Design and Application of High Stubble Rice Harvester

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Abstract. In recent years, the state has adopted the policy of returning straw to farmland in rural areas to further reduce environmental pollution. Based on the demand of straw returning to the field, the original header design can not meet the needs of high stubble, the spring teeth will dial the ear head, resulting in greater waste. This paper studies and analyzes the current situation and characteristics of combine harvester, focusing on the loss of header and the structure and principle of reel. Determine the overall design scheme suitable for combine reel, provide an optimal value in the ratio of reel speed, study the optimal reel radius, and provide help for the design of reel in the future.

1. Introduction
With the development of economy and the progress of the times, great changes have taken place in the countryside of our country. Most of the young and middle-aged people in the countryside have gradually invested in the construction of the city, resulting in the surplus labor force in the countryside unable to meet the needs of the production tasks, bringing difficulties to the agricultural production, affecting the development of agriculture and the income of the national food. Therefore, in order to solve this situation, the state has increased the input of agricultural machinery, which is the further improvement of agricultural machinery in China. The agricultural labor has changed from the original manpower to mechanization, which has greatly improved the productivity of agriculture, solved the problem of insufficient agricultural productivity, and increased the income of farmers and the increase of food production. However, compared with developed countries, the mechanization level of fee agriculture in China still has obvious deficiencies, and there are still some problems in the application of rice harvester. As a large agricultural country, the level of agricultural machinery technology directly affects the development of our national economy and the income level of farmers [1].

In recent years, in order to control the environmental pollution in rural areas, the government vigorously implemented the policy of returning straw to the field. In the case of high stubble harvesting demand under straw returning, the original header design can no longer meet the needs of high stubble, and the original stubble spring teeth will dial the ear head, causing great waste. In this paper, the current situation and characteristics of combine harvester are studied and analyzed, especially the loss of header and the structure and principle of reel. The overall design scheme for the reel of combine harvester is determined, and the best reel radius is studied by providing an optimal value of the reel speed ratio, which plays a certain role in the design of the reel in the future [2].

2. Key technology analysis
The overall design of rice harvester includes function planning, configuration of related parts, determination of whole machine parameters, selection of power mechanism, etc. The design goal of the
rice combine harvester is to complete the harvesting, threshing, hoof selection, separation and bagging operations in a second time, and to achieve small volume, light weight, flexible operation, good trafficability and adaptability, so as to better solve the difficult harvesting problems of large and medium-sized harvesters in the paddy fields of hills and mountains in the south.

The reel is the key part of the harvester, which has two main functions: one is to hold up the fallen rice and lead it to the header; the other is to send the cut straw to the thresher for threshing. In order to support the lodging rice, the horizontal position of the main shaft of the reel can be adjusted appropriately according to the lodging situation. When the reel is lodging in the forward direction, the reel should be moved forward properly to strengthen the supporting effect on the reel, otherwise, the reel can be moved back a little. In order to prevent the crop from toppling forward or taking up after being cut, the action point of the reel should be slightly higher than the center of the cut crop, so that the cut rice can be pushed stably to the back header. The position setting of this action point is very important. The center position of the cut crop is generally regarded as the downward position of the item part\cite{3}.

3. Modeling analysis
Since the proposal of straw returning to the field was put forward in 2011, high stubble harvesting is generally carried out in the operation of grain harvester, and then stubble is removed and returned to the field. During the operation of combine harvester, in order to reduce the cutting of rice straw, the distance between reel and cutter is correspondingly reduced. However, according to the previous header design, even if the header is raised and the reel is lowered, so that the distance between reel and cutter is adjusted to the minimum, the movement track of spring teeth will inevitably hit the head of spike, resulting in header loss. In this case, when the crop moisture content is high More serious \cite{4}, as shown in Figure 2. In order to avoid waste, it is necessary to improve the cooperation between the reel and the cutter when the header is in the state of high stubble \cite{5}.

Taking John Deere C230 reel as an example, the simulation curve of the original reel radius $R$ is 0.45M and $H$ is 0.78m. The reel model and dynamic simulation are shown in Figure 1 and Figure 2. See Table 1 for the summary of simulation results of the model established in SolidWorks software.

![Figure 1. The reel model](image-url)
Figure 2. The reel motion simulation

(1) the distance from point C to the ground is 0.6, which does not meet the requirement of 0.78 of the average height of spike tip.

(2) the height of point B from the ground is 0.55M, and the height of the center of mass is 0.68m, which is slightly higher than the center of mass

(3) x is 0.116, s is 0.245. After calculation, the action degree of reel η is 0.473. If the action of reel is too large, it will lead to the increase of grain falling.

Table 1. Curve export data

| Xc  | Ye  | Yb  | ΔX  | S   | η   |
|-----|-----|-----|-----|-----|-----|
| 0.84| 0.25| 0.20| 0.116| 0.245| 0.473|

If the reel pitch is too large, the rice will be cut neatly when harvesting, and the cycloid will form a ring buckle. The area below the horizontal line of the cycloid is the real area [3]. In order to reduce the impact of elastic teeth on the ear head, that is to say, when the elastic teeth enter into the rice clump, their horizontal division speed should be zero, and the range of grain supported by each elastic tooth in cooperation with cutting is Δ x, which is called the range of action of each paddle [4]. Only when the reel speed ratio is greater than 1, and the cutter is just below the lowest point of the cycloid, the front and back distance Δ X of the spring tooth direct reel is:

\[
\Delta x = \frac{R}{\lambda} \left( \sin^{-1} \frac{1}{\lambda} + \sqrt{\lambda^2 - 1} - \frac{\pi}{2} \right)
\]

According to the relationship between the different positions of the spring teeth on the circumference and the forward distance s of the reel turning machine for one cycle, the calculation formula of S is as follows:

\[
S = vt = \frac{2\pi}{zw}
\]

Where: \(v_m\) - machine forward speed
w - Reel angle speed
z - number of tine shaft
The action degree of reel η is the ratio of Δ x to S:

\[
\eta = \frac{\Delta x}{S}
\]

In the radius range of 0.2 and 0.3m, the values of X, s and η with radius are shown in Table 2.
Table 2. All data

| R  | ΔX  | S   | η   |
|----|-----|-----|-----|
| 0.20 | 0.104 | 0.120 | 0.408 |
| 0.21 | 0.099 | 0.124 | 0.401 |
| 0.22 | 0.091 | 0.130 | 0.395 |
| 0.23 | 0.085 | 0.138 | 0.388 |
| 0.24 | 0.077 | 0.145 | 0.382 |
| 0.25 | 0.071 | 0.151 | 0.370 |
| 0.26 | 0.065 | 0.170 | 0.355 |
| 0.27 | 0.061 | 0.181 | 0.332 |
| 0.28 | 0.058 | 0.188 | 0.297 |
| 0.29 | 0.053 | 0.195 | 0.266 |
| 0.30 | 0.051 | 0.202 | 0.260 |

According to Table 1, when the radius is 0.28, the action degree of reel is about 0.297, and the working effect of reel is the best. Therefore, the optimized reel radius of high stubble header should be 0.28M.

4. Simulation results

From the coordinates, the CD spacing X1 is 0.059, and because S1 is 0.195, the ratio η 1 is 0.303, which is almost the same as the calculation result of 0.297 above. The simulation results show that the optimal radius is 0.28M, which is in line with the actual requirements and can make the reel work well.

Table 3. Optimize data

| Xc | Yc | Yb | ΔX  | S   | η   |
|----|----|----|-----|-----|-----|
| 0.84 | 0.25 | 0.20 | 0.116 | 0.245 | 0.473 |

5. Summary

The characteristics of high stubble rice harvester were studied. In view of the fact that the original header design can no longer meet the needs of high stubble when straw is returned to the field, this paper mainly analyzes the loss of header and the structure and principle of reel, and determines the overall design scheme suitable for the reel of combine harvester.
References

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