Multi-objective optimization design of wheat centralized seed feeding device based on particle swarm optimization (PSO) algorithm

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Abstract: In order to solve the problem of interaction between multiple evaluation indexes of seed metering performance under multiple factors of centralized seed feeding device, a multi-objective optimization of structure based on particle swarm optimization (PSO) algorithm was proposed in this paper. The wheat centralized seed feeding device was taken as the research object, and the experimental factors were cone angle of type hole, working speed and seed filling gap. The working process of wheat centralized seed feeding device was simulated by discrete element method (DEM). The average seed number of type hole, the variation coefficient of the average seed number of type hole, and the maximum tangential force between seed and seed feeding mechanism were selected as the evaluation indexes. Through the variance analysis of the evaluation indexes by the experimental factors, the optimization objective function was constructed. Using PSO algorithm, the multi-objective optimization was carried out for the wheat centralized seed feeding device. The optimization results show that the best structural combination parameters of the wheat centralized seed feeding device are the hole cone angle of 31.6° and the seed filling gap of 4.6 mm. The validity of the method was verified by simulation and field test. The results show that the PSO algorithm multi-objective optimization method proposed in this paper can provide a reference for the structural improvement and optimal design of the centralized seed feeding device.

Keywords: centralized seed feeding device, multi-objective, optimization, PSO algorithm

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1 Introduction

Wheat high-speed quantitative sowing technology has the advantages of saving time, saving cost and high efficiency, which has become the development direction of wheat machinery planting in Huang-Huai Region of China. As the core part of the pneumatic seeder, the wheat centralized seed feeding device has the advantages of strong seed adaptability, low seed injury rate and easy to achieve precision and wide in width operation, which has become the mainstream of the future development of the seeder. Scholars at home and abroad have done fruitful research on this.[1–4] Anantachara et al.[5] and Karayel et al.[6] optimized the structure of the seed chamber to improve the seed filling performance. Lei et al.[7,8] used DEM-CFD coupling method to analyze the influences of Venturi throat area, throat length, air inlet velocity and seed rate on the operation efficiency of pneumatic collective row seeder from two aspects of air field and seed movement. In order to reduce the complexity of the set row seeder, Liao et al.[9] developed a new type of precision seed metering device with inner inflation. Zhang et al.[10] designed a kind of seed suction plate with hole group by using the combination of positive and negative air pressure to improve the precision of seed metering. Andri et al.[11] studied the effects of air velocity, material flow rate, angle position of distributor head and different outlet pipe length on the distribution accuracy of distributor head. Han et al.[12] used the method of DEM-CFD coupling to analyze the primary and secondary factors of the location, width and average arc length of the lateral hole that affect the performance of the inner filling corn metering device. Liu et al.[13] designed a pinhole wheat precision sowing device and its seed absorption performance was studied. In the field of different disciplines, multi-objective optimization is more and more widely used. Zhou et al.[14] using the approximate model and genetic algorithm, the multi-objective optimization of the structure of tilt table maneuver of multirotor unmanned aerial vehicle (MUAV) is carried out to improve its lightweight and control accuracy. Hrvoje et al.[14] used the multi-objective optimization method to analyze the influence of fire and tax on the natural gas consumption of adiabatic boiler. Paul et al.[15] proposed a multi-objective optimization method aiming at the optimization problem in the design process of nuclear power plant. For the problem of gear ratio and torque distribution in the electric vehicle with two motors, the multi-objective optimization was carried out by Kihan et al.[16]
with the acceleration time and energy consumption as the evaluation indexes. The above shows that experts at home and abroad have made rich achievements in the study of pneumatic seed metering, but most of the existing studies are limited to the optimization of an evaluation index by a certain factor or several factors. In the actual working process of seeder, many evaluation indexes interact with each other, such as seed filling performance of seed metering device, coefficient of variation of seed metering and seed breakage rate. Therefore, further discussion is needed in this respect. In the calculation of multi-objective optimization, it is easy to fall into the local optimal value, so a global solution is needed. Particle swarm optimization (PSO) is one of the most popular optimization categories at present. Its principle is to find the global optimal solution by imitating the natural biological foraging process, which is used to provide innovative solutions to complex problems\cite{17-19}.

In brief, many experts have achieved some results in the aspect of centralized seed feeding device, but the multi-objective optimization influenced by interaction factors needs further discussion. Therefore, based on the concept of multi-objective optimization, this paper takes the previously designed wheat centralized seed feeding device as the research object\cite{20}, mainly doing the following work: (1) put forward the key experimental factors of seed filling gap, and discussed the influence law of seed filling gap, cone angle of type hole and working speed on the tender delivery of the central seeder, (2) constructed the multi-objective optimization function including average seed number of type hole, variation coefficient of the average seed number of type hole and maximum tangential force between seed and seed feeding mechanism; (3) based on the PSO algorithm considering the weight coefficient, the objective function is optimized. According to the optimization results, the field test was carried out. Therefore, this study can provide a reference for the structure design and performance improvement of the centralized metering device.

2 Working principle of wheat centralized seed feeding device

The structure of air-assisted centralized seed feeding system was composed of high pressure blower, seed box, centralized seed feeding device, Venturi feeding device, seed conveying pipe, booster pipe, distribution head, etc. as shown in Figure 1a. At working status, the high-pressure blower is used as the air supply device to continuously provide the required air pressure; the seeds of seed box were transported quantitatively by wheat centralized seed feeding device as the research object\cite{20}, mainly doing the following work: (1) put forward the key experimental factors of seed filling gap, and discussed the influence law of seed filling gap, cone angle of type hole and working speed on the tender delivery of the central seeder, (2) constructed the multi-objective optimization function including average seed number of type hole, variation coefficient of the average seed number of type hole and maximum tangential force between seed and seed feeding mechanism; (3) based on the PSO algorithm considering the weight coefficient, the objective function is optimized. According to the optimization results, the field test was carried out. Therefore, this study can provide a reference for the structure design and performance improvement of the centralized metering device.

1. High pressure blower  2. Seed box  3. Wheat centralized seed feeding device  4. Venturi tube  5. Booster pipe  6. Distributor  7. Seed delivery pipe  8. Double disc ditcher

a. Composition structure

b. Working principle block diagram

Figure 1 Working principle of air-assisted centralized seed feeding system

3 Materials and methods

3.1 Establishment of simulation model of wheat centralized seed feeding device

In order to explore the performance of the wheat centralized seed feeding device, the dynamic simulation model of the wheat centralized seed feeding device is built based on the DEM. Because the model structure is complex, some structures that do not affect the performance analysis are simplified. Select 100 seeds of three large-area wheat varieties planted in Huai Bei plain, and measure their length, width and thickness, as shown in Table 1. Determine the geometric size of the grain model based on the average value of the triaxial size of the wheat, and establish the wheat model with seven spheres, as shown in Figure 3. According to the materials selected for a wheat centralized seed

![Diagram](image-url)
feeding device, the shell is set as aluminum alloy, the type hole wheel is set as engineering plastic ABS (acrylonitrile butadiene styrene copolymer), the contact of the model is set as Hertz-Mindlin, and the relevant mechanical properties are obtained through the test, as shown in Table 2\(^1\).

| Varieties       | Length/mm | Width/mm | Thickness/mm |
|-----------------|-----------|----------|--------------|
| Yannong19       | 6.36      | 3.37     | 3.02         |
| Bainong207      | 6.46      | 3.62     | 3.22         |
| Wanmai68        | 6.46      | 3.24     | 2.90         |
| Jimai22         | 6.35      | 3.37     | 3.10         |
| Average         | 6.41      | 3.4      | 3.06         |

![Wheat seed model and Simulation model of wheat centralized seed feeding device](image)

**Figure 3** Simulation model

**Table 2** Parameter setting of contact model between materials

| Parameters properties | Parameters | Values |
|-----------------------|------------|--------|
| Particle properties   | Density/kg·m\(^{-3}\) | 822 |
|                       | Poisson’s ratio | 0.42 |
|                       | Shear modulus | 5.1×10\(^7\) |
| Engineering material ABS properties | Density/kg·m\(^{-3}\) | 1060 |
|                       | Poisson’s ratio | 0.394 |
|                       | Shear modulus | 2.7×10\(^7\) |
|                       | Density/kg·m\(^{-2}\) | 2700 |
|                       | Poisson’s ratio | 0.3 |
|                       | Shear modulus | 8.96×10\(^8\) |
|                       | Static friction coefficient between particles and particles | 0.35 |
|                       | Dynamic friction coefficient between particle and particle | 0.05 |
|                       | Recovery coefficient of particles and aluminum alloy | 0.5 |
| Properties of aluminum alloy materials | Static friction coefficient between particles and aluminum alloy | 0.4 |
|                       | Dynamic friction coefficient between particles and aluminum alloy | 0.05 |
|                       | Recovery coefficient of particles and engineering plastics ABS | 0.6 |
|                       | Static friction coefficient of particles and engineering plastics ABS | 0.4 |
|                       | Dynamic friction coefficient between particles and engineering plastics ABS | 0.05 |
| Other parameters      | Gravitational acceleration/m·s\(^{-2}\) | 9.81 |
|                       | Fixed time step/% | 25 |
|                       | Grid size/mm | 4 |

### 3.2 Evaluation index of seed filling performance

This paper selects three evaluation indexes: average seed number of type hole, variation coefficient of the average seed number of type hole and maximum tangential force between seed and seed feeding mechanism. The average seed number of type hole reflects the seed filling capacity of the seed feeding device, variation coefficient of the average seed number of type hole shows the seed filling stability of the seed feeding device, maximum tangential force between seed and seed feeding mechanism directly affects the damage rate of seeds. In order to ensure the reliability of the data, the data within 3.0-8.0 s after the simulation test were extracted for analysis. The calculation method of each evaluation index is as follows.

#### 3.2.1 Average seed number of type hole

Select the total number of seed and the total number of type holes from 3.0 to 8.0 s, and calculate the average seed number of type hole.

\[ Y_1 = \frac{M}{T} \]  

where, \( M \) is total number of seed; \( T \) is total number of type holes; \( Y_1 \) is average seed number of type hole.

#### 3.2.2 Variation coefficient of average seed number of type hole

The number of seed filling particles in a single hole from 3.0 s to 8.0 s was extracted, the standard deviation was calculated, and the variation coefficient of the average seed number of type hole was calculated.

\[ Y_2 = \frac{\bar{S}}{Y_1} \times 100\% \]  

where, \( \bar{S} \) is standard deviation; \( Y_2 \) is variation coefficient of the average seed number of type hole.

#### 3.2.3 Maximum tangential force between seed and seed feeding mechanism

The maximum tangential force between the seed and the seed feeding mechanism \( Y_3 \) in 3.0-8.0 s was extracted.

### 3.3 Simulation model verification

According to the test selection, the cone angle of type hole is 40°, the seed filling gap is 4mm, and the working speed is 50 r/min. In order to extract parameters easily, set the number of type hole wheel in DEM as 1, simulation time as 8.0 s, and generate 3000 wheat seeds in the first 1.0 s. At the 1.0 s, the type hole wheel starts to rotate, and the number of seeds in the 3.0-8.0 s type hole of Analyst post-processing module is extracted. The comparison between simulation and the bench test is shown in Figure 4. The bench test equipment is shown in Figure 5, mainly including bench, wheat centralized seed feeding device, TB86BL120-430 stepping motor (Changzhou Yuankong Ltd), i-SPEED 3 high-speed camera system (Japan OLYMPUS company), etc. The test material is Bainong 207, with the mass of 1000 grains is 51.19 g and moisture content of 8.07%. Select the same time period to extract data, calculate average seed number of type hole and variation coefficient of the average seed number of type hol.
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Figure 4 Comparison of simulation and bench test

1. Seed box 2. Wheat centralized seed feeding device 3. Stepping motor 4. Aggregate device 5. High-speed camera system 6. Bench

Figure 5 Bench test

4 Effect of experimental factors on performance index of wheat centralized seed metering device

In order to further explore the influence of different parameters on the seed metering performance of wheat centralized seed feeding device, orthogonal experiments were performed with cone angle of type hole and seed filling gap as experimental structural parameters, working speed as operating parameters, and average seed number of type hole, the maximum tangential force between seed and seed feeding mechanism and variation coefficient of the average seed number of type hole as evaluating indicator. The test factor level coding table is shown in Table 4. Create simulation tests under different combinations through Table 4, and the results of the tests are shown in Table 5.

Table 4 Experimental factors and level codes

| Level | \(X_1\) | \(X_2\) | \(X_3\) |
|-------|--------|--------|--------|
| 1.682 | 50     | 70     | 0.006  |
| +1    | 46     | 62     | 0.005  |
| 0     | 40     | 50     | 0.004  |
| -1    | 34     | 38     | 0.003  |
| -1.682| 30     | 30     | 0.002  |

Note: \(X_1\) is the code value of cone angle of type hole, (°); \(X_2\) is the code value of working speed, r/min; \(X_3\) is the code value of seed filling gap, m.
### Table 5: Experimental project and results

| Test No. | X1 | X2 | X3 | Y1 | Y2 | Y3 |
|----------|----|----|----|----|----|----|
| 1        | −1 | 1  | −1 | 2.49| 0.56| 0.8164 |
| 2        | 0  | 0  | −1.682 | 2.38| 1.66| 0.6542 |
| 3        | 1.682 | 0 | 0 | 3.32| 0.0013| 0.4107 |
| 4        | 0  | 0  | 0 | 3.85| 0.044| 0.4612 |
| 5        | 0  | 1.682 | 0 | 3.29| 0.035| 0.6602 |
| 6        | −1.682 | 0 | 0 | 2.79| 0.0064| 0.5216 |
| 7        | 0  | −1.682 | 0 | 3.65| 0.007| 0.3478 |
| 8        | 1  | −1 | 1 | 4.06| 0.035| 0.3625 |
| 9        | −1 | −1 | 1 | 3.27| 0.0012| 0.4143 |
| 10       | 0  | 0 | 0 | 3.83| 0.033| 0.4826 |
| 11       | −1 | 1 | 1 | 3.16| 0.0046| 0.7416 |
| 12       | 0 | 0 | 0 | 3.66| 0.055| 0.5532 |
| 13       | 1  | −1 | −1 | 3.77| 0.43| 0.5179 |
| 14       | 0 | 0 | 0 | 4.15| 0.039| 0.6602 |
| 15       | −1 | −1 | −1 | 2.75| 0.82| 0.3602 |
| 16       | 0 | 0 | 1.682 | 3.42| 0.02| 0.4778 |
| 17       | 1 | 1 | 1 | 3.88| 0.022| 0.5581 |
| 18       | 1 | 1 | −1 | 3.26| 0.33| 0.4861 |
| 19       | 0 | 0 | 0 | 3.97| 0.029| 0.5453 |

Note: Y1 is the average seed number of type hole, grain; Y2 is the maximum tangential force between seed and seed feeding mechanism. N: Y3 is the variation coefficient of the average seed number of type hole.

### Table 6: Analysis of variance of test factors to average seed number of type hole

| Variation source | SS  | df | MS   | F    | p      |
|------------------|-----|----|------|------|--------|
| Model            | 4.57| 9  | 0.51 | 9.35 | 0.0008** |
| X1               | 1.29| 1  | 1.29 | 23.71| 0.0007** |
| X2               | 0.20| 1  | 0.20 | 3.74 | 0.0818 |
| X3               | 1.08| 1  | 1.08 | 19.99| 0.0012** |
| X1 X2            | 0.013| 1  | 0.013| 0.24 | 0.6377 |
| X1 X3            | 9.8×10⁻³ | 1  | 9.8×10⁻³ | 0.18 | 0.6799 |
| X2 X3            | 0.029| 1  | 0.029| 0.53 | 0.4830 |
| X1²              | 0.84 | 1  | 0.84 | 15.40| 0.0028** |
| X2²              | 0.13 | 1  | 0.13 | 2.35 | 0.1563 |
| X3²              | 1.26 | 1  | 1.26 | 23.20| 0.0007** |
| Residual         | 0.54 | 10 | 0.054| –    | –      |
| Lack of fit      | 0.40 | 5  | 0.080| 2.86 | 0.1371 |
| Pure error       | 0.14 | 5  | 0.028| –    | –      |
| Total value      | 5.11| 19 | –    | –    | –      |

Note: SS is sum of squares; df is freedom; MS is mean squares; * shows this term is significant (0.01<p<0.05); ** shows this term is high significant (p<0.01).

### Table 7: Analysis of variance of test factors to maximum tangential force between seed and seed feeding mechanism

| Variation source | SS  | df | MS   | F    | p      |
|------------------|-----|----|------|------|--------|
| Model            | 2.98| 9  | 0.33 | 16.14| <0.0001** |
| X1               | 0.024| 1  | 0.024| 1.19 | 0.3080 |
| X2               | 7.616×10⁻³ | 1  | 7.616×10⁻³ | 0.37 | 0.5558 |
| X3               | 1.71 | 1  | 1.71 | 83.51| <0.0001** |
| X1 X2            | 2.578×10⁻³ | 1  | 2.578×10⁻³ | 0.13 | 0.7303 |
| X1 X3            | 0.056| 1  | 0.056| 2.75 | 0.1284 |
| X2 X3            | 0.015| 1  | 0.015| 0.75 | 0.4072 |
| X1²              | 4.643×10⁻³ | 1  | 4.643×10⁻³ | 0.23 | 0.6444 |
| X2²              | 2.036×10⁻³ | 1  | 2.036×10⁻³ | 0.099| 0.7591 |
| X3²              | 1.11 | 1  | 1.11 | 54.20| <0.0001** |
| Residual         | 0.21 | 10 | 0.021| –    | –      |
| Lack of fit      | 0.20 | 5  | 0.041| 369.84| <0.0001 |
| Pure error       | 5.528×10⁻³ | 5  | 1.106×10⁻⁴ | –   | –      |
| Total value      | 3.18| 19 | –    | –    | –      |

### 5 Multi-objective optimization design of wheat centralized seed feeding device

#### 5.1 Selection of design variables

Take cone angle of type hole, working speed and seed filling gap of wheat centralized seed feeding device as design variables.

\[ X = [X_1, X_2, X_3] = [\sigma, \eta_s, \eta_l] \]  

where, \( X_1 \) corresponds to variable cone angle of type hole \( \sigma \); \( X_2 \) corresponds to variable working speed \( \eta_s \); \( X_3 \) corresponds to variable seed filling gap \( \eta_l \).
5.2 Constraint condition

5.2.1 Design of the cone angle of type hole

In order to obtain the parabola curve, it is necessary to combine the seed filling angle, seed dropping angle and the key dimension of the type hole structure of seed filling device, and finally combine the position of the special point of the parabola to get the curve equation of the parabola as Equation (7), and the type hole structure is shown in Figure 6.

\[ y = x^2 \quad (x \in [-1.5402, 2.8393]) \]  

Figure 7 Structure curve of type hole

Due to the continuous movement of wheat seeds in the seed filling chamber in the form of discrete particles, the type hole can actively pick up multiple seeds with the rotation of the type hole wheel. Taking the particle system composed of multiple seeds filled into the type hole as the research object, it is assumed that the seeds are rigid bodies with uniform material, regardless of the friction and vibration between the research object and the population. The stress analysis is shown in Figure 7. The auxiliary coordinate system is established according to the normal and tangent directions of particle system motion, and its stress equation is as follows:

\[ \begin{align*}
N \cos \sigma &= N_p \sin \alpha + f \sin \sigma + G \cos \alpha \\
F_x + G \sin \alpha &\leq N_p \cos \alpha + f \cos \sigma + N \sin \sigma \\
f &= \mu N \\
F_i &= ma \omega^2 R \\
G &= mg \\
\omega &= \pi n_p / 30
\end{align*} \]  

Figure 8 Design of the cone angle of type hole

where, \(N\) is the support force of the side wall of the hole to the particle system, \(N_p\) is the lateral pressure of seed heap on the system of mass points, \(N\); \(f\) is friction force between particle system and type hole wheel, \(N\); \(F_i\) is inertial centrifugal force, \(N\); \(G\) is the gravity of particle system, \(N\); \(m\) is mass of particle system, \(kg\); \(\alpha\) is initial seed filling angle, (°); \(\sigma\) is cone angle of type hole, (°); \(\omega\) is angular velocity of type hole wheel, rad/s; \(R\) is radius of type hole wheel, m; \(\mu\) is the friction coefficient of contact surface between seed and wheel, take 0.55; \(n_p\) is the number of type hole wheel, r/min; \(g\) is the acceleration of gravity, m/s².

Table 8 Analysis of variance of test factors to variation coefficient of the average seed number of type hole

| Variation source | SS  | df | MS  | F    | P    |
|------------------|-----|----|-----|------|------|
| Model            | 0.26| 9  | 0.029| 5.72 | 0.0059** |
| \(X_1\)         | 0.026| 1  | 0.026| 5.18 | 0.0461*  |
| \(X_2\)         | 0.16 | 1  | 0.16 | 31.79 | 0.0002** |
| \(X_3\)         | 0.012| 1  | 0.012| 2.35 | 0.1560 |
| \(X_1/X_2\)     | 0.048| 1  | 0.048| 9.61 | 0.0113** |
| \(X_1/X_3\)     | 4.914 \times 10^{-6} | 1 | 4.914 \times 10^{-4} | 0.098 | 0.7602 |
| \(X_2/X_3\)     | 1.213 \times 10^{-3} | 1 | 1.213 \times 10^{-3} | 0.24 | 0.6329 |
| \(X_1^2\)       | 6.547 \times 10^{-3} | 1 | 6.547 \times 10^{-3} | 1.31 | 0.2790 |
| \(X_2^2\)       | 9.068 \times 10^{-4} | 1 | 9.068 \times 10^{-4} | 0.18 | 0.6791 |
| \(X_3^2\)       | 2.820 \times 10^{-3} | 1 | 2.820 \times 10^{-3} | 0.56 | 0.4698 |
| Residual        | 0.50 | 10 | 4.996 \times 10^{-3} | –– | –– |
| Lack of fit     | 0.026| 5  | 5.154 \times 10^{-3} | 1.07 | 0.4732 |
| Pure error      | 0.024| 5  | 4.838 \times 10^{-3} | –– | –– |
| Total value     | 0.31 | 19 | ––  | ––  | ––  |

5.2.2 Design of the seed filling gap

The particle system composed of several seeds in contact with the regulating plate is taken as the research object. Supposing that the seeds are rigid bodies with uniform material and the vibration between seeds is not considered. A mechanical model of seed filling process considering the effect of regulating plate is established, shown in Figure 8. According to the motion characteristics of the particle system, the auxiliary coordinate system is established, and the force formula is as Equation (11).

\[ \begin{align*}
F_x &= F_{t2} \sin \sigma + f_i + f_2 \\
F_{x1} + G_i &\geq F_t + F_{t2} \cos \sigma \\
f_i &= \mu F_{x1} \\
f_2 &= \mu F_{x2} \cos \sigma \\
G_i &= mg \\
F_t &= ma \omega^2 (H/2 + R)
\end{align*} \]  

Figure 9 Mechanical analysis of wheat seed filling process
where, $G_i$ is weight of seed pile, N; $\theta$ is the angle between the gravity direction of particle system and the $F_{\text{Ni}}$ direction, ($^\circ$); $f_i$ is friction between particle system and seed filling regulating plate, N; $f_2$ is friction between particle system and seed supply organization, N; $F_{T}$ is the support of indoor seeds to the particle system, N; $F_{\text{g}}$ is inertial centrifugal force, N; $m_i$ is mass of particle system, kg; $H$ is seed filling gap, m; $\mu$ is friction coefficient between wheat seed and aluminum alloy; $F_{\text{Ni}}$ is pressure of seed filling regulating plate on particle system, N; $N_i$ is support force of seed supply organization to particle system, N.

5.3.2 Multi-objective optimization

Based on the PSO algorithm, Equation (18) is optimized. The initial feasible solution number is 25, the population size is 100, the inertia weight is initialized to 0.95, the iterative algebra is 250, and the limit tolerance requirement is $10^{-5}$. The optimization results obtained after solving are shown in Table 9, and the optimization iteration is shown in Figure 9.

| Parameters                  | Before optimization | After optimization | Rate of change |
|-----------------------------|---------------------|--------------------|----------------|
| Cone angle of type hole     | 40                  | 31.6               | −21%           |
| Working speed               | 50                  | 50                 | 0              |
| Seed filling gap            | 0.004               | 0.0046             | 15%            |
| Average seed number of type hole | 3.85              | 3.72               | −3.4%          |
| Maximum tangential force    | 0.044               | 0.037              | −15.9%         |
| Variation coefficient of    | 0.4612              | 0.27               | −41.5%         |
| the average seed number     |                     |                    |                |
| of type hole                |                     |                    |                |
| Objective function value    | 0.2312              | 0.1721             | −25.56%        |

6 Field test

The optimized type hole wheel were made by 3D printing technology. Firstly, the bench test was carried out, the average number of hole particles and the variation coefficient of average seed number of type hole as the evaluation indexes. The comparison of the margin between the evaluation indexes before and after optimization is shown in Figure 10. It can be seen from Figure 10 that the margin between before and after optimization increases with the increase of working speed.

The field test was carried out in Huigu Town, Suzhou City, Anhui Province (116:97'E, 33:63'N) at Wanbei comprehensive test station of Anhui Agricultural University on October 19, 2018. The experimental area is corn field after cultivation. During the test, the wheat centralized seed feeding device is controlled by the self-designed electric control feedback control system, and the motor drives the power 1:1 to the driving sprocket of the seed feeding device through the chain drive, so as to realize the quantitative seeding. The width of the seeder is 2.2 m, the number of rows is 11, the traction power is FOTON LOVOL 900 tractor, and the driving speed is 5.4 km/h, Figure 11. According to the requirements of farmers, three kinds of field experiments were carried out, which were 382.5 kg/hm², 322.5 kg/hm² and 170 kg/hm². Seeding measurement was carried out on December 5, 2018, to measure the emergence rate of wheat under different sowing amounts, randomly select one square for plant measurement under different sowing amounts, randomly select three groups for measurement under the same sowing amounts, and the test data is shown in Table 10. The coefficient of variation of uniformity was less than 16%, compared with 21.97% before optimization, it was improved by 37.3%.
for using maximum tangential force between seed and seed feeding mechanism to study seed breakage rate.

(2) Compared with wheat centralized seed feeding device before and after optimization, the results of bench test show that the variation coefficient of the average seed number of type hole of wheat centralized seed feeding device after optimization are significantly reduced, and the field test shows that the uniformity variation coefficient of wheat centralized seed feeding device after optimization is higher than that before optimization 37.3%.

In addition to the factors considered in this paper, there are other external disturbances when the seed feeding device is operated in the field. For example, the vibration of machines and tools caused by the uneven ground, the air pressure instability caused by the uneven tractor power and other factors will affect its seed metering performance. Therefore, further research will be carried out on the performance of the centralized seed feeding device in the field operation.

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