DESIGN AND EXPERIMENT OF 5TG-85 BUCKWHEAT THRESHER
/
5TG-85 型荞麦脱粒机的设计与试验

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ABSTRACT
A 5TG-85 buckwheat thresher was designed to solve the problems of low mechanical harvesting level of buckwheat in hilly and mountainous areas, high work intensity of threshing and grain cleaning, and few available machines and tools. The machine adopts rasp bar-nail tooth combined threshing device and air screen cleaning device, which can complete threshing and grain cleaning at one time. In the paper, the structure, transmission system and key components of the thresher were designed, the parameters were calculated, and the threshing performance test was carried out. The results show that when the moisture content of buckwheat stem is 75%, the moisture content of grain is 17%, and the grass grain ratio is 4.4, when the rotating speed of the threshing drum of the thresher is 500r/min, the threshing gap is 10mm, the feeding amount is 0.8kg/s, the air speed of suction mouth is 8m/s, and the vibration frequency of vibrating screen is 25.12 rad·s^{-1}. The crushing rate Z_p is 1.13%, the impurity content Z_z is 2.73%, the unthreshed loss rate S_w is 0.07%, the entrainment loss rate S_j is 1.77%, the cleaning loss rate S_q is 1.96%, the spatter loss rate S_f is 0.62% and the total loss rate S is 4.42%. The threshing effect is good, which meets the requirements of buckwheat threshing. The development of this machine will reduce the manual cost of buckwheat threshing, improve the work efficiency, improve the mechanized harvest level of buckwheat, and promote the development of buckwheat industry.

摘 要
针对丘陵山区荞麦机械收获水平不高，脱粒和清粮作业工作强度大，可用的机具少等问题，设计了一种 5TG-85 型荞麦脱粒机。该机采用纹杆——钉齿组合式脱粒装置和风筛式清选装置，可一次完成脱粒和清粮作业。文章对该脱粒机的整机结构、传动系统和关键部件进行了结构设计和参数计算，并开展了脱粒性能试验。试验结果表明，当荞麦茎杆含水率为 75%，籽粒含水率为 17%，草谷比为 4.4 时，调整脱粒机的脱粒滚筒转速为 500 r/min、脱粒间隙为 10 mm、喂入量为 0.8kg/s、吸杂口风速为 8m/s、振动筛振动频率为 25.12 rad·s^{-1} 的条件下，脱粒机的破碎率 Z_p 为 1.13%、含杂率 Z_z 为 2.73%、未脱净损失率 S_w 为 0.07%、夹带损失率 S_j 为 1.77%、清选损失率 S_q 为 1.96%、飞溅损失率 S_f 为 0.62%、总损失率 S 为 4.42%，脱粒效果良好，满足荞麦脱粒要求，可以进行脱粒作业。本机的研制将减少荞麦脱粒环节的人工作业成本高，提高工作效率，提升荞麦机械化收获水平，促进荞麦产业的发展。

INTRODUCTION
Buckwheat belongs to the buckwheat genus of Polygonaceae *(Gim é Nez Bastida, 2015; Ye S.B. et al, 2021)*. It is an annual herb and belongs to small-scale miscellaneous grain crops. It is mainly distributed in alpine or hilly mountainous areas in China *(Xiang D.B. et al, 2013).* It is internationally recognized as a multi-purpose miscellaneous grain cash crop with nutrition, health care, medicine, feed and honey *(Zhang R.M. et al, 2016)*. It has the growth characteristics of cold tolerance, drought tolerance, barren tolerance, strong stress resistance and short growth period. It is of great significance in stable grain income, crop rotation, soil fertilization and regulation of people's diet in mountainous and dry lands *(Xu B., 2021; Hang X.N. et al, 2018).* Because the topography of its growing area is mainly mountain or sloping land, the large-scale modern combine harvester is very difficult to work, resulting in a low level of buckwheat harvest mechanization, which affects the development of buckwheat industry *(Ji J.T. et al, 2016; LU Q. et al, 2020)*. Threshing and grain cleaning are the main links in the harvest process, therefore it is of great significance to develop a small buckwheat thresher suitable for use in hilly and mountainous areas or family farms.

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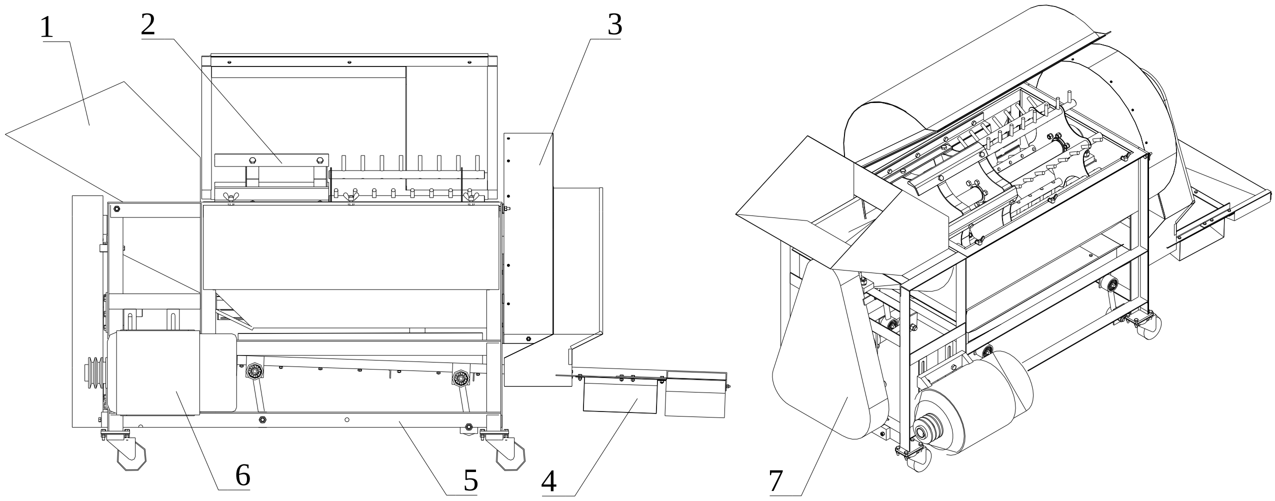
In recent years, some scholars have studied and explored the buckwheat threshing device or harvester, and made some progress. *Zhang Kunkun* designed a buckwheat harvester, studied and analysed the layout of the main working parts, and established a multi-body dynamic model of the whole machine layout. The results show that when the slope increases to 30°, the tipping angle of the harvester reaches the limit *(Zhang K.K., 2019)*. *Huang Xiaona* improved the design of a shear-transverse axial flow threshing device and carried out bench tests *(Hang X.N., 2020)*. *Dang Weilong* improved and designed a double-drum buckwheat threshing device, the front drum is a bar drum, and the rear drum is a combined drum of bar and rod tooth, and the bench test is carried out *(Dang W.L., 2018)*. *Wang Jiawei et al*. designed an internal and external drum buckwheat separation device, and analysed the overall situation of the threshed materials, the content of each component in the mixture and the axial distribution along the threshing drum *(Wang J.W. et al, 2019, Wang J.W. et al, 2020)*. *Morishita T*. and *Suzuki K*. analysed the loss rate of combine harvester in the process of harvesting buckwheat *(Morishita T. et al, 2012)*.

In order to solve the problem of mechanized harvesting of buckwheat in small plots in hilly and mountainous areas, a smaller buckwheat threshing machine is developed in the paper. It adopts rasp bar - nail tooth combined threshing device and air-sieve type grain cleaning device, which integrates threshing and grain cleaning as a whole. It can greatly reduce the labour intensity, improve the production efficiency and improve the mechanized harvest level of buckwheat.

MATERIALS AND METHODS

Overall structure design and working principle

- **Overall structure and working principle**



(a) *(b)*

Fig. 1 - Schematic diagram of the whole machine structure

a) Upright view; b) Axonometric drawing

1. Feeding device; 2. Threshing device; 3. Fan; 4. Reciprocating vibrating screen; 5. Rack; 6. Motor; 7. Transmission system

As shown in figure 1, 5TG-85 buckwheat thresher is mainly composed of feeding device, threshing device, fan, reciprocating vibrating screen, rack, transmission system, etc. During operation, the buckwheat plant enters the rasp bar-nail tooth combined threshing device from the feeding device. Under the combined action of the threshing drum and the concave plate, the buckwheat grain and stem are separated through its impact, rubbing and impact. The grain and part of the miscellaneous residue fall on the reciprocating vibrating screen and enter the air screen cleaning system.

During the conveying process of vibrating screen transportation, the light miscellaneous residue and chaff on the screen surface are sucked in and blown out of the machine through the air suction of the centrifugal fan, and the clean grains on the sieve surface are collected into the material-bearing device. In the process of threshing, long stalks and residual ears are gradually transported to the discharge outlet, and discharged out of the machine.

The technical parameters of the whole machine structure are shown in Table 1.

Table 1

Technical parameter of 5TG—85 buckwheat thresher

Project		Parameters
Matching power [kW]		5.5
Motor type		Y132M-4
Size (length × width × height) [mm × mm × mm]		2160×878×1380
Total weight [kg]		300
Feeding quantity [kg/s]		0.8
Transmission type		Belt drive
Threshing device	Structural pattern	rasp bar-nail tooth
	Drum diameter [mm]	450
	Drum speed [r/min]	500
	Speed regulating device	APH- 5 continuously variable transmission
Vibrating screen	Structural pattern	Reciprocating vibrating screen
	Installation angle [°]	2
	Vibration frequency [rad·s^{-1}]	25.12
Grain cleaning fan	Cleaning type	Suction type
	Structural pattern	Centrifugal type
	Leaf number [set]	3
	Rotational speed [r/min]	1036

- **Design of transmission system of the whole machine**

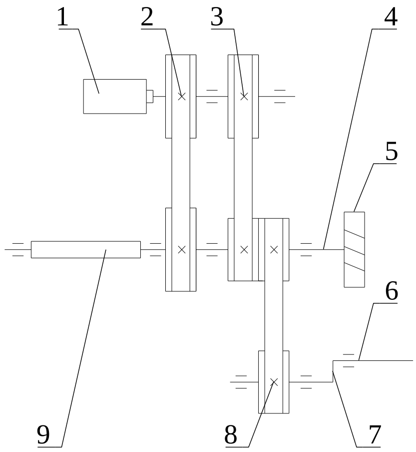


Fig. 2 - Schematic diagram of the whole machine transmission

1. Motor; 2. Belt drive of threshing device; 3. Belt drive of centrifugal fan; 4. Drive shaft of centrifugal fan; 5. Centrifugal fan; 6. Reciprocating vibrating screen drive connecting rod; 7. Eccentric device; 8. Reducer belt drive; 9. Threshing drum drive shaft.

As shown in figure 2, the power of the whole machine comes from the motor. The motor transfers the power to the threshing device and the cleaning device through belt transmission, because the connecting force between buckwheat grain and stem is small and it is easy to thresh. The rotating speed of the threshing device is low, while the rotating speed of the air screen cleaning system is high. Therefore, in the design of the transmission system, the driving shaft of the threshing device and the driving shaft of the centrifugal fan are arranged coaxially and driven separately. The driving shaft of the threshing device adopts the hollow shaft, and the driving shaft of the centrifugal fan adopts the solid shaft. The solid shaft is installed inside the hollow shaft, to realize coaxial and independent transmission. The structure is shown in figure 3. Due to the low vibration frequency of the reciprocating vibrating screen, the power transmitted by the fan drive shaft needs to be transmitted through the reducer belt and decelerated by the reducer output shaft, and through the eccentric device, the power is transferred to the reciprocating vibrating screen drive connecting rod, the rotary motion is transformed into reciprocating linear motion, and the reciprocating motion of the vibrating screen is realized.

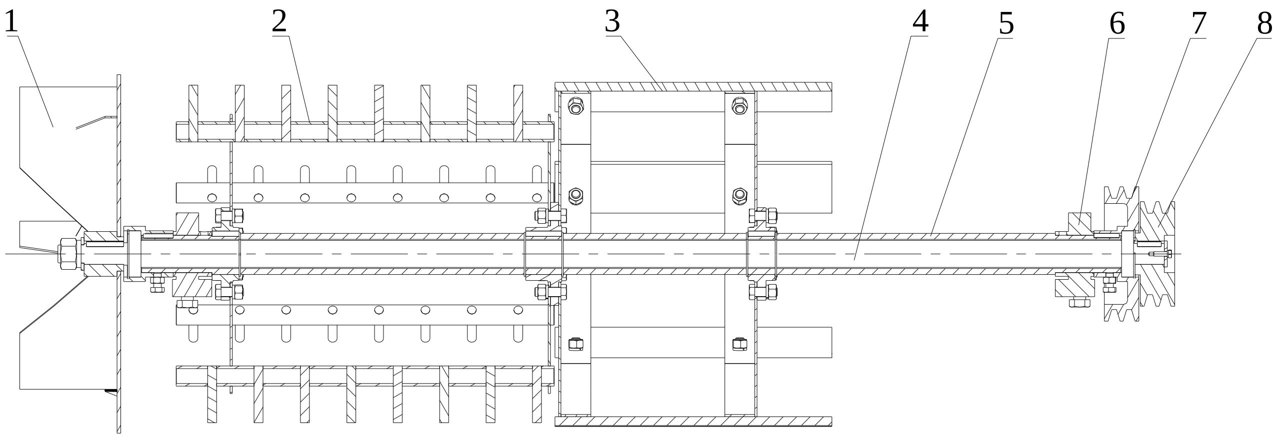


Fig. 3 - Transmission assembly drawing

1. Fan; 2. Nail tooth threshing device; 3. Rasp bar threshing device; 4. Inner drive shaft; 5. Outer drive shaft; 6. Bearing seat; 7. Threshing device drive pulley; 8. Fan drive pulley

Design of threshing device

- **Arrangement of threshing drum**

According to the direction of crop movement along the drum, the common arrangement of threshing drum can be divided into tangential flow type and axial flow type. The advantages of tangential threshing device are relatively simple structure, short threshing time, and relatively low energy consumption, but the purification rate is not high and the separation capacity is poor. The axial flow threshing device has the advantages of long threshing and separation time, high removal rate and good separation effect, but the power consumption is relatively large. As shown in figure 4, the axial flow threshing drum process has four main forms according to the feeding and discharge modes *(Di Z.F., et al, 2018; Ling S.Y. et al, 2021)*. In order to enhance the threshing and separation effect of buckwheat and improve the work efficiency and quality, combined with the structural layout of the whole machine, the technical scheme of axial feeding and radial discharge is adopted in this design, which is shown in figure 4 (c).

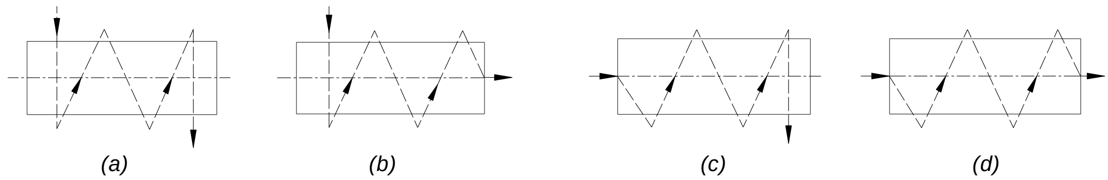


Fig. 4 - Arrangement of axial flow threshing device

a. Radial feeding, radial discharge; b. Radial feeding, axial discharge; c. Axial feeding, radial discharge; d. Axial feed, axial discharge

- **Structural design of threshing drum**

(1) Determination of drum diameter

The diameter of the drum directly affects the effect of threshing. If the diameter is too small, it is easy to wind the crop, and the separation area of the concave plate is reduced. If the drum diameter is large, it can adapt to large feeding amount and high working efficiency. However, if the diameter is too large, the structural size of the whole machine becomes larger and the weight increases, which is not conducive to the operation of small plots and road transfer. Combined with the Chinese standard (NJ105-75), the diameter of roller is 450 mm in this paper.

(2) Determination of drum length

The length L of the threshing drum is determined according to the productivity and is calculated according to the following formula *(China Academy of Agricultural Mechanization Sciences, 2007)*:

$$L \geq q/q_0 \tag{1}$$

where, q is the feeding amount of the threshing device (kg/s); q_0 is the allowable feeding amount per unit length of the drum (kg/(s m)). Generally, the longitudinal feeding thresher is q_0 =1.5 kg/(s m).

The feeding amount of threshing device is equal to the design feeding amount of thresher, taking q = 0.8 kg/s. L≥530 mm is calculated from formula (1). Considering that the thresher is mainly suitable for individual farmers and small plots in hilly and mountainous areas, the model should not be too large, and the drum length L = 850 mm is comprehensively considered.

(3) Determination of the type and structure of threshing elements

The common threshing components of full-feeding harvester mainly include rasp bar type and nail tooth type. Rasp bar threshing has relatively soft effect, weak striking effect, strong kneading effect, high production efficiency, but weak separation ability. The nail-tooth threshing element mainly relies on impact to complete threshing, with high grain crushing rate, strong stirring capacity and strong separation capacity. However, due to the impact of nail teeth on the stem, the protruded stem is broken, resulting in more impurities in the mixture, which increases the load on the subsequent cleaning device. At present, the drum is a transverse axial flow drum, and most of the threshing elements are nail tooth. Because the buckwheat is easy to thresh, but the stems are brittle, if the impact force is too large, the stems are short and broken too much, resulting in an increase in the burden of the air-sieve cleaning system. In order to comprehensively consider the effect of threshing and cleaning, the threshing device designed in this paper is "rasp bar - nail tooth" combination type. The front section is a rasp bar type threshing device, and the rear section is a nail tooth type threshing device. Its structure type is shown in figure 3.

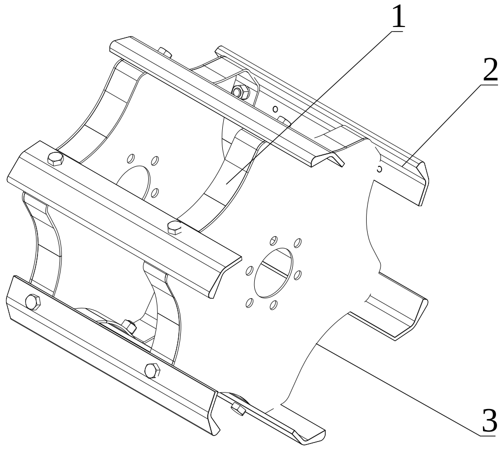


Fig. 5 - Rasp bar threshing device

1. Rasp bar connecting plate; 2. Rasp bar; 3. Spoke plate

The rasp bar threshing device is shown in figure 5, and its main structure is composed of a spoke plate, a rasp bar connecting plate and a D-shaped rasp bar. Its drum diameter is D=450 mm, drum length L_1 = 350, and the form of the drum is an open drum. In order to facilitate the balance of the drum, the number of stripes is usually even. According to the Chinese standard NJ105-75, the number of stripes is Z=6. In order to facilitate the movement of materials from the feed port to the grass outlet, the twill bars are installed in the same direction.

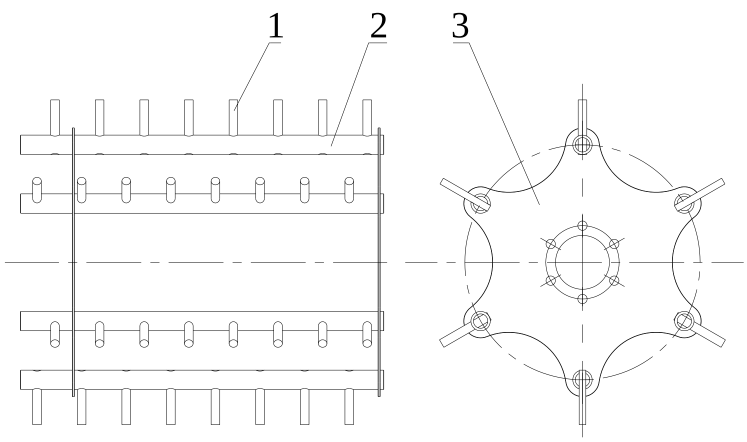


Fig. 6 - Nail tooth threshing device

1. Nail tooth; 2. Nail tooth connecting pipe; 3. Spoke plate

As shown in figure 6, the nail tooth type threshing device is mainly made of nail tooth fixing tube, nail tooth drum spoke plate and nail tooth welding. Its drum diameter D = 450 mm, drum length L_2 = 500. The screw tooth fixing pipe is an empty pipe with Φ = 27 mm and thickness 3.5 mm. The nail tooth is a solid steel pipe with Φ = 12 mm and 76 mm length. In order to balance with the threshing device of the grain bar, the number of tooth rows is 6, and the total number of teeth is 48 teeth. In order to ensure that the material has the ability of conveying backward, the nail teeth are arranged according to the helix with the number of screw heads as 3, the tooth trace distance as 62 mm and the pitch as 182 mm.

(4) Productivity calculation

In order to verify whether the productivity of the designed threshing device can meet the designed feeding capacity of the threshing machine, it is necessary to calculate the designed "rasp bar-nail tooth" combined threshing device. The productivity is determined by the productivity of the rasp bar threshing device and the nail-tooth threshing device.

Productivity of rasp bar threshing device q_1 *(China Academy of Agricultural Mechanization Sciences, 2007)*:

$$q_1 = \frac{ZnL_1\mu_0}{60} \tag{2}$$

where, Z is the number of striated bars, taking 6; n is the rotational speed of drum, taking 500 r/min; L_1 is the length of roller, taking 350 mm; μ_0 is the threshing ability per unit length of striated rod, which is usually 0.018~0.024 kg/m, taking 0.02 kg/m.

Substituting the corresponding data, the productivity of the rasp bar threshing device is calculated to be 0.35 kg/s.

Productivity of nail tooth threshing device q_2 *(China Academy of Agricultural Mechanization Sciences, 2007)*:

$$q_2 \le \frac{0.6zq_d}{1-\beta} \tag{3}$$

where, β is the weight ratio of grain fed into crops. According to standard T/NJ 1217-2020, the grass-grain ratio of buckwheat crops is generally 1.5~6, taking 0.25; q_d is the threshing ability of each nail tooth, taking 0.02; z is the number of nailed teeth on the drum, taking 48.

Substituting the corresponding data, it is calculated that the productivity of the nail-tooth threshing device is q_2 ≤0.72 kg/s.

Productivity of the designed threshing device Q:

$$Q \le q_1 + q_2 \tag{4}$$

The calculated Q ≤ 1.07 kg/s. That is, the maximum productivity of the designed threshing device is Q = 1.07 kg/s, which is larger than the designed feeding capacity q = 0.8 kg/s of the thresher. Therefore, the structure design of the threshing device is reasonable.

- **Threshing speed and threshing clearance**

Because of the biological characteristics of buckwheat, it is easy to thresh. According to the reference [15-16], it is determined that the threshing interval is 10 mm and the threshing speed is 500 r/min.

Concave design

The length of the concave is generally determined by the length of the drum. At the same time, within a certain range, the larger the wrapping angle α, the better the effect of threshing and separation, and the wrapping angle is generally 150°~ 240°. In this paper, the wrapping angle is 180°.

The main function of the concave plate is to cooperate with the threshing device to complete buckwheat grain threshing and stem separation. The common concave plate forms include grid screen type, punching screen type and braided screen type. Among them, the grid screen has high strength and good rigidity, while the braided screen has the highest porosity and the highest screening efficiency, but it has low strength and easy to deform. This design comprehensively considers its strength requirements and screening efficiency, and adopts the combined concave plate of "grid format concave frame + braided screen". As shown in figure 7, the grid format concave frame is mainly composed of a concave mounting frame, a concave grid and a screen connecting plate, and the grid size is 145 mm × 137 mm. The mesh with diameter of Φ = 2.5 mm and spacing of 3 mm is installed on the connecting plate of concave screen by bolting.

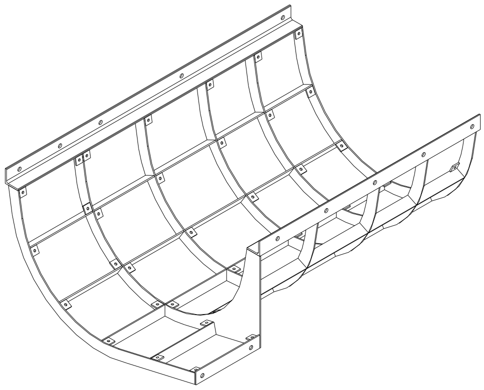


Fig. 7 - Grid format concave frame

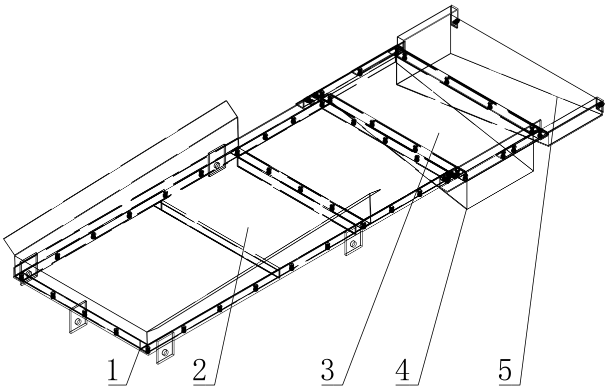


Fig. 8 -The body structure of vibrating screen
1. Screen frame; 2. Conveyor screen; 3. Separating screen; 4. Grain collector; 5. Impurity collector

Vibrating screen design

- **Structural design**

The structure and motion characteristics of the vibrating screen determine the cleaning effect of grain and impurity residue *(Tang Z. et al, 2010))*. In this paper, a reciprocating vibrating screen is designed. The vibrating screen body is connected to the frame through four equal rockers with a length of 220 mm, and the installation angle of the screen surface is α = 2°. The structure of the vibrating screen is shown in figure 8, which is mainly composed of a sieve frame, a conveying sieve plate, a grain collector, a separation screen and a miscellaneous collector. The sieve frame adopts 30 mm × 30 mm × 3 mm angle steel to form the welded structure. The conveying sieve plate and collector are welded on the sieve frame with 1 mm thick steel plate. The braided sieve with wire diameter of 0.5 mm and mesh number of 3 is selected to meet the screening requirements of buckwheat grains.

- **Motion analysis and test of grain on the sieve surface**

In the reference [12], the force and motion characteristics of the vibrating screen grain on the screen surface are analysed and calculated, and the motion simulation analysis is carried out by using ADAMS software. The analysis results show that the motion of connecting rod and rocker changes periodically, each angular displacement, angular velocity and angular acceleration change gently, there is no obvious inflection point in the curve, and the curve has no obvious inflection point, violent vibration and large impact. The vibrating screen has reasonable structure design and good performance. The experimental results show that when the vibration frequency of the vibrating screen is 25.12 rad·s^{-1}, the installation inclination angle of the screen surface is 2°, and the vibration direction angle is 23°, the screening efficiency is 89.8% and the conveying speed is 0.133 m·s^{-1}.

Design of air suction centrifugal fan

- **Overall structural design**

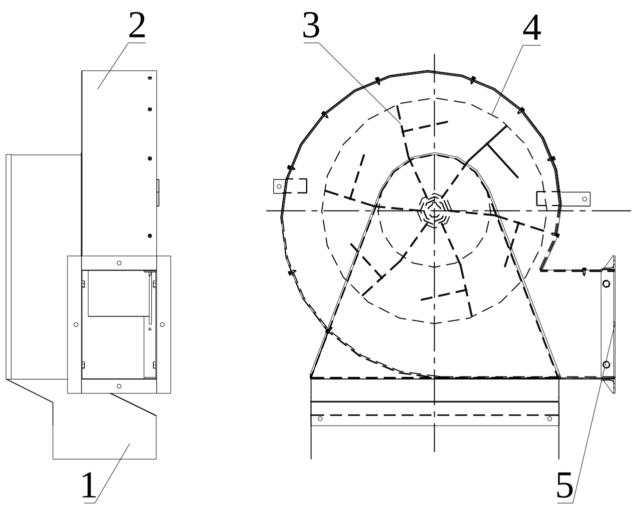
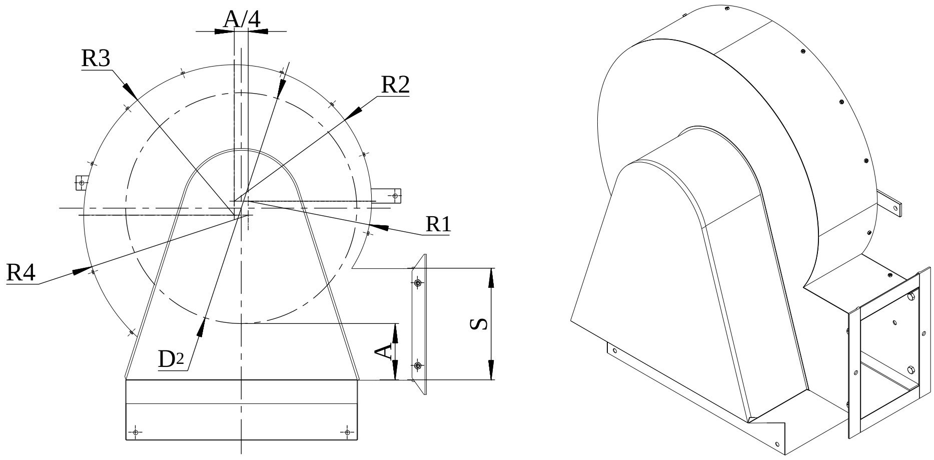


Fig. 9 - Schematic diagram of fan structure
1. Suction mouth; 2. Volute; 3. Leaf; 4. Spoke plate; 5. Air outlet

As shown in figure 9, the air suction centrifugal fan is mainly composed of blades, volutes, suction vents, air vents and so on. Six blades were evenly distributed and welded on the spoke plate with a thickness of 5 mm. The spoke plate is connected with the fan transmission shaft through the flange, and the volute is composed of a thin plate with a thickness of 1 mm. During operation, the fan transmission shaft drives the fan blade to rotate, and the air flow enters the fan through the suction port, forming a pressure difference. When the air speed of the suction port is greater than the suspension speed of the impurity, the impurity will be sucked into the fan through the suction port. Under the action of centrifugal force, the impurity is discharged through the exhaust outlet to complete the cleaning operation.

- **Shell design**



(a) (b)

Fig.10 - Shell structure

(a) Shell size; (b) Axonometric drawing

The shell of the air suction centrifugal fan adopts a spiral volute. According to the reference (*China Academy of Agricultural Mechanization Sciences, 2009*), the spiral drawing method of the shell is shown in figure 10(a). The side length of the square in figure 10(a) is $A/4$. The connected arcs are drawn from the four vertex corners of the square with the radius of R_1, R_2, R_3 and R_4 respectively, which is the shape of the spiral case.

$$\begin{cases} R_1 = \dfrac{D_2}{8} + (1/8)A \\ R_2 = \dfrac{D_2}{2} + (3/8)A \\ R_3 = \dfrac{D_2}{2} + (5/8)A \\ R_4 = \dfrac{D_2}{2} + (7/8)A \end{cases} \tag{5}$$

where, D_2 is the impeller diameter (mm), for suction fans, the impeller diameter D_2 is mostly 250~500 mm, in this paper, taking 480 mm; A is taken as the spiral volute shell expansion size (mm), generally A = (0.1 ~ 0.2) D_2, taking 80 mm.

It is calculated that R_1, R_2, R_3 and R_4 are 72 mm, 276 mm, 300 mm and 324 mm.

S is the height of the air outlet, S = (0.35-0.45) D_2, taking 192 mm.

- **Parameter design of suction port**

The size of the suction port directly affects the gas flow of the fan, and the minimum air volume V_0 required for air separation is related to the impurity content. The calculation is as follows:

$$V_0 = \beta Q / \mu\rho \tag{6}$$

where, Q thresher feed volume (kg/s), Q = 0.8 kg/s; β is taken as the ratio of removing impurities to machine feed, β = 20% *(Cheng F., 2021)*; ρ is air density (kg/m³), ρ = 1.225 kg/m³; μ is the mixed concentration ratio of impurity flow, about 0.2 ~ 0.3, taking 0.2. Calculated V_0=0.653 m³/s.

In order to ensure that the residue in the buckwheat extract entering the vibrating screen can enter the air separation device through the impurity suction port, the minimum wind speed of the suction port should not be lower than the suspension speed of the residue. The results of suspension velocity of buckwheat exudates show that the suspension velocities of grains, branches, stems and leaves of buckwheat are 4.47 ~ 10.18, 1.85 ~ 5.18, 2.80 ~ 8.37 and 0.76~ 2.99 m/s, respectively *(Hou H.M. et al, 2018)*. The suspension speed of light miscellaneous residue such as leaves is lower, and easy to be separated. The suspension speed of branches and stems has a great relationship with the physical characteristics of diameter and length of stems. The suspension speed of stems and branches with small diameter and short length is lower, and easy to separate from grains *(Liao Q.X. et al, 2015)*. Because the concave plate screening uses a braided screen with a mesh number of 5, there are fewer long stems and branches in the extrudates on the vibrating screen, mainly light residue such as leaves, in order to ensure the cleanliness of the air separation, comprehensively consider the suspension speed of stems and rods as the design basis, so as to ensure that short stems, branches, leaves and light miscellaneous residue are cleaned.

The minimum air intake area S_0 of the suction port is calculated as follows:

$$S_0 = \frac{V_0}{v_1} \tag{7}$$

where, v_1 is the wind speed of the suction mouth, and the maximum suspension speed of the stem is about 8 m/s, and the S_0 = 0.0816 m^2 is calculated.

Considering the combination of suction port and vibrating screen, the structure of suction port is rectangular and its size is 482×220 mm. It is calculated that the actual air intake area is S_1 = 0.105 m^2, which is larger than S_0, which meets the requirement of the minimum air intake area, and the actual air intake of the suction port is V_1 = 0.84 m^3/s.

Test and result analysis

In order to verify whether the working performance of the thresher can meet the use requirements, the production assessment of the designed 5TG-85 buckwheat thresher was carried out on October 25, 2021. The test site is the Agricultural Machinery Laboratory of Shanxi Agricultural University. The photo of the test site is shown in figure 11.

Fig.11 - Threshing performance test

- **Materials**

The test materials were Shanxi Hongshan buckwheat planted in Shenfeng experimental base of Shanxi Agricultural University. During the experiment, the moisture content of buckwheat stem was 75%, the grain moisture content was 17%, and the grass grain ratio was 4.4.

- **Method**

According to the Chinese standard《Test method of Thresher》 (GB/T 5982-2017), it is necessary to determine the crushing rate Z_p, impurity content Z_z, unremoved net loss rate S_w, entrainment loss rate S_j, cleaning loss rate S_q, spatter loss rate S_f and total loss rate S. The parameters are calculated as follows:

$$\begin{cases} Z_p = \dfrac{m_p}{m_x} \times 100\% \\ Z_z = \dfrac{m_{xz}}{m_{xh}} \times 100\% \\ S_w = \dfrac{m_w}{m} \times 100\% \\ S_j = \dfrac{m_j}{m} \times 100\% \\ S_q = \dfrac{m_q}{m} \times 100\% \\ S_f = \dfrac{m_f}{m} \times 100\% \\ S = S_w + S_j + S_q + S_f \\ m = m_c + m_w + m_j + m_q + m_f \end{cases} \tag{8}$$

where:

m_p is the broken grain mass in the sample (g);
m_x is the grain mass in the sample (g);
m_{xz} is the impurity mass in the sample (g);
m_{xh} is the grain mixture weight in the sample (g);
m_w is unpurged grain mass (g);
m is total grain mass (g);
m_j is entrainment loss grain mass (g);
m_q is cleaning loss grain mass (g);
m_f is splash loss grain mass (g);
m_c grain mass at outlet (g).

The specific operation was as follows: at the grain outlet, 1 kg of small samples were taken randomly each time, the samples were screened and selected, and m_p, m_x, m_{xz} and m_{xh} were obtained respectively. Within the specified time of the experiment, the grain mixture and the lost grains of each part (m_j, m_q, m_f) were collected, and the m_c was obtained by sieving the grain mixture. The performance indexes were calculated according to the formula (8). Each group of data was repeated for 5 groups, the average value was taken, and the results were recorded.

RESULTS

Combined with the requirements of mechanized threshing of coarse grain crops in hilly and mountainous areas, it is required that the crushing rate Z_p, impurity content Z_z and total loss rate S should be less than or equal to 5%. *(Shi R.J., 2021)*. According to the test scheme and calculation method, when the threshing drum speed of the thresher is adjusted to 500 r/min, the threshing gap is 10 mm, the feeding amount is 0.8 kg/s, the air speed of the suction port is 8 m/s, and the vibration frequency of the vibrating screen is 25.12 rad·s^{-1}. The test results are shown in Table 2. The test results show that all the performance indexes of 5TG-85 buckwheat threshing machine meet the requirements, with good threshing effect and small loss, and can be used for buckwheat threshing.

Test results of threshing performance **Table 2**

Test index	Standard values	Test result
Z_p	≤5%	1.13%
Z_z	≤5%	2.73%
S_w	≤5%	0.07%
S_j	≤5%	1.77%
S_q	≤5%	1.96%
S_f	≤5%	0.62%
S	≤5%	4.42%

CONCLUSIONS

(1) In view of the low level of mechanized threshing of buckwheat in Hilly and mountainous areas, a 5tg-85 buckwheat thresher was designed, the structure and transmission system of the whole machine were designed, and the structure selection and parameter calculation of key components such as threshing device, vibrating screen and centrifugal fan were carried out. The design results show that the design scheme of the thresher is feasible and the structural design is reasonable.

(2) The performance test shows that when the moisture content of buckwheat stem is 75%, the moisture content of grain is 17%, and the grass grain ratio is 4.4, when the rotating speed of the threshing drum of the thresher is 500 r/min, the threshing gap is 10 mm, the feeding amount is 0.8 kg/s, the air speed of suction port is 8 m/s, and the vibration frequency of vibrating screen is 25.12 rad·s^{-1}. The crushing rate Z_p is 1.13%, the impurity content Z_z is 2.73%, the unthreshed loss rate S_w is 0.07%, the entrainment loss rate S_j is 1.77%, the cleaning loss rate S_q is 1.96%, the spatter loss rate S_f is 0.62% and the total loss rate S is 4.42%. The threshing effect is good, which meets the requirements of buckwheat threshing and can be used for threshing.

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