranged beside the hanging rod, and the standing device is fixed in the thread; the riding device is composed of a fixing plate, a pedal and a spring; one end of the fixing plate is fixed on the hanging rod, and the other end is connected by bolts and pedals; The position of the pedal is controlled by a spring[6]. The specific structure is shown in Figure 2.

![Figure 2 Hand-held rice transplanter riding stand](image)

3. Design calculation of the pedal in the 3-riding mechanism
The pedal is the main component of the load, and the weight of the staff is mainly concentrated on the pedal. The pedals must have a tread surface, must be safe and reliable, and have a certain anti-slip performance.

3.1 Structural design of the pedal
The structure of the pedal is shown in Figures 3 and 4.

![Figure 3 Two-dimensional pedal diagram](image)  ![Figure 4 Pedal fixed plate](image)

The hanging piece (shown in Figure 5) is fixed on the frame, and the hanging beam is connected by the bolt on the hanging part (as shown in Fig. 6), so that the position of the pedal can be fixed; the hanging beam is connected with the fixing piece (such as Figure 7) is fixed on the floating plate; the fixing plate (shown in Figure 8) is fixed on the hanging beam, and the hanging beam fixes the pedal fixing plate by screws[7], and the fixing plate controls the movable range of the pedal to form a Complete ride.
3.2 pedal strength calculation

The pedal is affected by the gravity of the worker and is bent, which is checked \[ 3,4 \].

The formula for calculating the strength of one-way bending and bending members:

$$\frac{N}{A_n} + \frac{M_x}{W_{nx}} \leq f$$

Formula for calculating the strength of two-way bending and bending members:

$$\frac{N}{A_n} + \frac{M_x}{W_{nx}} + \frac{M_y}{W_{ny}} \leq f$$

In the formula:

- $N$ ---- Axis pressure design value
- $A_n$ ---- Check the cross-sectional area of the net cross-sectional area
- $M_x$, $M_y$ ---- Bending moments in two main planes
- $W_{nx}$, $W_{ny}$ ---- Check the net section modulus of the two main axes
- $\gamma_x$, $\gamma_y$ ---- Sectional plasticity development coefficient of section in two principal planes

In the following three cases, edge yielding is used as the basis for component strength calculation in design, $\gamma_x = \gamma_y = 1$.

1. For components that need to calculate fatigue, there is currently no research on the plastic properties of the section;
2. For lattice members, when the bending moment acts around the imaginary axis, there is little potential for plasticity development due to the absence of solid parts in the abdomen;
3. In order to ensure the width to thickness ratio of the compression flange $13 < b/t < 15$, plastic development is not considered.

Support plate with a span of 0.4 m, subject to uniform load, where the permanent load standard value $q_k = 2kN/m$, the variable load standard values are $q_{1k} = 2.4kN/m$. The overall stability meets the requirements. Try to select the ordinary steel section, the structural safety level is two, then its load combination is as follows:

Standard load:

$$q_0 = q_k + q_{1k}$$

Design load:

$$q = \lambda_0(q_k + \phi \gamma_{c1} q_{k1})$$
γ_0 ---- Structural importance coefficient. Safety level two, γ_0 = 1.0
γ_G ---- permanent load partial coefficient, generally taken γ_G = 1.2
γ_G1 ---- Variable load partial coefficient, generally taken γ_G1 = 1.4
ϕ ---- load combination coefficient, ϕ = 1.0

Standard load:

\[ q_0 = q_x + q_{1k} = 2 + 2.4 = 4.4 kN/m \]

Load design value:

\[ q = 1.0(1.2 \times 2 + 1.0 \times 1.4 \times 2.4) = 5.76 kN/m \]

Load standard value:

\[ q = 1.0(2 + 2.4) = 4.4 kN/m \text{(not including the weight of the beam)} \]

1. Calculate the maximum bending moment
The maximum bending moment under the design load (not counting the weight):
\[ M = q l^2 / 8 = 5.76 \times 0.4^2 / 8 = 0.1152 kN \cdot m \]

2. Select section
Required net section resistance moment:
\[ W_{nx} = M / \gamma_G f = 48.6 \times 10^3 / 1.05 / 215 = 215 cm^2 \]
\[ I_x = 2369 \text{ cm}^4, \quad W_{x} = 237 \text{ cm}^3, \quad I_x/S_x = 17.4 \text{ cm}, \quad t_w = 7 \text{ mm}, \quad g = 0.27 kN/m \]
Add the weight of the support plate and recalculate the maximum bending moment:
\[ M = q l^2 / 8 = (43.2 + 1.2 \times 0.27) \times 3^2 / 8 = 49.0 kN \cdot m \]

3. Intensity check
1. Calculation of bending strength
\[ \sigma = \frac{M}{W_{nx}} = \frac{49 \times 10^6}{237 \times 10^3 \times 1.05} = 197 N \text{ mm}^2 < f = 215 N/mm^2 \]
2. the shear strength check
\[ \tau = \frac{V_s}{I_x t_w} = \frac{1}{2} \left( \frac{45.3 \times 3 \times 10^3}{174 \times 7} \right) = \frac{53.5 N}{mm^2} < f_v = 125 N/mm^2 \]

So, the checking calculations meet the requirements.

4. Pedal design and finite element analysis in 4 riding mechanism
The pedal is the part that the staff stepped on and is the place where the maximum force is required, so the finite element check analysis [3,4] is performed. The three-dimensional design model of the pedal is shown in Figure 9.

To take into account the weight of all people, assume that the weight of the staff is 100 kg, \( G = mg = 100 \times 9.8 = 980 N \), so the bearing on the pedal 980 N. Force. For its idealization, finite element analysis is performed, as shown in Figures 10, 11, and 12.
Figure 10 Strain distribution of the worker standing on the pedal

Figure 11 Static stress distribution of the worker standing on the pedal

As can be seen from Figures 10 and 11, the stress distribution on the pedal is reasonably sized and within acceptable limits.

5. Conclusion
The riding mechanism is an important part of the rice transplanting machine. It mainly includes the floating plate mechanism and the pedal mechanism. Its design and continuous improvement not only promote the improvement of the quality of the rice transplanter, but also solve the standing problem of the staff and meet the human machine. In this paper, not only the structural design of the riding mechanism, but also the calculation of the strength and stiffness and the analysis of the finite element, the design feasibility and the reliability of the use are improved, which has certain guiding significance for the manufacturing and processing of the enterprise.

Acknowledgments
Fund: Taizhou Science and Technology Support (Agriculture) Project (tn201717)

references
[1] Zhao Xiaojun. Hand-held rice transplanter use and maintenance [j]. Agricultural machinery use and maintenance, 2010 (5), 79.
[2] Zhang Jiaqing, Wang Wei. Analysis of vertical feeding mechanism of rice transplanter [J]. Journal of Jinhua Vocational and Technical College, 2002 (3), 41-42.
[3] Zhang Zhiwei. Operational performance and analysis of rice transplanter floating plate [J]. Agricultural Mechanization Research, 1987 (02): 24-28.
[4] Liu Meimei. Design and finite element analysis of main components of small multi-functional field management machine [d], Xi'an: Northwest A&F University, 2011.
[5] Wang Lingguo. Current situation and development trend of rice transplanter [J]. Hunan agricultural machinery: academic edition, 2011.
[6] liu wenhua. Analysis and development forecast of rice transplanter [J]. Hunan agricultural machinery: academic edition, 2009, 36(7): 4-6.
[7] Chen ge. Analysis on the development trend of rice transplanter [J]. Modern agriculture,2014(02):51-52.