Experimental Results and Analysis of Threshing Effect of Threshing Elements

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Abstract

In order to solve the problem of high damage rate of corn during the mechanical harvesting of corn, information technology was used to efficiently count the harvest of corn kernels, and a low-damage corn threshing element was designed to improve the threshing effect of corn during threshing. The method is used to analyze, design and optimize the key components of the thresher. Through the information technology big data statistics, the experimental results are acquired, processed, processed, and presented to obtain the result big data analysis image, and the results of the image analysis are deeply discussed to obtain the mechanism of damage to the corn kernel by the threshing element. When processing different threshing parts under the background of informatization, when the threshing element is a round head nail; when the drum speed is 520 r/min; four tooth bars, the number of nail teeth on each tooth bar is 14 time; results with relatively good threshing effect. Then verify the conclusion that the designed threshing element can effectively improve the threshing effect.

Keywords: *damage rate; information technology, big data statistics; threshing effect*

1. INTRODUCTION

In recent years, in-depth research has been conducted on how to reduce the damage rate of corn kernels during harvest [5]. A large number of designs have been made for the movement of threshing device, the impact of threshing elements on grains, and the combination of threshing elements' sizes on threshing quality [4][7].

In 2013, Steponavicius studied the effect of ear feeding on threshing performance [6]. However, due to the lack of consideration of threshing effect, the optimization has not been achieved. In 2019, Aljibouri A Mousa A studied the length design of threshing drum, and concluded that 200rpm was relatively good [1]. In 2020, Chang Zhiqiang conducted a model experiment on the relationship between corn harvest damage and machine types, and it was concluded that different machine types had significant effects on threshing quality [3]. In 2021, Bai Weiwei harvested equipment at work, Experiment on the damage and impurity rate of grain, and analyze the influencing factors of threshing quality, so as to master different threshing methods [2]. However, the problem of corn kernel damage has not been effectively solved. A sectional combined threshing tooth bar is designed, which can effectively reduce the grain crushing rate when installed in cooperation with round-headed nail teeth. Improves the separation rate of grains, reduces the space occupied by threshing elements, reduces the weight of threshing drum, and is beneficial to saving energy and realizing the variable diameter threshing of nail teeth.

2. THRESHING TEST RESULTS AND ANALYSIS OF DIFFERENT NAIL TEETH

Through the comparative analysis test of threshing nail teeth, the threshing effect of grain was optimized, the designed nail teeth were designed and assembled, and the experiment was carried out with the nail tooth type as a single variable. Repeat 5 times according to each group of tests, and take the average of the results of 5 tests. Under the condition that the feeding amount is 10 kg/s, the nail teeth are arranged on a tooth bar with an inclination of 10 degrees after being sparse in front. When the drum speed is 520 r/min, the threshing gap is 35 mm, and the corn moisture content is 20.6%, the comparative test of different nail teeth elements is carried out. Figure of each nail tooth element is shown in Figure 1, and the test results are shown in Table 1.

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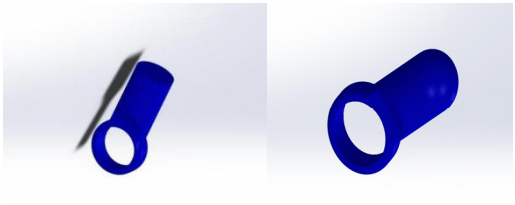

(a) Cylindrical nail teet (b) Round head nail teeth

Fig. 1 Modeling different nail-toothed elements

Table 1： Test results of different nail teeth

No.	Nail tooth type	Grain crushing rate/%	Netting rate/%
1	Cylindrical nail teeth	8.63	97.03
2	Round head nail teeth	5.48	98.86

After sorting out the experimental data in Table 1, it is shown in Figure 2, which is a comparison of the test results of different nail teeth.

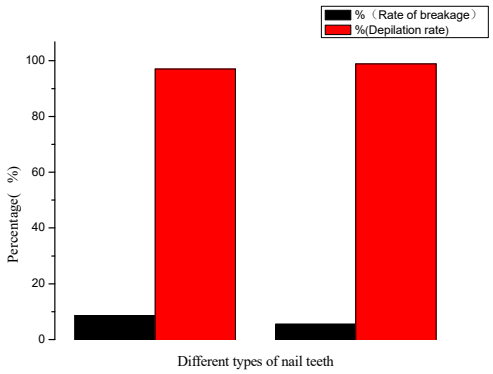

Fig. 2 Comparison of test results of different nail teeth

Test conclusion: As can be seen from Table 1 and Figure 2, under the same conditions, when the grain crushing rate of the designed low-damage round head nail teeth is 5.48%, the crushing rate of the cylindrical nail teeth is 8.63%, which is reduced by 3.15%; On the threshing rate: when the round head nail teeth are 98.86%, the cylindrical nail teeth are 97.03%. Therefore, through the comparison of experimental results, it is better to choose the round head nail teeth to design the low-damage threshing nail teeth.

Analysis of variance: By comparing the experimental results of different types of nail teeth and their combination forms, the results are shown in Table 2 from the aspects of grain breaking rate and threshing rate.

Table 2 Variance analysis of test indexes of different nail teeth pairs

No.	Nail tooth type	Grain crushing rate/%	Netting rate/%
1	Cylindrical nail teeth	8.32	96.11
2	Round head nail teeth	5.42	97.21

It can be seen from Table 2 that the effect of round-headed nail teeth is better, and the crushing rate is relatively low. There is not a big difference between them for the unwashed rate. In summary, the effect of round head nail teeth is better.

The final conclusion is that the threshing effect of round-headed nail teeth is better than that of other nail teeth, and the modeling is shown in Figure 3.

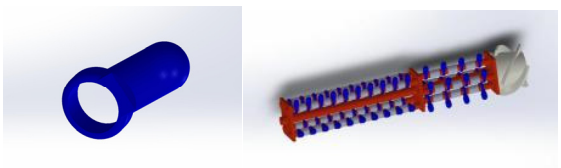

Fig. 3 Round head nail teeth

3. TEST RESULTS AND ANALYSIS OF THRESHING DRUM LENGTH AND DIFFERENT ROTATING SPEEDS

The length and rotation speed of the drum are also one of the factors affecting threshing effect, and also an important parameter for studying low-damage threshing equipment. The length of the drum and the rotation speed of the spindle indirectly affect the rigidity, frequency and striking force of threshing elements and grains during striking. With the mechanical change of the threshing element in contact with the grain, the threshing effect with low damage will be affected, by changing the rotating speed of the drum, the experiment is carried out, and the influence law of the rotating speed of the drum on the crushing rate and the unwashed rate is obtained, so as to determine the most suitable length and rotating speed of the drum. For analysis and design, set up as shown in Figure 4.

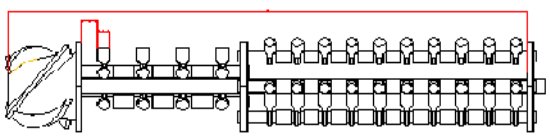

Fig. 4 Threshing drum

Threshing roller length L_2,Determine according to Equation 1, 2:

$$L_2 = \delta(\frac{N_d}{K} - 1) + 2\Delta L \qquad (1)$$

In：

$$\delta=2(b+r_{min}) \quad (2)$$

In:

δ——Tooth distance, unit: mm；

Nd——Nail number；

K ——The number of spirals, according to the literature, suitable for this article, take K = 4；

ΔL——Distance, unit: mm , design adaptability , take $\Delta L = 82mm$；

b——Diameter, unit: mm， Value b = 17 mm；

γ_{min}——Minimum gap, unit:mm，Adaptive design, take $\gamma_{min} = 36$mm；

Substituting the above data into Formula 5, the roller length is $L_2^* = 1542mm$. As shown in Figure 3-12, considering that there is a movement of one to two centimeters between the nail teeth and the shaft sleeve, therefore L_2 Take 1700 mm. When, its L_2 The grain separation rate at =Z can be expressed as Formula 3.

$$\varepsilon_Z=\frac{1}{\tau_1-\tau_2}[\tau_1(1-e^{-\tau_2 z})-\tau_2(1-e^{-\tau_1 z})]\times100\% \quad (3)$$

In：

$$0\leq Z\leq L_2$$

In：

ε_Z——The quality of the degree of threshing in Z is a percentage of all grain quality; τ_1、τ_2——coefficient，take τ_1= 3.428， τ_2= 3.265；

Z——The axial position of the drum, unit:mm；

L_2——Roller length, unit:mm.

Substituting the above coefficients into Formula 6, L_2 The value is 1700mm. Meet the requirements of net removal rate.

According to the above test method, when the feed rate is 10 kg/s, a comparative test of two kinds of nail teeth is carried out. Under the condition that the threshing gap is 35 mm, the threshing effect of different rotating speeds is studied. The experimental results are shown in Table 3.

Table 3 Experimental results at different drum speeds

No.	Rotating speed (r/min)	Cylindrical nail teeth		Round head nail teeth	
		Grain crushing rate/%	Netting rate/%	Grain crushing rate/%	Netting rate/%
1	320	7.45	97.20	5.46	99.12
2	420	8.12	97.15	5.21	99.06
3	520	8.63	97.03	5.48	98.86
4	620	10.45	96.58	6.45	98.34
5	720	12.69	96.01	7.58	97.43
6	820	14.42	95.13	8.76	96.42

The experimental data in Table 3 are analyzed, and the curves of broken grain rate and unwashed grain rate with the rotation speed of the drum are obtained, as shown in Figures 5 and 6.

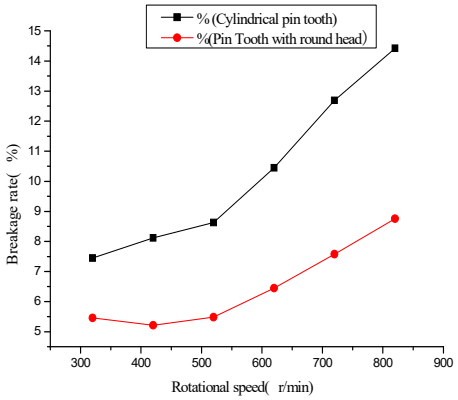

Fig. 5 influence curve of drum speed on crushing rate

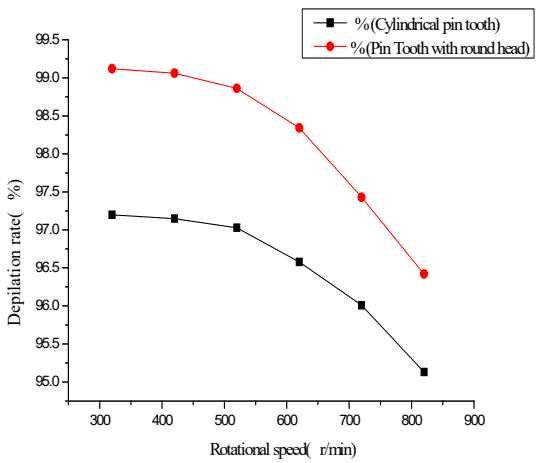

Fig. 6 influence curve of drum speed on cleaning rate

As shown in figs. 5 and 6, with the increase of the rotating speed of the drum, the crushing rate of both kinds of nail teeth increases, while the stripping rate decreases. It is mainly because the increase of drum speed leads to the increase of linear speed, hitting frequency, contact time between spike teeth and corn kernels, and the unit load on corn kernels. At the same time, with the increase of rotating speed, the acting force of threshing elements on corn ears, so that the crushing rate gradually increases.

With the increase of the impact force of threshing elements on ears, the impact force of threshing elements on the stalk of corn grains is increased, but the destructive power to the grains is also increased. The rotating speed of the drum affects the frequency of ear beating. The contact times between threshing element and corn ear increase, the damage rate increases, and the unwashed rate decreases. However, it is found from Table 3 of the test results that when the rotating speed of the drum is 520 r/min, whether it is cylindrical nail teeth or round head nail teeth, the change is relatively small. For example, when the rotating speed of the drum is 520 r/min, the breakage rate is 8.63%, and the variation difference of 5.48% is small compared with other rotating speeds. The net removal rate is 97.03% and 98.86%, which has little change compared with other rotating speeds.

4. TEST RESULTS AND ANALYSIS OF DRUM INSTALLATION ANGLE

The installation inclination angle of the threshing drum can reduce the output energy of the motor to a certain extent. When the threshing drum has a certain inclination angle, it can not only save energy, but also make the nail teeth have a larger contact area with corn kernels. When the contact area increases, the unit load decreased. Theoretically, it can reduce the damage rate of grain and increase the threshing rate. However, when the installation inclination angle exceeds a certain range, the sliding force provided by the corn kernels themselves is too large, which makes the corn ears stay in the threshing space for a relatively short time, and accumulate and overstock at the ear outlet. Not conducive to threshing. Therefore, the following tests should be conducted at a reasonable angle (eight to twelve degrees). The results are shown in Table 5 and Figure 7.

Table 5 Experiment on threshing effect of drum with different installation inclination angles

Roller mounting inclination angle (°)	Grain crushing rate/%	Netting rate/%
8	5.58	98.57
9	5.32	98.93
10	5.12	99.13
11	5.29	98.91
12	5.73	98.36

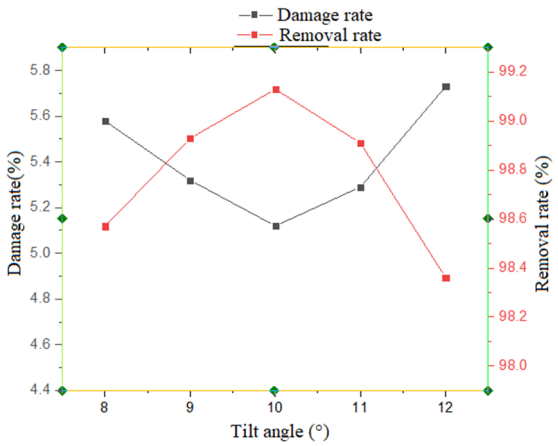

Fig. 7 Analysis of threshing effect of drum with different installation inclination angles

According to the test data and analysis in table 5 and fig. 7, it can be seen that different installation inclination angles of the drum have influence on threshing effect of AK168 corn varieties. With the gradual increase of the installation inclination angle of the drum within ten degrees, the threshing effect is obviously improved, the breakage rate is reduced, and the threshing rate is increased. A turning point has taken place in the tenth degree, and the threshing effect is getting worse and worse after the tenth degree. It can be seen that ten degrees of threshing drum is helpful to threshing effect.

5. CONCLUSION

(1) Through the threshing experiment of different threshing elements designed under the same conditions, the threshing effect is different, which verifies that the designed round-headed nail teeth can reduce the damage of grains.

(2) It provides an idea for developing the shape of flexible threshing elements in the later period, and also provides a basis for the design of the thresher with variable diameter and nail teeth and the design of nail teeth installation. Thus promoting the development of mechanized automatic harvesting of corn.

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