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Half-precision Self-walking Variable Fertilization Seeder Design

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Abstract

The half-precision fertilization seeder of rice and wheat is designed against the problems of large straw mulching quantity, high soil water content, the traditional rice and wheat seeder easily blocked and poor fertilization seeding uniformity in Jianghuai region. The machine uses the rotary tillage stubble cleaning way to actively block and improves the traditional furrowing fertilization seeding method easy to cause winding grass. Electric control mode is used to drive the seed fertilizer shaft for sowing and fertilizing, the machine can carry on the straw returning to field, applying fertilizer, sowing, covering earth, rolling and other operations at one time, and can achieve the goal of half-precision fertilization seeding rice and wheat. The test results show that the machine has good anti-blocking performance and high operation efficiency. It works stably and reliably, and the various technical indexes meet the requirements of precision and half-precision mechanization planting, suitable for rice and wheat.

Keywords*: Seeder; Rotary tillage anti-blocking; Planting; Electronic control; Rice and wheat*

1. Introduction

Jianghuai rice and wheat area is one of important agricultural production bases in our country, and plays a big role in ensuring the national food security. The straw mulching quantity in the rice and wheat farmland is large and soil water content is high in the region. When the traditional seeder is used for operation, on the one hand, straw and stubble entwines through the soil working parts easily, causing congestion, makes the machine passing performance poor [1-2]; On the other hand, seed fertilizer shaft rotation is driven by the land wheel, and its high slip rate makes sowing and fertilizing uniformity poor [3-4]. So solving the problems of machine congestion and poor fertilization seeding uniformity is the key to design the rice and wheat seeder [5-6]. In order to solve the problems of poor seeder passing performance and poor fertilization seeding uniformity, on the basis of the study of active anti-blocking method and fertilization seeding electronic control technology, this paper designs the half-precision fertilization seeder of rice and wheat through adopting rotary tillage anti-blocking and improving the furrowing fertilization seeding method easy to cause winding grass, and using single chip microcomputer as the core to control DC motor to replace the land wheel to drive seed fertilizer shaft, and rice and wheat fertilization seeding experiment is carried out on the test bench and in the farmland.

2. Overall Structure and Main Technical Indexes

2.1. Whole Machine Structure and Working Principle

The whole structure of half-precision fertilization seeder of rice and wheat as shown in Figure 1, is connected to the rear of the tractor by trifilar suspension, and is mainly composed of the traction frame, gear box, gear rotary tillage stubble cleaning pulverizing

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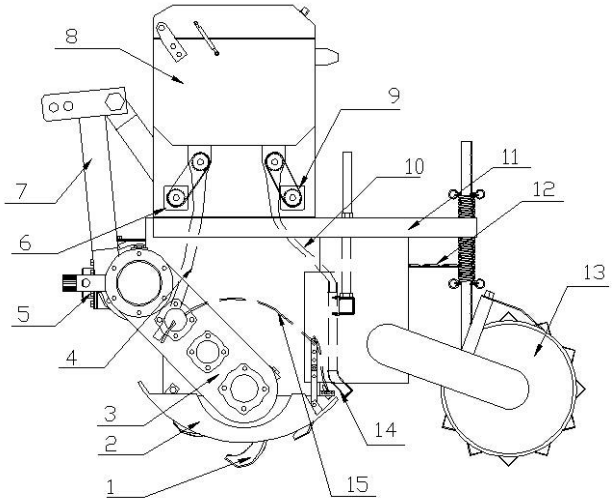
soil device, breast board, fertilizing device, sowing unit, fertilizing motor, sowing motor, suppress wheel and other parts. This machine can complete rotary tillage, stubble cleaning, fertilizing, seeding and rolling at one time.



1. Rotary tillage mechanism 2. Bottom plate 3. Side gear box 4. Fertilizing tube 5. Intermediate gear box 6. Fertilizing motor 7. Suspension mechanism 8. Seed fertilizer box 9. Seeding motor 10. Seeding tube 11.Rack 12. Foot plate 13. Press wheel 14. Seeding tube 15. Breast board

Figure 1. Structure Diagram of Half-Precision Fertilization Seeder of Rice and Wheat

According to the requirement of the seeding quantity, fertilizer quantity, displacement parameters per mu are input on the control panel of seed fertilizer electric control system over work, and precision fertilization seeding is completed automatically by the electric control system. When the unit operates, seeding motor and fertilizer motor are driven by the power of the tractor battery, and the power is transferred to seeding shaft and fertilizer shaft through the chain drive, to realize the seeding and fertilizer; At the same time, the tractor power input shaft drives the intermediate gear transmission by the universal joint, and after the power is inverted, the side gear box drives the rotary knife shaft rotation for rotary tillage, stubble cleaning, pulverizing soil and other operations. The operation order is: first the fertilizer falls on the cultivated land surface in front of rotary cultivator structure in strips, then the rotary knife conducts the rotary tillage on the soil, to mix the soil, rice and wheat straw, stubble, and fertilizer evenly, at the same time, the seeder will sow the seeds to the finely-divided soil surface after the rotary tillage directly through seeding tube in strips, and the thrown soil by rotary tillage and straw are used to cover the seeds through the guidance of breast board, and finally the seed bed is leveled and tamped by the press wheel.

2.2. Main Technical Parameters of Design

According to the agronomic requirements of rice and wheat dry direct seeding in Jianghuai region, and the technical requirements of farmland energy saving and emission reduction mechanization planting patterns, combined with the electric control way of precise fertilization seeding, the main technical parameters of the machine are determined, as shown in Table 1.

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Table 1. Main Technical Parameters of Machine

Parameters	Crops	
	Wheat	Rice
Matched power /kw	36.75~51.45	
Operating width /mm	2300	
Seeding depth /mm	30-50	20-30
Seeding rows	12	
Fertilizing rows	12	
Row spacing /mm	190	
Rotary tillage depth /mm	80~120	
Fertilizing depth /mm	70-100	
Seeding quantity /kg·hm-2	150~375	75~150
Fertilizing quantity /kg·hm-2	150~525	
Operating speed /km·h-1	2~3.8	
Production efficiency /hm2·h-1	0.4~0.53	

3. Design of Key Components

3.1. Rotary Tillage Anti-Blocking Device

For the minimum and no tillage operation, there is a lot of straw stubble on the earth's surface, and it is unevenly distributed on the earth's surface. When the seeder operates, it is easy to generate congestion causing the seeder not working properly. Especially the rice straw has large water content, good toughness, and large mulching quantity and it is not easy broken, so it entwines through the opener shovel shaft easily, or gathers between two adjacent working parts, increasing the working load, and affecting the working quality. So how to solve the congestion problem is one of the key factors to design the half-precision fertilization seeder of rice and wheat. The machine adopts the way of rotary tillage drive anti-blocking against the characteristics of large straw mulching quantity and high soil water content in Jianghuai region, as shown in Figure 2, and it is mainly composed of the rotary knife, tool apron, and breast board. On the one hand, stubble cleaning and crushing earth are conducted through the high-speed rotation of rotary blade over work, effectively preventing straw stalking and wrapping soil working parts; On the other hand, the traditional furrowing fertilization seeding method is improved, hoe fertilizer opener easy to hang grass is removed, and the soil and fertilizer of rotary layer are mixed unevenly, to realize the fertilizer deep fertilization. The disk seed opener is removed, the seeds are sown on the surface of the soil through the seeding pipe directly, and the thrown soil by rotary tillage is used for seed covering, effectively avoiding the hanging grass congestion of the opener.

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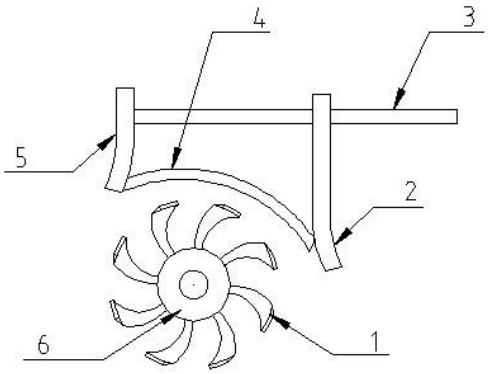

1. Rotary blade 2. Seeding tube 3. Rack 4. Breast board 5. Fertilizer feeding tube 6. Tool apron

Figure 2. Rotary Tillage Anti-Blocking Mechanism

For the rotary tillage stubble pulverizing soil effect, operation energy consumption, and blade manufacturing cost concerned, the machine adopts the method of forward rotary tillage, blade model is IIT225, and its turning radius is about 225 mm. Knife shaft adopts the method of double helix arrangement, there are 70 curved knives arranged on the knife shaft, and its arrangement expansion is as shown in Figure 3. When cutting soil with rotary tillage, right and left curved knives are buried alternately, knife axis is forced uniformly, with low power consumption, and simple and reliable structure.

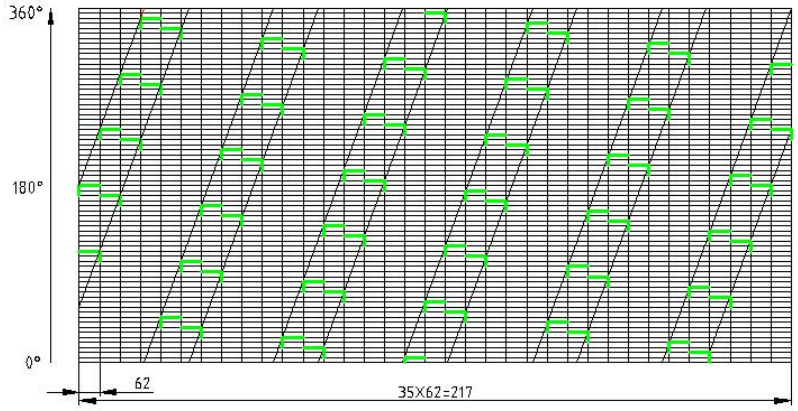

Figure 3. Expanded View of Blade Arrangement

3.2. Electronic Fertilization Seeding System

3.2.1. Composition and Working Principle

In order to solve the problems of high seeder drill ground wheel transmission slip rate, inconvenient seed fertilizer adjustment and failing to control fertilization seeding quantity per mu precisely at this stage, a set of electric control fertilization seeding device is designed. The device takes the STC89C52 single-chip microcomputer as the control core, Hall sensor is used to detect the walking speed of the seeder, and combined with the settings of seed fertilizing rate per mu, and the rotation speed of DC motor is adjusted in real time, to control the seed fertilizer shaft to realize the precise fertilizer seeding.

This device is mainly composed of speed sensor, DC motor, single-chip microcomputer, PWM and control panel, and its overall block diagram is as shown in Figure 4. Its working principle is: First, the tractor battery is used for power supply, after

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square-wave signal is collected by Hall sensor installed on the driven wheel of tractor, it enters into single chip microcomputer for processing, and the walking speed of tractor can be calculated according to the mathematical relationship between the number of installed magnet; Then, the relevant parameters of the fertilizer quantity per mu are set on the control panel, after single-chip microcomputer conducts the data analysis and processing based on seed fertilizing rate per mu, walking speed and rotation speed of the motor, it controls the rotation of fertilizer motor and seeding motor, to realize the servo of seed fertilizer shaft speed and walking speed, so as to complete the precise control of target fertilization seeding quantity per mu.

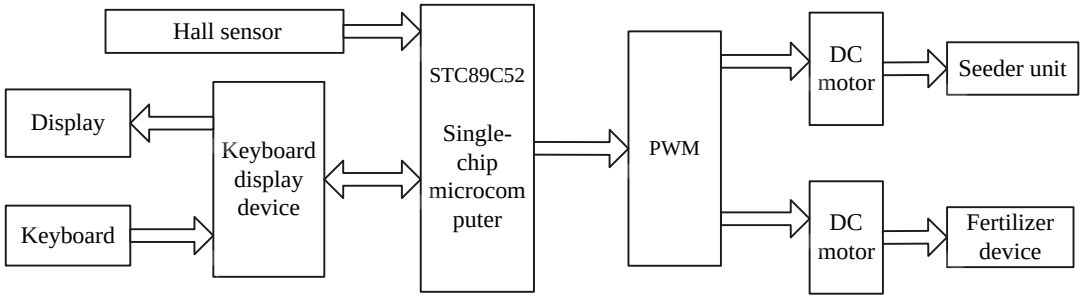

Figure 4. General Device Block Diagram

3.2.2. Control System Function Relation Model

In order to make this system accurately control the fertilization seeding quantity of seeder, when setting the target seed fertilizing rate per mu, we need to control seed fertilizer shaft speed and conduct the real-time adjustment on the seed fertilizing rate according to the speed, that is, DC motor speed needs to be changed with the change of the walking speed of tractor. We need to determine a function relationship between the DC motor speed, fertilization seeding quantity and walking speed of tractor. And the walking speed of tractor is measured through the Hall sensor, if the number of installed magnet is n, wheel makes a round, single chip microcomputer will receive n pulse signals; If single chip microcomputer receives N pulse within the time T, the rotation speed w of the tractor within the time T is as follows:

$$w = \frac{N}{Tn} \tag{1}$$

Let the tractor driven wheel radius be r, and the walking speed v of tractor within the time T is:

$$v = 2\pi wr = 2\pi r \frac{N}{Tn} \tag{2}$$

After the walking speed v of tractor is measured, it is necessary to establish the relationship between it and the rotation speed of DC motor. Let fertilizer seeding area be S, and seeder width be M, the rotation speed of DC motor be v_t, seed fertilizer shaft revolution be N_t, so the required time t to complete the fertilization seeding area is:

$$t = \frac{S}{Mv} \tag{3}$$

Motor and seed fertilizer shaft adopt chain drive, its drive ratio is i, so the rotation speed v_t of DC motor within the time t is

$$v_t = \frac{iN_t}{t} \tag{4}$$

According to the *Agricultural machinery knowledge handbook*, there is a corresponding relationship between revolution N_t of seed fertilizer shaft and fertilization seeding quantity Q , their relationship is:

$$Q = kN_t + b \tag{5}$$

Where: k and b are the constant, Q and N_t is a one-to-one relationship.

When the walking speed of tractor speed is v, to make the extracted seed fertilizer quantity be Q, so the corresponding rotation speed of motor is v_t, and the follow-up relationship between the two is determined. We can get by (3), (4), (5):

$$\frac{S}{Mv} = \frac{iN_t}{v_t} = \frac{(Q-b)i}{kv_t} \tag{6}$$

So the function relationship between walking speed v of tractor and rotation speed v_t of DC motor is determined under the condition of given seed fertilizer quantity per mu $m = 667\frac{Q}{S}$.

Table 2. Groove Wheel Structure Parameters

Model	Groove wheel diameter d (mm)	Grooves radius r(mm)	The number of grooves Z	Lmax(mm) Maximum working length Lmax(mm)
Fluted wheel	40	4.5	10	40
Fertilizer wheel	60	5.5	14	40

Finally, taking huaimai 22# seed and Aimei compound fertilizer as the object, the commonly used outer groove-wheel seeder unit is adopted, and its structure parameters are shown in Table 1. Let the working length be 20 mm, and the electric control system carries on the testing calibration on the delivering performance test bench. Through data processing and analysis, the function relation between the rotation speed n_z of seeding shaft, walking speed v of tractor speed and seeding quantity per mu Q_Z is as follows:

$$n_z = 0.0288vQ_Z \tag{7}$$

The function relation between the rotation speed n_z of seeding shaft, walking speed v of tractor speed and seeding quantity per mu Q_Z is:

$$n_F = 0.0192vQ_F \tag{8}$$

The function relation between seeding quantity parameters per mu f_Z and the actual seeding quantity per mu B_Z is as follows:

The function relation between fertilizer quantity parameters per mu f_s and the actual fertilizer quantity per mu B_s is as follows:

$$B_Z = 0.2598 f_Z - 0.1392 \tag{9}$$

$$B_S = 0.2544 f_S - 0.0479 \tag{10}$$

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4. Sample Test

4.1. Test Condition

The rice fertilizer and seeding test was carried out on the indoor JPS-12 type seeding performance test bench in October 2014, wheat seeding test was conducted on the half-precision fertilization seeder of rice and wheat in Yanling Town, Danyang, Jiangsu in November. Test field is located in the southern bank of the middle and lower Yangtze river, the south of Jiangsu province, and has the characteristics of humid climate, sufficient sunlight, abundant rainfall, long frost-free period, and four distinct seasons. The test field is the medium clay soil, soil moisture content is about 26%, with flat terrain, and it belongs to the rice and wheat rotation area, covering an area of 0.8 hm2. Figure 5 and Figure 6 are the test site.

Figure 5. Bench Test

Figure 6. Filed Test

4.2. Test Method

According to the test index of ministry of fertilizer seeding quality of rotary tillage fertilization seeder formulated by the China Agricultural Machinery Testing Center, the test contents mainly include the fertilizer seeding quality, seed covering situation, machine field passing performance, *etc*. Main inspection basis is GB/T20865-2007 No-tillager Fertilization Seeder, DG32/T 007-2008 Appraisal Program of Rotary Tillage Stubble Fertilization Seeder Promotion, and JB/T8401.1-2007 Rotary Tillage Combination Process Machine Rotary Tillage Fertilization Seeder and Precision and Half-precision mechanical seeding Implementation Technology Point. Test equipment includes electronic scale, tape measure, vernier caliper, stopwatch and steel ruler, *etc*.

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4.3. Bench Test Results and Analysis

4.3.1. Bench Test Results

The forward speed of tractor is 2.2 km/h, 3.8 km/h and 6.2 km/h, the seeding quantity is 150 kg/hm2, fertilizer quantity is 225 kg/hm2, fertilization seeding accuracy and seeding uniformity test is conducted, and the test results are shown in Table 3 and Table 4.

Table 3. Fertilizing and Seeding Accuracy Test

(km/h) Speed(km/h)	Sow		Fertilize	
	(kg/hm2) Seeding quantity(kg/hm2)	Variation coefficient (%)	Fertilizer quantity (kg/hm2)	Variation coefficient (%)
2.2	151.3	0.9	219.9	2.3
3.8	148.4	1.1	221.1	1.8
6.2	148.2	1.2	217.3	3.4

Table 4. Seeding Uniformity Test

Speed (km/h)	Number of times	The number of seeds per 10cm										Uniformity variation coefficient
		1	2	3	4	5	6	7	8	9	10	
3.8	1	10	7	8	12	9	8	6	9	11	7	20.5
	2	6	8	10	9	7	6	8	11	9	12	22.2
	3	10	8	11	6	7	11	8	12	9	6	23.2

4.3.2. Result Analysis

The table test data shows that under different walking speed of the tractor, the stability variation coefficient of total seeding quantity is 1.3% or less, the stability variation coefficient of total fertilizer quantity is 7.8% or less, and the seeding uniformity variation coefficient is 40% or less. When electric control system conducts the conventional rice seeding, it works stably and reliably, its fertilization seeding accuracy and seeding uniformity accord with the requirement of national standards, and the goal of half-precision fertilization seeding of rice can be achieved.

4.4. Field Test Results and Analysis

4.4.1. Field Test Results

(1) Machine passing performance test

The passing performance test is carried out on the machine in the stubble rice straw-mulched field, stubble height is not greater than 25 cm, the chopped straw length is not more than 20 cm, and testing area length is 60 m, with a round trip. The test results show that the field operation of half-precision fertilization seeder of rice and wheat is smooth, and no straw blocking phenomenon happens in six tests.

(2) Seeding performance test

After the data measured in the field is processed, the field seeding performance of seeder is as shown in Table 5.

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Table 5. Test Results

Number	Test items	Technical requirements	Test results
1	Tilling depth	≥8	10.1
2	Tilling depth stability	≥85	90.3
3	Consistency variation coefficient of total seeding quantity in each row %	≤3.9	3.49
4	Stability variation coefficient of total seeding quantity in each row %	≤1.3	1.01
5	Consistency variation coefficient of total fertilizer quantity in each row %	≤13	3.91
6	Consistency variation coefficient of total fertilizer quantity in each row %	≤7.8	1.5
7	Qualified rate of seed covering depth %	≥75	81.67

4.4.2. Result Analysis

(1) With the method of rotary tillage anti-blocking, rotary blade can effectively cut stubble and mix straw with soil uniformly for returning application, achieving anti-blocking function; In addition, the improved traditional ditching fertilization seeding way removes the seed fertilizer opener easy to wind grass, and also effectively reduces the machine working parts hanging grass blocking phenomenon, and both ensure the machine has good passing performance.

(2) When half-precision fertilization seeder of rice and wheat sows in the field, the machine works stably; Rotary tillage structure is designed reasonably, and tilling depth stability is good; Throw soil with rotary tillage to cover soil, the qualified ratio of seed covering depth meets the requirements; Electric control device drives seed fertilizer shaft for fertilization seeding, various main technical indexes of seeding and fertilizer feeding reach the requirements of relevant national standards, and the goal of precision and half-precision fertilization seeding of wheat can be achieved.

5. Conclusions

Half-precision fertilization seeder of rice and wheat implements the combination operation of rotary tillage, stubble cleaning, fertilization, sowing, earth covering and rolling. The simplified operating procedure reduces the number of machine field, reduces the operation cost, and two purposes improve the machine utilization. The machine adopts the rotary tillage stubble cleaning, improves the anti-blocking method of the traditional ditching and fertilizing seeding method, has good anti-blocking ability and earths up the seedbed actively. It can meet the demand of rice and wheat planting in Jianghuai area, and achieve the minimum and no tillage seeding of rice and wheat. The machine has a complete set of electric control system to carry on the fertilization seeding, with stable work, seed fertilizing rate adjustment is easy and convenient, and power supply voltage is safe and reliable. The machine effectively solves the problem of uneven fertilization seeding of rice and wheat area in Jianghuai due to serious land wheel skidding, and improves the quality of the fertilization seeding; At the same time, sowing quantity parameters per mu can be set up to precisely control the actual seeding and fertilizer quantity per mu, with high intelligent degree, which can reduce the seed and fertilizer inputs, and reduce the consumption of resources. Bench and field experiments show that

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the machine works stably and reliably, average tilling depth is 10.1cm, tilling depth stability is 90.3%, the qualified rate of seed covering is 81.67%, the stability variation coefficient of total seeding quantity is 1.3% or less, the stability coefficient variation of the total fertilizer quantity is 7.8% or less, the variation coefficient of seeding uniformity is 40% or less, which conforms to the requirements of the precision and half-precision mechanization planting, and the goal of half-precision fertilization seeding of rice and wheat can be achieved.

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