Combination blade roller for straw returning cultivator

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Abstract: The straw was buried in field in transitory and busy farming season whether it’s paddy or dry land. Mechanized straw application was beneficial to solve the problem of straw burning, and also conducive to the fertility of soil and beneficial to soil improvement. It was an important measure to develop ecological agriculture and agriculture sustainable development. In order to solve the problem of crop residue burning, we designed a straw burying rotary tiller. It can bury crop straw not only in wet land, but also in dry land. It is suitable for tillage in middle and lower reaches of Yangtze River, where the principal crop rotation is wet land rice after dry land crop annually. Based on our previous research achievements, the cultivator for high stubble returning in paddy field and so on, are widely used. So there are two main kinds of cultivating blades in this rotary tiller. They are rotary blades IIT245 and spiral blades. The former blades are used to cut soil, while the latter blades are to bury straw. The results provide the basis for the structure optimization of the cultivator for straw returning and the improvement of its working performance, and also provide a suitable implement to achieve high stubble straw mulching and soil tillage in paddy field and dry land.

1. Introduction
Straw burying and returning is one of the effective ways to solve the problem of burning[1]. It can not only eliminate weeds and some pests and diseases, reduce the amount of pesticide application, but also improve the content of soil organic matter, reduce the amount of chemical fertilizer application, and maintain land fertility. Li Yonglei et al[2]. studied the problem of burying and returning corn straw in dryland by double-roller rotary tillage, and Wang Jinwu et al. studied the problem of burying and returning rice straw in whole plant, combining straw returning with paddy rotary tillage, in order to solve the problem of straw wrapping around the blade shaft. Ding Weimin et al. studied the problem of straw burying and returning to field, and installed a ditching device just below the straw discharge mouth of the combine harvester to bury and return the straw falling in the ditch. Liu Tianxing et al. studied the problem of straw mulching in ditches. They combined the ditcher with the plough, opened ditches first, and then ploughed straw into ditches. Guo Jun et al. compared and analyzed the straw burying ability of positive and reverse rotary tillage machine, and thought that the straw burying rate of positive rotary tillage machine was higher than that of reverse rotary tillage machine, but there was a problem of blade shaft winding. Jia Honglei studied the problem of corn straw-root stubble crushing combined with returning to field, and studied the bionic returning blade of corn stubble. Song Jiannong and so on studied the double-roller straw returning rotary tiller. The straw was crushed by the front blade roller, and the land was ploughed by the rear blade roller. Xia Junfang et al.[3-7]
combined high stubble straw returning with soil rotary tillage, using single blade roller positive rotary tillage method, using special-shaped rotary tillage blade (spiral transverse blade) to realize soil rotary tillage and high stubble straw buried returning at the same time, the high stubble straw of rice, wheat, rape and other high stubble straw after single rotary tillage cutting, buried returning to the field, which improves the quality and efficiency of the combine harvester, but also reduces the number of tractor field operations, saving farming time. This paper mainly introduces the key components of high stubble straw returning tillage machine.

2. Materials and Methods

2.1. Key component of combination blade roller

The key component of high stubble straw returning machine is straw returning combined blade roller, which is distributed on the blade roller. The whole blade roller is composed of six sections, and each section is composed of spiral cross blade, rotary tillage blade and cutter head.

2.1.1. helical blade

The structure and function of the spiral cross blade are equivalent to the tangent part of the standard rotary blade, the spiral cutters are evenly arranged along the circumference direction according to the three spiral lines. The number of spiral cutters in each section of the cutter roller is 3, and two cutter seats are welded between each two spiral cutters. The definition of the left and right spiral cutters is according to the working direction along the forward direction of the unit. A spiral cross blade that has the effect of lateral push to the left axial flow on the soil is called the left cross blade, conversely, called the right transverse blade. The left spiral blade on the left spiral blade roll and the right spiral blade on the right spiral blade roll are arranged in a "herringbone" shape and arranged opposite each other, in order to prevent the tools from being too dense and causing soil to be caught during the rotary tillage operation. Three spiral transverse cutters are evenly distributed along the 120°circle of the cutter roller. The structure of the spiral transverse cutter is shown in Figure 1. The spiral transverse blade model is established by Pro/E software, two sections are intercepted from one end, and a fixed coordinate system is established at the intersection point between the end face of the spiral transverse blade and the axis of the cutter roll. The x axis pointing horizontally to the direction of the cutter roll, the y axis is axial along the cutter roll and the z axis is vertical. The coordinate system Oxyz is shifted along the positive direction of the x axis and then rotated around the positive direction of the x axis. The OoXoZo plane in the resulting coordinate system is the spiral cross blade modeling cross section coordinate system, as shown in Fig. 2.

![Fig.1 Main view and vertical view of spiral blade](image1)
![Fig. 2 Cross-sectional coordination of the spiral blade](image2)

2.1.2. rotary blade

Rotary tillage cutter belongs to the national standard parts. In order to reduce the leakage, heavy tillage, soil clamping and avoid assembly interference in the process of rotary tillage and so on, the distance between the rotary tillage cutter and the two spiral transverse cutters is equal. The rotary blade is evenly distributed between the spiral blades. In the process of tillage, the spiral blade and the rotary blade have axial push effect on the soil. In order to make these two effects counteract each other in
order to improve the surface smoothness after tillage, the left and right rotary tillers are arranged as follows: the right rotary tillers are arranged between the left spiral transverse knives, and the left-handed tillers are arranged between the right spiral transverse knives. Both spiral cross blade and rotary tiller have axial flow lateral push effect on soil, which is helpful to improve surface smoothness after tillage when they weaken each other. Therefore, the right-hand blade is arranged between the left-hand blade and the left-hand blade is arranged between the right-hand blade. However, the field experiment shows that the axial thrust effect of the rotary tiller and the spiral cutter on the soil cannot be completely offset each other, so there are four right-handed tillers distributed between the right-handed cutter and four left-handed cutters distributed between the left-handed cutter. Taking the first blade roller as an example, the rotary blade arrangement is shown in Figure 3. The rotary tillage cutter is arranged between the spiral cutters. In order to prevent the uneven distribution of the cutters and the local dense soil, the distance between the rotary tillage cutter and the front and rear two spiral cutters is equal, and the axial layout is shown in Figure 4.

![Fig.3 Expanded view of first partial rotor](image1)

![Fig.4 Arrangement of Rotary blade 2nd in the first part of rotary rotor](image2)

2.2. Combination blade roller

The combination blade roller is a combination blade roller for straw returning in paddy field and dry field, which is called combination blade roller for short. The structure is shown in Fig. 5. This cutter roller combines the advantages of traditional rotary tiller with its strong soil breaking ability and the good straw burying performance of the spiral cross cutter developed by the research group, and is suitable for direct burying and returning of high stubble straw in paddy field and dry land.
3. Results & Discussion
The quantitative cooperation relationship between the spiral cutter and the rotary blade was introduced by using the cooperation mode of the spiral cutter and the rotary blade, and the better arrangement scheme of the rotary blade was given. The rotary tiller can cut the untilled soil and straw along the forward direction of the unit, and at the same time, the spiral cross blade can press the straw in the stubble area and crush the soil again, so as to meet the need of paddy field and dry land tillage.

4. Conclusions
1) The main structure of the key components of the combined cutter roller of the high stubble straw returning tillage machine was introduced.
2) The arrangement of rotary tillage cutter is reasonable, which has a complete stubble breaking effect on the subsequent transverse cutter. The overall stubble width accounts for one third of the total tillage width, which effectively reduces the soil entry and cutting resistance of the subsequent transverse cutter.
3) The operation mode of spiral blade and rotary blade was adopted to realize the rotary blade cutting the uncultivated soil and straw along the direction of the unit. At the same time, the spiral blade pressed the straw in the stubble area and crushed the soil again, so as to meet the needs of paddy field and dry land tillage.

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