A kind of new "dust-free" rice thresher

Jiacheng Li*, Yue Cui, Wenyu Han
Wuhan University of Technology, Hubei, China

*Corresponding author: 283491@whut.edu.cn

Abstract. The project was designed based on air curtain dust control of novel small rice threshing apparatus, mainly involves dust reduction in the working process of agricultural machinery, specifically belongs to the field of agricultural machinery emission reduction. The apparatus is designed feeding modules, threshing modules, dust module, the control module total four modules, means by using a vertical multi-feeding port semi-feeding type of structure, in the while maintaining efficiency reduction rolling straw produced powder dust and realizes dust removal from the source. By adopting the air curtain dust control technology, the dust produced is restrained within the specified range at the first time of diffusion, and further dust control is realized.

1. Introduction
In the southern China region (and other rice-growing areas), mainly rice as for the main food crops. However, based on China's basic national conditions, our country most of the farmers' land more dispersed of, and and many rice fields (such as the Southwest) are located in the foothills of the area is not suitable for large-scale agricultural machinery working, mountain plateau and basins, which will so that these areas of rice harvest can not make use of large combine harvester to complete. After farmers harvest by manual or small machinery, they often need small rice thresher to separate the grain from the stalk.

Rice threshing process, since the threshing drum when compacted straw may produce a large amount of dust or debris, dust, or debris such from the grass clippings discharge groove by wind action gas splash or escape out port. Because these dusts and disintegrating slags are easy to splash or escape under the action of wind, the dust diffused into the air will not only affect people's sight, hinder people's breathing, but also reduce the efficiency of rice threshing; and after the dust is inhaled into the respiratory system also it will further damage harm physical health Kang.

This device aims to realize the dust-free threshing process and protect the health of the operators through the innovation of the mechanical structure and the increase of the air curtain.

2. Research significance
For use in rice thresher dust problems, the most conventional thresher have the following methods (see Table 1) or dusted Dust:
Table 1. Comparison of dust suppression methods of existing threshers in China

| Dust removal method | Applicable agricultural machinery                      | Energy consumption | Limitations of existence                  |
|---------------------|--------------------------------------------------------|--------------------|------------------------------------------|
| Fan method          | Suitable for all kinds of model number of agricultural | Big                | Low efficiency, poor dust suppression effect |
| Bag method          | Small and medium agricultural machinery                 | no                 | Obstruct airflow, low work efficiency     |
| Filter method       | Small and medium agricultural machinery                 | in                 | Frequent replacement, low work efficiency |

After field research and group analysis can be found, rice thresher during the working process dust arising primarily from the crushing mechanism and seismic screening mechanism portion, and the main dust measures (table of existing installations 1) it is produced in the dust, in row wind opening increasing means to prevent their diffusion into the air, but since the conventional thresher threshing is open and has a plurality of outlets, which led to the above-described embodiment dust and dust suppression effect is not obvious, there are still many dispersion of dust into the air.

Based on this, this project designed a new type of small rice thresher. Through the improved design of the threshing structure and the sorting structure, the source dust reduction and air curtain dust control are realized, which can reduce the amount of dust discharged into the air by the device. It can also create a healthy working environment for farmers.

3. Design plan

3.1. Overall device design

The apparatus of the present work flow thresher rice can to be divided into feed module, threshing module and removal module (FIG. 1). The device can be roughly divided into three steps: feeding, threshing, and winnowing according to the device's work flow. During feeding and threshing, the drum is driven by the motor to rotate at a high speed and the feeding shell rotates at a low speed. The air curtain method is used during winnowing. Perform dust control.

![Figure 1. Overall model of the device.](image)

3.2. Feeding module design

![Figure 2. Feeding module.](image)
3.2.1. Feeding shell
The rotating feeding shell is designed as a cylindrical shell. The upper part of the shell is provided with a number of feeding ports in an annular array. A circular slide rail is designed on the base below the feeding shell. A number of rollers are installed at the bottom of the shell, and the rollers can move on the slide rail. The top of the shell is designed with internal teeth that can mesh with the gear of the transmission mechanism, so the gear of the transmission mechanism can drive the feeding housing (the entire feeding module) to rotate slowly.

3.2.2. Slide rail mechanism
The slide rail mechanism is mainly placed outside the bottom of the drum to prevent strong vibration of the feeding module.

3.2.3. Clamping mechanism
The clamping mechanism is set at the feeding port of the feeding shell, which mainly realizes the clamping of the grain straw after feeding, preventing it from being wound into the threshing device by the hitting drum and causing damage, and it is also convenient for farmers to quickly take out the straw. The clamping mechanism is mainly composed of upper and lower clamping leaves, left and right threaded rods, reset racks, driving gears, etc. The mechanism has two working states, namely clamping state and release state:

Clamping mode: After the grain is put in, the threaded rods on both sides rotate, and the upper and lower clamping leaves close inward under the rotation of the threaded rod, thereby clamping the fed grain.

Release mode: After the fed grain is completely threshed, the threads on both sides are re-rotated by resetting the rack and the drive gear, and the upper and lower clamping blades are returned to the original position. At this time, the grain straw has been threshed and can be taken out directly.

3.3. Threshing module design

Grain threshing generally has beat threshing method and card threshing method. After comparison, it is found that the beat threshing block and straw are kept intact. Therefore, this device adopts the principle of beat threshing for threshing. The threshing module mainly includes a beat drum and a hopper, Motor and speed changing mechanism.

3.3.1. Striking roller mechanism
The beating roller is located in the upper part of the device (in the feeding port). The upper part of the beating roller is connected to the motor through the speed change mechanism, and the lower part is connected to the hopper. The bottom of the entire beating roller is located on the slide rail at the bottom of the device.

The beating drum is designed as a round table with a certain taper, the bottom surface of the upper end is small, and U-shaped steel bars are arranged on the arc surface of the round table, and the distance

![Figure 3. Threshing module](image-url)
between the steel bar and the outside gradually decreases with the increase of the radius. The motor drives the main shaft to rotate and drives the drum to rotate at a high speed after passing through the speed change mechanism.

3.3.2. Speed change mechanism
The speed change mechanism is composed of three reduction gears and a small power gear. The four gears mesh with each other as shown in the figure. When the motor is working, by driving the main shaft to rotate, the main shaft drives the small power gear to rotate, and the small gear drives three reduction gears to rotate. Since the number of teeth and radius of the large gear are much larger than the small gear, the mechanism can realize the high-speed rotation of the main shaft to the large The bottom speed of the gear rotates. Since the outer side of the big gear meshes with the top of the feeding shell, it can slowly drive the outer feeding shell to rotate.

![Variable speed gear set](image)

3.3.3. Hopper
The hopper mainly accepts the grains produced by the drum beating and other broken disintegrating slag, blades (theoretically still mainly grains), dust and other substances, and all enter the winnowing module with the help of the hopper.

3.3.4. Threshing module works
When the threshing module is working normally, the ears put through the feeding port are just within the reach of the beating drum. The U-shaped steel strips distributed on the drum are driven by the drum to strike the ears in turn, and the grains are in the process of beating. Medium threshing rice ears. Because the beating drum itself has a certain taper, when the U-shaped steel bar hits the ear of the grain, it will gradually start to strike from the ear to the axis side, and slowly thresh to the outside of the ear. The layer-by-layer threshing method prevents the ears from being broken or the whole grain is involved.

3.4. Winnowing module design
The module is mainly located directly below the threshing module and consists of a winnowing mechanism and an air curtain dust control mechanism. The winnowing mechanism and the air curtain dust control mechanism are located on both sides of the hopper. The module realizes the separation of grain from dust, disintegrating slag, broken leaves, etc. through winnowing, and the disintegrating slag, dust, etc. separated by air curtain prevention and control are raised into the air again.

The module is mainly composed of fan, air curtain pipe, ash storage room, grain outlet, etc.
After removal when particles treated after the mixture grains, disintegrating slag, dust, etc. through the hopper into the threshing module winnowing module, using an air flow fan sustained wind speeds, the use of grain and debris, dust mass and density of Obvious difference, so as to realize that the fan blows the dust and disintegrating slag into the dust control tube of the front air curtain, and the degree of grain deviation is relatively small. The air curtain dust control tube mainly plays a buffering role. The speed of dust gra...
Table 2 Experimental data related to air curtain dust control

| Air curtain jet velocity (m/s) | Narrow slit width (mm) | Dust control effect                        |
|--------------------------------|------------------------|--------------------------------------------|
| 20                             | 6                      | The dust is concentrated                    |
| 15                             | 15                     | Very little dust                            |
| 10                             | 20                     | Very small amount of dust, discretely       |
| 5                              | 25                     | A small amount of dust, but not spread      |
| 0                              |                        | Dust moves freely and continuously spreads  |

Taking into account the wind source and size requirements of the wind curtain of this device, this device uses a wind speed of 5-10m/s and a narrow slit of about 10mm, so the dust control requirements required by the device can be achieved.

5. Benefit analysis

5.1. Dust -benefit analysis

This means the energy saving benefits mainly in that the emission reduction, reduction thresher embodied in the course of dust emissions. The emission reduction benefits are calculated as follows:

Assuming that the device can process grains of mass \( m \) (unit: t) during normal working time \( t \) (unit: h), the grain feeding rate \( v \) (unit: t / h):

\[ v = \frac{m}{t} \tag{1} \]

Suppose the mass of a single plant is \( m_0 \) (unit: kg), and \( N \) plants are processed in total, then:

\[ N = \frac{m}{m_0} \tag{2} \]

When the degree of compaction of a single rice plant is \( p \) (0\(<\( p <\)100\%), the amount of dust generated is \( p q \) (unit: mg).

The dust removal rate achieved by winnowing method is \( \eta \) (0\(<\( \eta <\)1).

The dust leakage rate that still exists in the method of air curtain dust control is \( \lambda \) (0\(<\( \lambda <\)1).

The entire rice threshing process, the device is used in a unit of dust in the air mass diffusion \( x \) (unit: m G) as:

\[ x = mpq(1-\eta+\eta\lambda)/m_0t \tag{3} \]

Here, after consulting relevant information, the relevant parameters of the rice thresher we designed are shown in the following table:

Table 3 Some design parameters of the device

| Parameter meaning                                | Parameter symbol | Design value |
|-------------------------------------------------|------------------|--------------|
| Grain feeding rate                              | \( v \)          | 1t/h         |
| Quality of individual plant                     | \( m_0 \)        | 0.05kg       |
| Degree of rolling                               | \( p \)          | 40%          |
| The amount of dust produced by full crushing     | \( q \)          | 20mg         |
| The average wind election law in addition to the dust efficiency | \( \eta \)     | 94.8%        |
| Air curtain dust leakage rate                    | \( \lambda \)    | 5.1%         |
After calculation, the quality of dust discharged into the air per unit time using this device can be obtained:
\[ x = 7736.628 \text{ mg/h} \]

Similarly, using a similar method, currently on the market the same power ordinary fan dust thresher, "clean" thresher, dust bag machine of dust in the air mass per unit of time within the diffusion follows:

| Types of thresher               | Dust emission in 1 hour (mg) | This means the same ratio of rise rate |
|--------------------------------|-----------------------------|-------------------------------------|
| Ordinary fan dust removal      | 24648                       | 68.63%                               |
| thresher                      |                             |                                     |
| Bag dust collector             | 30960                       | 75.03%                               |
| "Dust-free" Thresher          | 23488                       | 67.16%                               |

After compared with currently available on the market several rice thresher better dust, dust removal effect of the present apparatus can be seen to some extent, preferably to a conventional rice thresher.

6. Conclusions

Due to the advantages of high threshing efficiency and less dust generated during threshing, the device can be widely used in the threshing work of rice farmers in hilly areas, plateau mountainous areas, basins and other areas not suitable for large-scale agricultural machinery. In this paper, a new type of dust-free rice thresher was designed, its structure and principle were introduced, and its good dust removal performance was described. At present, China vigorously promotes agricultural mechanization, and emphasizes energy conservation and emission reduction in agricultural production. The design of this device can enable farmers to have a healthier threshing environment, and make a certain contribution to China's agricultural mechanization and agricultural energy conservation and emission reduction.

Acknowledgments
National innovation and entrepreneurship training program for college students+S202010497078.

References
[1] Meng Fanjiang. Current situation and problem analysis of the use of grain thresher in China [J]. Agricultural Machinery Use and Maintenance , 2017 (07): 34.
[2] Deng Xiaoming, Zhang Lei. Talking about the structure and use of grain thresher [J]. Sichuan Agriculture and Agricultural Machinery , 2012(03):32.
[3] Meng Fanjiang. Current situation and problem analysis of grain thresher in China [J]. Agricultural Machinery Use and Maintenance, 2017, (7): 34. DOI: 10.14031/j.cnki.njwx.2017.07.023.
[4] Li Yucheng, Liu Jian. Numerical simulation of air curtain dust control based on gas-solid two-phase flow [J]. Journal of Liaoning Technical University ( Natural Science Edition ), 2012, 31(05): 765-769.
[5] Huang Xu, Zhao Mian. Research on air curtain dust control device based on plane turbulent jet [J]. Journal of Longdong University , 2017, 28(03): 85-89.
[6] Sun Dong. Winnowing scheme for separation of expanded tobacco stems [A]. Shanghai Tobacco System 2005 Excellent Academic Paper Collection [C]: Shanghai Tobacco Society , 2005:5.