Study on the compacting device of combination for ridge-till and no-till planters

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Abstract. Ridge tillage and conservation tillage combination is an important technology. The compacting device is one of the key components of no till planter. According to different agronomic requirements, a general type of combined type of pressing device was designed. In the device, the compacted wheel set should be designed, the ridge is compacted along the loose soil, and the ridging effect is enhanced. Meanwhile, the ring structure is designed on the compacting wheel to suppress the seeding belt. Through the force analysis and Simulation of the suppression device, the structural parameters are determined, and the adjustable mechanism is designed to realize the adjustability of the pressure of the town. By designing movable pressing ring, the number and size of the ring can be adjusted to meet the needs of different agronomic conditions. The modelling of combined press device is conducive to the promotion of no tillage seeding technique, which is a better combination of advantages of ridge tillage and conservation tillage.

1. Introduction

Because ridge-till and no-till planter is operating in the original ridge tillage with crop stubble and weed cover, it will lead to a large number of soil blocks, coupled with the impact of stubble weeds, so that the seeds cannot be very good contact with the surrounding soil. It is more difficult to sow and suppress than traditional tillage method [1, 2]. Therefore, according to the physical properties of soil and the form of ditch opener in no-tillage operation, it should select or design a good and reliable soil covering and suppressing device.

The traditional development process of agricultural machinery product has to go through many design steps, such as prototype design, trial production, field test, improvement design, re-trial production, re-test and so on, resulting in high cost and long cycle. With the application of information technology, computer technology and automation technology in machinery manufacturing industry, new vitality has been brought to agricultural machinery manufacturing industry. Using virtual prototyping technology to develop agricultural machinery products, designers can build prototype models on computers, carry out structural analysis and dynamic analysis of the prototype according to research purposes, and replace traditional physical experiments with digital simulation [3, 4]. Because the virtual design of components is a three-dimensional entity design, and can endow all kinds of real materials, which can obtain parameters information such as volume, quality, centroid position, cross-section area, cross-section inertia moment, and cross-section bending and torsion modulus directly from the computer [5]. It can provide convenience for designers to make decisions and administrators to approve the cost, thus realizing the whole product. Optimum design of performance before actual
manufacture. In addition, the virtual prototyping technology is used to evaluate the product assembly in the product development stage, so that the manufacturability of the product can be considered from the assembly point of view of the whole product in the design stage, rather than from the point of view of a single part, avoiding design errors, providing convenience for future production finalization and saving time. In addition, the traditional two-dimensional drawings design cannot find the assembly interference caused by the design in advance, and the results often wait until all parts are processed and manufactured before they are actually assembled, resulting in a waste of time and money. By using assembly process simulation software and virtual assembly technology, designers can inspect the assembly clearance and interference between parts in an all-round way before the prototype is actually processed.

2. Agronomic Situation and Design Ideas of the Combination Press
The single-ridge and multi-row planting mode is a new technology for planting multi-row crops on ridges. The combination of large-ridge planting and conservation tillage technology is a new technology. Especially when the ridge spacing matches the wheel spacing of tractor, the machine works in the field. All the wheels are running in fixed ridges and furrows. Because there is no machine to suppress the crop growth belt, it does not need to plough or loosen deeply every year, so it can keep good crop life. In no-tillage mode with large ridges, wheels run in fixed ridges and furrows. The width of ridges matches the distance of tractor wheels, and the tractor is guided by ridges and furrows, which is helpful for furrow openers to avoid residual corn stubble and realize seeding without corn stubble [6]. The planter equipped with the combined suppressor seeded six rows of wheat on the ridge of two rows of corn stubble, aiming at the agronomic requirements of two cropping areas and high stubble of Maize in one year.

Because the planter requires no-tillage planting on the big ridge, the original ridge will be damaged by man-made, machine operation and wind and rain. In order to realize no-tillage planting on the original ridge and ensure the quality of planting, it is necessary to repair the damaged area of the big ridge. However, after Ridge restoration, the soil along the ridge is loose and easy to collapse, so it is necessary to repair it. Compaction of loose soil along the ridge after restoration can solve the problem that the soil along the ridge is easy to fall into the ridge and furrow after restoration. Therefore, it is necessary to design a suitable combined compactor to suppress both the ridge and the planting belt at the same time.

Force Analysis and Parameter Determination of Pressure Wheel
The forces of no-tillage machine when planting include self-gravity, spring pressure, and tractor pulling force acting on monomer through frame, working resistance of ditch opener and reaction force of soil to crushing wheel. The supporting force of the single articulation point and the rolling resistance of the roller bearing are neglected [1]. The whole force analysis of the planter is shown in Fig. 1.
Fig. 1 Whole force analysis of the planter

Where:

- $G$ - Single body weight (including spring pressure)
- $R_x$ - Horizontal working resistance of ditcher
- $R_y$ - Vertical working resistance of ditcher
- $Q_0$ - Reaction force of soil to the wheel
- $Q'$ - Rolling resistance of pressure wheel
- $P$ - Soil reaction force
- $F$ - Monomer tension
- $\phi$ - The angle between tension and horizontal line (clockwise direction is positive) ($\phi = 15^\circ$)

If these forces are decomposed along the Y-axis perpendicular to the tie rod, then

$$
\sum Y = 0
$$

$$
Q_0 \cos \phi + R_x \cos \phi - G \cos \phi + Q' \sin \phi + P_x \sin \phi - P_y \cos \phi = 0
$$

(1)

Where: $Q' = Q_0 f_0$

$f_0$ - Rolling Resistance Coefficient ($f_0 = 0.28$)

According to the principle that the action force and reaction force are equal, the action force of the crushing wheel on the ground in the vertical direction is $Q = Q_0$, then put $Q'$ into the Eq. 1. It can obtain Eq. 2.

$$
Q = Q_0 = \frac{G - R_x - R \tan \phi - P_x \tan \phi + P_y}{1 + f_0 \tan \phi}
$$

(2)

The working resistance $R_x$ and $R_y$ are related with the shape of the opener, the work speed of the opener and the seeding, which can be expressed in the following Eq. 3 [1].

$$
R_x = A_x + B_x V + C_x h_2
$$

$$
R_y = A_y + B_y V + C_y h_2
$$

(3)
Where: \( V \) - Planting speed (km/h); \( H \) - Ditching depth (cm)

Ax, Bx, Cx, Ay, By, Cy - The regression coefficients related to the type of ditcher. For sharp-angle ditcher, \( Ax = 7.3701 \), \( Bx = 1.2658 \), \( Cx = 0.3626 \), \( Ay = 4.4215 \), \( By = 0.3512 \), \( Cy = 0.0893 \).

If planting speed \( V \) is 5km/h and furrow depth \( h \) is 5cm, which is calculated by substitution formula: \( Rx = 22.7641N \), \( Ry = 8.41N \), driving traction \( F = 700N \), vertical traction \( N = 55N \), so \( Px = F - Rx = 677.2359N \), \( Py = N - Ry = 46.59N \). If the weight of no-tillage planter is 300 kg, and plus weight and spring pressure is 100 kg, then \( G = 4000N \). By substituting \( Rx \), \( Ry \), \( Px \), \( Py \), \( f0 \), it can get \( Q = 2396N \), then \( Q' = 670N \).

The diameter of the crushing wheel has a great influence on the crushing effect. Generally, when the wheel weight is equal, the smaller the wheel diameter, the greater the soil breaking effect and pulling force. The force analysis is shown in Fig. 2. According to the principle of moment balance,

\[
\sum A = 0 \\
H \cdot r = R_y \cdot s + R_x \cdot h \\
\sum C = 0 \\
H \cdot (r - h) = G \cdot S
\]

By combining two formulas, it can get the Eq. 4.

\[
H \cdot r = G \cdot s + H \cdot h = R_y \cdot s + R_x \cdot h
\]

(4)

In the formula: \( H \)-traction, \( G \)-Wheel weight and Spring Pressure, \( R \)-wheel radius, \( S \)-wheels advancing when sinking 2.64 cm, \( R \)-Supporting Force, \( V \)-Speed of Wheel Forward, \( T \)-the time when the wheel advances.

When the traction force and wheel weight are fixed, the wheel diameter is smaller and the compaction time is shorter, the compaction effect of soil will be less ideal. The slip coefficient will increase, which will easily drag the soil back. The results show that the diameter of the wheel should be 20-50 cm, and the diameter of the roller is selected as 40 cm.

Fig. 2 Stress analysis of the compacting roller

3. Modeling of Composite Compression Device

The combined crusher mainly includes compacting wheel, crushing wheel axle, wheat crushing wheel I, wheat crushing wheel II, spacer tube and other parts. The compacting wheel is welded by the hemisphere of the compacting wheel and the welding box of the end plate of the compacting wheel [7,
8]. The model of the parts is shown in Fig. 3. The model of the wheat crushing wheel I and the crushing wheel II is shown in Fig. 4.

![Fig.3 Compacting wheel](image1)

![Fig.4 Crushing wheel](image2)

![Fig. 5 Assembly of combined compacting device](image3)

After the parts model of the No-tillage Planter is drawn, it enters the assembly environment. In the assembly drawing of the combined compressor, the compacting wheel, the wheat crushing wheel I, the wheat crushing wheel II and the spacer pipe are connected with the compressing wheel axle through insertion constraints and motion constraints, while the rod-pulling device of the compressing wheel is connected with the compressing wheel axle through the wear-resistant axle, mainly using insertion and motion constraints to assemble. The overall assembly results are shown in Fig. 5. The compaction wheel is used to compact the loose soil along the ridge after Ridge pruning to enhance the effect of ridge pruning, and the planting belt relies on the ring structure on the roller I and the roller II to achieve the suppression. The spacing canal is the corn stubble zone. Because the common stubble is strong in the protuberance of about 50 mm on the surface, it is easy to lift the compressor, which affects the suppression effect. Therefore, the spacing canal is used to open the gap in the stubble zone, and the distance between the spacing canal and the surface is about 70 mm during planting time, which weakens the uplifting effect of the corn stubble [8].

Due to different agronomic conditions and tillage systems, the demand of no-tillage planters in different areas is different (such as ridge height, width, ridge shape, row spacing, plant spacing, etc.). Through the establishment of the universal parts design library of no-tillage planter, the size of parts can be changed by modifying the parameters to meet different needs.

4. Conclusion
A general combined crushing device was designed for different regions with obvious agronomic differences. The device belongs to a combined type of suppression, and simultaneously suppresses the seeding belt and ridge edge. A compaction wheel was designed to compact the loose soil along the
ridge after Ridge pruning to enhance the effect of ridge pruning and solve the problem that the soil along the ridge is easy to fall into the ridge and furrow after Ridge pruning. The device is universal. Its parameters are determined by the force analysis of the roller. The roller shaft is connected with the connecting rod of the roller through the wear-resistant shaft. The roller tie rod can adjust the rotary shaft by adjusting the nuts and the pressure, and the magnitude of the pressure can be adjusted according to the need. An adjustable crushing ring is designed, which can be refitted according to the actual needs of the number and thickness of the ring to meet the needs of different agronomic conditions. The three-dimensional model of the combined crushing device is established, which is helpful for structural analysis and dynamic analysis according to research purposes, and for checking assembly clearance and interference between components.

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