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Simulation System of Wheat Broad Width Intelligent Precision Seeding

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Abstract

In order to overcome the deficiencies of miss-seeding and random seeding in the current ground wheel driven seeding,a set of intelligent control simulation system for wheat precision seeding was studied and built.The system adopts self-designed seeding apparatus and intelligent control method to complete broad width and precision seeding of wheat. The system uses keys to set parameters such as seeding rate, thousand-grain weight and seeding space, etc.According to the measured value of the operating speed of the planter by the encoder, the speed of the DC motor is dynamically adjusted by controlling the pulse width modulation (PWM) of the chip, so as to achieve the purpose of changing the operating speed of the seeder and keeping the seeding rate and seed spacing unchanged. The DC motor is poweredby tractor's own battery to drive seeding, and all information is displayed on the LCD.The simulation test of the rotation speed measurement of the seeding shaft shows that there is only slighterror caused by vibration between the corresponding theoretical and actual rotation speeds of the seeding shaft for different operating speeds when the intelligent control system of wide planting of wheat is used for seeding, which can meet the requirements of precision seeding.

Keywords: *seeding apparatus, broad width, precision seeding and intelligent control, DC motor, PWM speed regulation*

I. Introduction

Precision seeding is an important part of precision agriculture. Precision seeding refers to sowing seeds into the soil according to the accurate number of seeds, seed spacing and row spacing to achieve the purpose of uniform seed distribution, saving seeds and improving yield [1], which represents the development trend of current sowing technology. At present, the traditional mechanical planter with the ground wheel driving the seeding shaft is widely used for wheat seeding. Because the ground wheel needs to drive the seeding shaft, it is easy to slip and cause uneven seeding or even missing seeding [2], and cannot set the seeding rate and seed spacing according to their own wishes. It is necessary to manually adjust the chain or replace the seedingapparatus. Atpresent, most of the domestic researchon apparatus. Atpresent, most of the domestic research on intelligent control precision seeding machine stays in monitoring the miss-seeding, seed fertilizer remaining, fault alarm and so on [3-4].

In 2004, Xiuhua Liu used a five-wheel meter to measure the operating speed of the seeder. And the stepper motor was used to drive the rotation of the seeding shaft by intelligent control method. The rotation speed of the seeding shaft was determined by the calculation of parameters such as seeding amount [5]. The price of five wheel was high, which was not conducive to the promotion of the planter. In 2009, Yaohua Tang controlled the stepper motor to drive the seeding shaft by installing Hall sensor on the front wheel of the power source tractor of the seeder [6].The accuracy of Hall sensor was too low, which was not conducive to real-time speed acquisition. In 2012, Jie Li studied the real-time acquisition of seeder operating speed information by encoder under the condition of fixed thousand-grain weight of wheat, and the intelligent real-time adjustment of stepper motor speed by setting seed

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spacing or seeding rate to drive seeding apparatus sowing [7]. But conditions for fixing thousand-grain weight were too strict for wheat varieties. In 2020, Baosheng Li built a real-time control system using STM32, and proposed a fuzzy PID algorithm to improve the seeding performance [8].Intellectualization is a hot topic in today's research. Through the study of intelligent sowing, a set of intelligent control simulation system for wheat wide planting is designed. The system sets the information of wheat thousand-grain weight and seeding rate by keys, and the seed spacing changes accordingly. When the operating speed of the seeder changes during the seeding process, the control chip drives the rotation speed of the seeding shaft by PWM speed control DC motor, ensuring that the seeding spacing and seed rateremain unchanged. All information can be displayed on the LCD, which makes up for the shortcomings of the previous seeding machine [9].

II. General Design Method

2.1 Systematic structure and operation principle

The whole simulation systemconsists of mechanical and control parts. The mechanical system adopts the self-designed seeding apparatus which can complete the function of broad width precision seeding.The control system consists of seeder operation speed simulation, host speed acquisition and parameter setting, slave information receiving and motor control, as shown in Fig. 1.

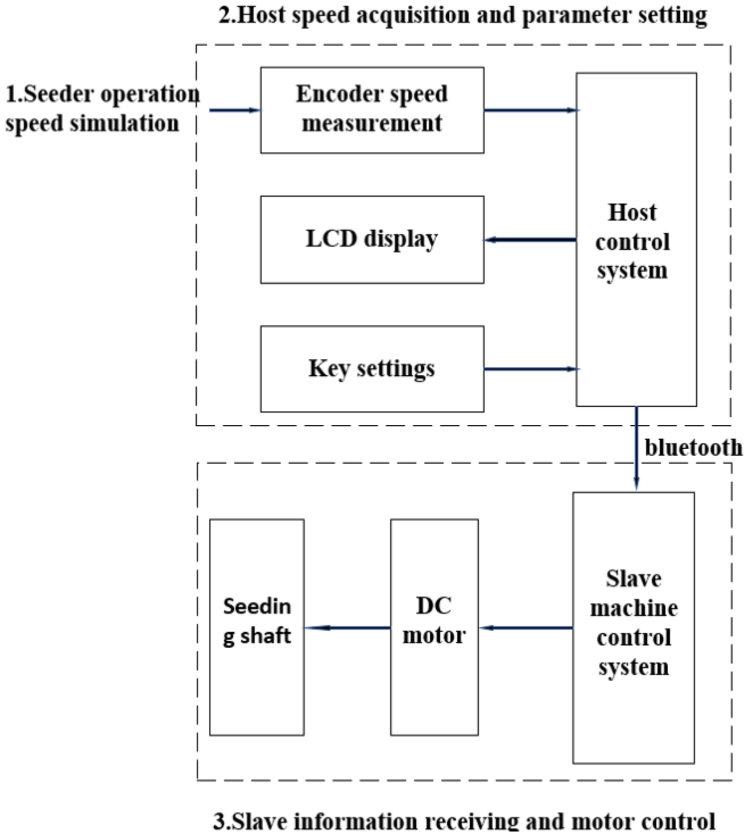

Fig1: Structure diagram of control system.

Principle of operation:The speed simulation part of seeder is connected with the rotary encoder,and the rotary encoder will collect speed of seeder. The seedingrate and thousand-grain weight are set by the key. All information is sent to the host control system. And the processed information,including the operating speed of the seeder, thousand-grain weight of wheat, seeding rate and seed spacing, is displayed on the LCD screen in real time to make man-machine conversation conveniently. At the same time, the host uses Bluetooth wireless transmission

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module to send the seed spacing and the operating speed of the seeder to the slave control system.The slave adjusts the speed of the DC motor dynamically according to the received information through PWM speed regulation, so as to achieve the purpose of changing the operating speed of the seeder, and keeping the seeding rate and seed spacing unchanged.

2.2 Test parameters and theoretical calculation

2.2.1 Relationship between thousand-grain weight, seeding rate and seed spacing

$$1\text{acre} \approx 666.67\text{m}^2 \tag{1}$$

The width of the designed eight sets of seeding apparatus:

$$W = 222\text{cm} = 2.22\text{m} \tag{2}$$

The forward distance which sowing machine sow 1 acre of land:

$$S = \frac{1acre}{W} = \frac{666.67m^2}{2.22m} \approx 300m \tag{3}$$

Suppose the wheat sowing rate per acre is G g, thousand-grain weightof wheat is G1000 g, the number of wheat grains per acre:

$$N = \frac{1000G}{G_{1000}} \tag{4}$$

Number of seeds per seeding apparatus:

$$N_1 = \frac{1000G}{8*G_{1000}} = \frac{125G}{G_{1000}} \tag{5}$$

Suppose the plant spacing of wheat is D meters:

$$D = 300 \div \frac{125G}{G_{1000}} = \frac{12G_{1000}}{5G} \tag{6}$$

It can be seen that the seed spacing of wheat is determined by two parameters of thousand-grain weight and sowing rate.

2.2.2 The relationship between rotational speed of seeding shaft and operating speed and seed spacing

Assuming the operating speed of the seeder is V m/s, the sowing time per acre:

$$T = \frac{300}{V} s \tag{7}$$

Seeding shaft will sow 187 seeds when it turns a circle,so seeding shaft speed:

$$V_1 = \frac{N_1}{187} \div T*60 = \frac{N_1 * V}{935} r / \text{min} \tag{8}$$

Insert plant spacing D into the above formula, get:

$$V_1 = \frac{60V}{187D} r / \text{min} \tag{9}$$

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It can be seen that the rotation speed of seeding shaft is determined by the operating speed and seed spacing of the seeding machine.

III.Mechanical System Design

The mechanical system mainly includes the design of seeding apparatus. The seeding apparatus is designed as shown in Fig. 2. This seeding apparatus is a type of hole wheel seeding apparatus designed according to the corresponding size of wheat particles. The inner core of the seeding apparatus is uniformly distributed with circular grooves, and each circular groove can only contain one seed, which can complete the seed sowing function of wheat.

This seeding apparatus adopts the method of 5 grains and 6 grains interval distribution in each row to increase the distance between the sowing wheat grains and grains, which makes the overall distribution of the sowing effect more uniform, and can complete 11 rows of sowing at the same time. The wheat seeds slide down to the ground along the corresponding droppingtube below to achieve the purpose of broad width precision seeding. The inner core of the seeding apparatus rotates and sowed 187 seeds a circle [10].

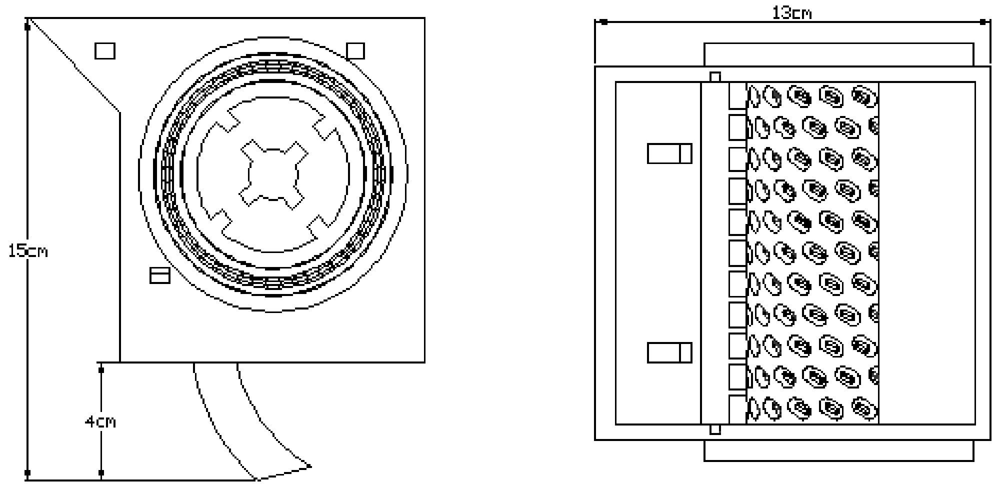

Fig 2: Structure of seeding apparatus.

IV. Control System Design

4.1 Hardware circuit design of control system

4.1.1 Simulation of speeder operating speed
The control system collects the operating speed of the seeder through an encoder, and under laboratory conditions, we cannot collect the speed of the seeder in real time. Therefore, we design the simulation part of the operating speed of the seeder. In the seeding process, the operating speed of the seeder is calculated by collecting the pulse numberof the encoder fixed on the ground wheel. In the experiment, the encoder isconnected and fixed with asmall DC motorthatsimulates the rotation of the ground wheel during the operation of the seeder through a coupling.The control circuit is shown in Fig. 3. The working principle is to change the analog voltage value of the input digital-to-analog and analog-to-digital conversion chip PCF8591P by slowly rotating the potentiometer knob. After the analog voltage collected by PCF8591P chip is converted by analog-to-digital converter, and transmitted from the I2C bus of the chip to the STC89C52 control chip [11].After calculation, the calculation result is used to adjust the duty ratio of the PWM wave by using the timer interrupt method [12]. The PWM signal drives the small DC motor through the driving circuit to achieve the purpose of changing the speed of the small motor by rotating the potentiometer to simulate the gradual change of the operating speed of the seeder [13].

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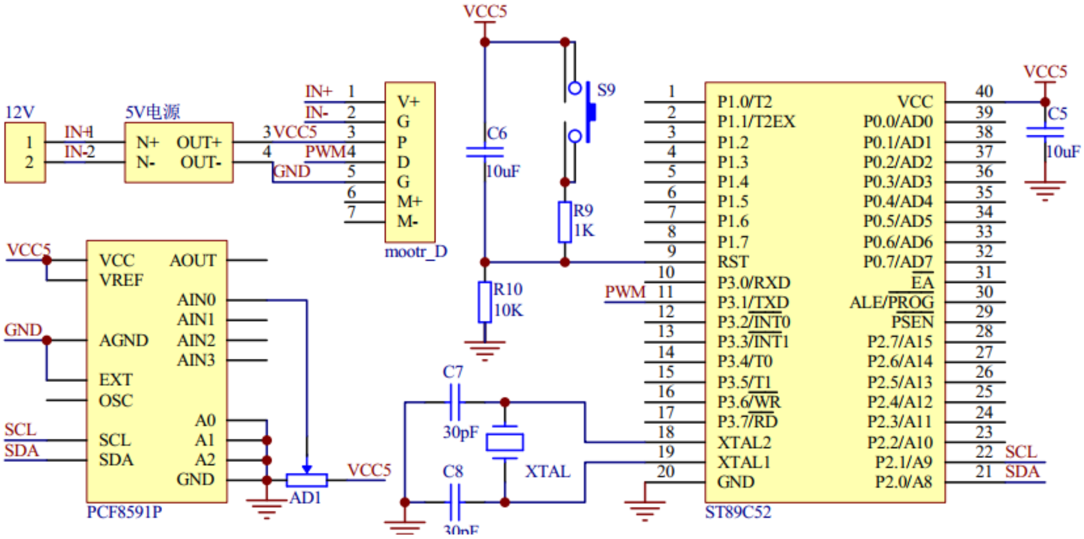

Fig3: Schematic diagram of simulation operation speed acquisition.

4.1.2 Host control system

The MK60DN512ZVLQ10 chip used is the microcontroller of ARM Cortex-M4 core. The host machine system uses the LCD to display the parameters after the key setting and system processing. The schematic diagram of the host control circuit is shown in Fig. 4.The actual measured thousand-grain weight and the actual required sowing quantity were set by keys. After the setting is completed, the correspondingplant spacing was automatically calculated and displayed by the control chip according to the corresponding relationship obtained from the previous theoretical calculation.Using timer interrupt acquisition of encoder pulse to complete the speed measurement, the acquisition frequency is 5 times per second, which means that the real-time speed calculation is performed 5 times per second and displayed on the LCD screen. Through the Bluetooth wireless transmission module, the seed spacing and the speed information collected in real time are sent to the slave machine for further processing.

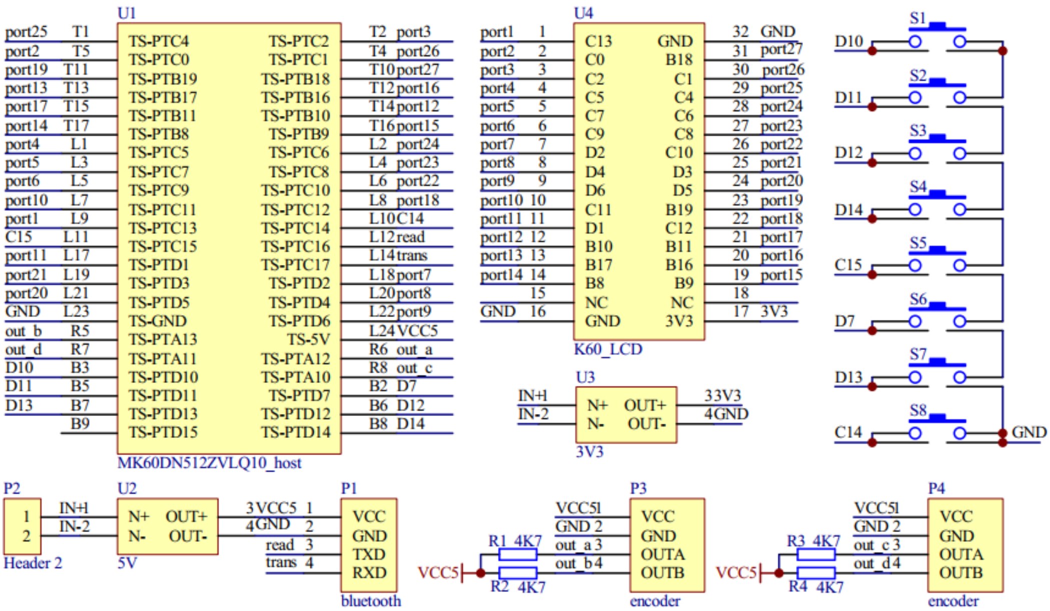

Fig 4: Schematic diagram of host machine circuit.

4.1.3 Slave control system

The schematic diagram of the slave control system is shown in Fig. 5. The MK60DN512ZVLQ10 chip is also used to receive the plant spacing and speed information through Bluetooth wireless transmission. The theoretical rotation speed of seeding shaft was calculated according to the corresponding relationship obtained from the previous theoretical calculation.

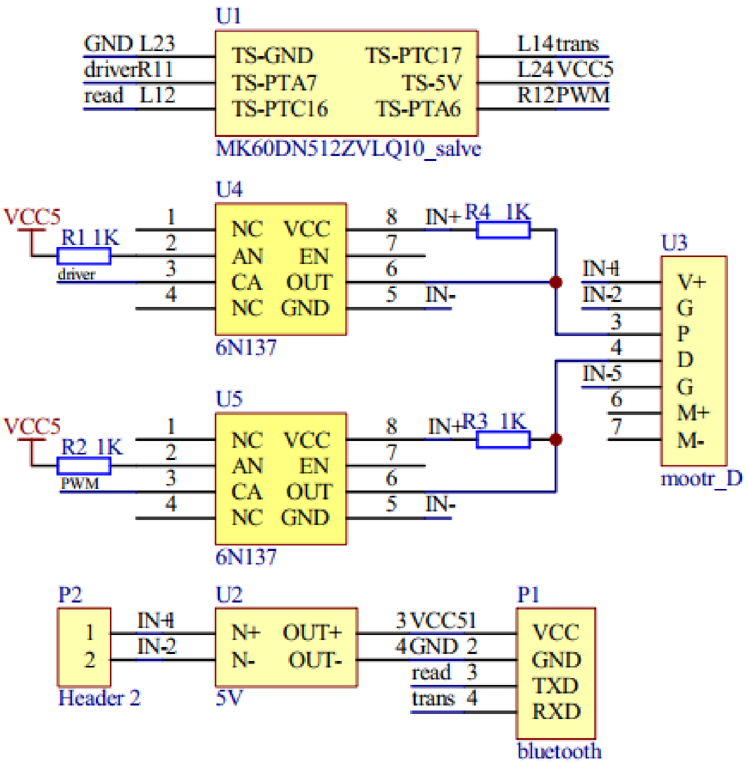

Fig5: Schematic diagram of slavemachine circuit.

The control chip dynamically adjusts the speed of DC motor by PWM signal, which is consistent with the calculated speed of the seeding shaft of the seeder, so as to achieve the purpose of changing the speed of the seeder and keeping the sowing quantity and seed spacing unchanged[14]. Because the voltage of driving DC motor is 12V, the voltage of control system is 5V and 3.3V, in order to isolate voltage shock and prevent current pouring, two photoelectric isolators 6N137 are designed in the slave machine system. The input and output of the photoelectric isolator are coupled by ‘light’, which hasgood electrical isolation characteristics and is suitable for occasions with high data transmission speed requirements.

4.2 Software flow chart of control system

The system starts to run after the initialization. During the operation of the program, the control chip realizes real-time speed measurement by rotary encoder.The operator can set the thousand-grain weight and sowing quantity at any time by pressing the key.After the real-time processing of the system, the corresponding parameters are displayed by LCD and the information of the seed spacing and the operating speed of the seeder is sent to the slave machine through Bluetooth module. After receiving information from the machine, the DC motor speed is adjusted in real time by PWM signal to control the seeding shaft to realize quantitative and fixed spacing seeding.The control system process is shown in Fig. 6.

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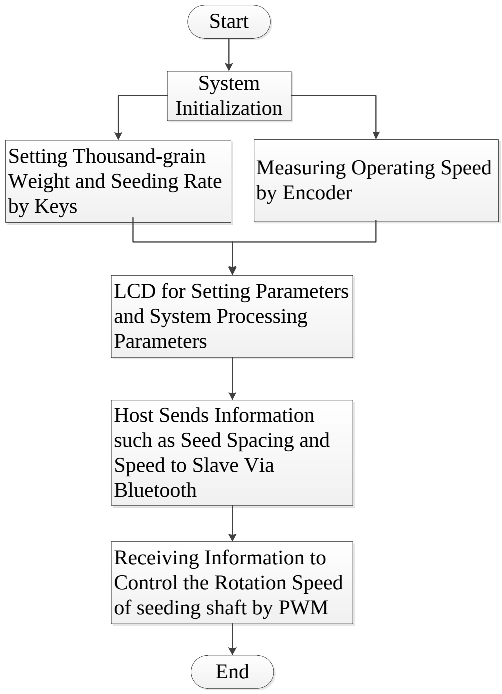

Fig6: Software flow chart of control system.

V. Experiment Simulation

5.1 Speed calibration of PWM speed-governing system for motor drive seeding shaft

PWM is pulse width modulation. Without changing the square wave period of PWM, the duty ratio of PWM is adjusted by adjusting the PWM control register of single chip microcomputer by software. Different duty ratios correspond to different speeds of DC motor [15-16]. When PWM adjusts the speed of DC motor, the frequency setting of PWM pulse is too low, which will lead to severe motor vibration.In order to reduce the vibration, it is necessary to improve the PWM frequency of the motor. The frequency set in the program is 10000Hz, because the minimum PWM pulse width time of the DC motor drive chip is 30us, so the duty ratio is less than 30 %.If you want to keep rotating, you can change the motor drive chip or adjust the PWM frequency [17]. In order to achieve the goal that the actual rotation speed of the seeding shaft is accurately rotated according to the theoretical rotation speed of the seeding shaft, the speed of the PWM speed control system of the motor-driven seeding shaft is calibrated. The relationship between rotational speed and duty ratio of metering shaft is measured by encoder, and the data are shown in table 1.

Table 1 The relationship between seeding shaft speed and duty ratio.

PWM duty ratio (%)	rotational speed of seeding shaft (r/min)
29	0
30	11.4
35	15.6
40	19.2
45	23.1
50	27.6
55	32.4
60	35.7
65	39.3
70	43.5
75	47.7
80	51.6

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85	55.5
90	59.4
95	63.3
100	69.6

According to the data obtained curve fitting, the results are shown in Fig. 7,

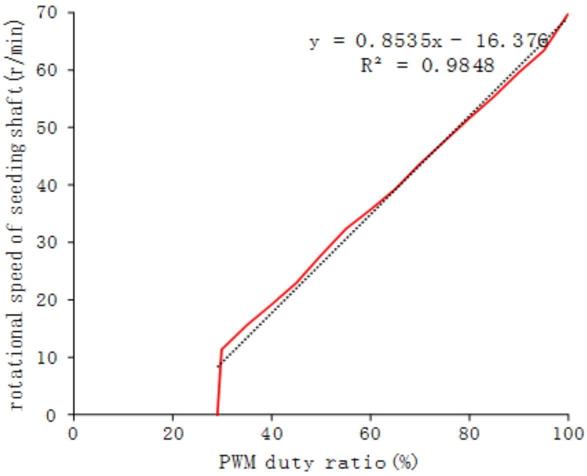

Fig 7: The fitting curve of rotational speed of seeding shaft and duty ratio.

It can be seen from the figure that the fitting curve is approximately a straight line [18], namely, the rotational speed of seeding shaft:

$$V = \frac{60V}{187D} r/\min = (0.8535X - 16.376)r/\min \tag{10}$$

X represents the duty ratio, whose value is between 30 and 100, because the duty ratio X has the value range, so for different seed spacing D have the corresponding seeder operating speed V suitable range. The corresponding relationship is written into the program [19]. After the slave in the control system receives the information of the operating speed V and the plant spacing D of the seeder, the corresponding duty ratio is obtained. The control chip uses this duty ratio to adjust the speed of the DC motor in real time to achieve the purpose of changing the operating speed of the seeder, changing the speed of the seeding shaft, and fixing the seeding amount and the seed spacing.

5.2 The rotational speed test of seeding shaft

When the seed spacing was 1.6 cm, the research content was tested. According to the previous formula, he suitable range of seeding speed was 1.56 km/h ~ 12.38 km/h. The theoretical seeding shaft speed and the actual seeding shaft speed are obtained under different operating speeds of the seeder, and the corresponding measurement data are shown in table 2 [20].

Table 2 The measurement data of rotational speed test of seeding shaft.

Seeder operating speed (km/h)	The rotational speed of theoretical seeding shaft (r/min)	The rotational speed of actual seeding shaft (r/min)
2.23	12.4	13.2
2.86	15.9	16.4
3.58	19.9	21.2
4.27	23.8	25.1
4.86	27.1	29.1
5.05	28.1	30.6
5.93	33	34.8
6.31	35.1	36
6.61	36.8	37.8

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7.19	40.1	40.8
7.29	40.6	41.4
8.74	48.7	48.9
9.42	52.5	53.1
10.01	55.8	56.1
10.3	57.4	58.2
11.27	62.8	63.3
12.13	67.6	68.6

Curve fitting is carried out according to Table 2, and the results are shown in Fig. 8. The test proves that the control chip can be used to intelligently control the rotation speed of seeding shaft through the PWM speed control system, which can achieve good results.

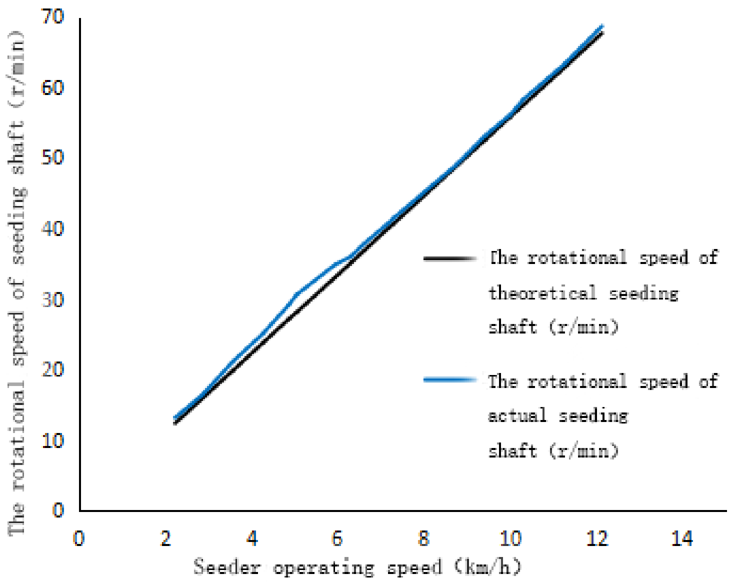

Fig8:The fitting curvediagram of rotation speed effect of seeding shaft.

VI. Conclusion

The system can set the seeding rate and thousand-grain weight parameters by keys, collect the operating speed of the seeder by encoder, and automatically calculate the seed spacing and the corresponding rotation speed of the seeding shaft, so as to achieve the purpose of changing the operating speed of the seeder and keeping the seeding rate and seed spacing unchanged. The conclusions are obtained through experiments:

(1) According to the information of seeding rate and thousand-grain weight, the seed spacing is calculated. For different seed spacing, the corresponding suitable operating speed of the seeder is obtained.
(2) There is only slighterror caused by vibration in the rotation speed of the theoretical and practical seeding shafts, which can meet the actual seeding requirements. Intelligent is the development direction of the future seeder, and the simulation design is a preliminary exploration, which needs further optimization design.

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