

Optimization of Fertilizer Shunt Plate Structure Based on EDEM

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Abstract—In order to solve the problem of the uniformity of fertilization, the structural parameters of fertilizer shunt plate were optimized by EDEM. The variation coefficient of fertilization uniformity was used as an evaluation index of the fertilizer shunt plate. Simulation model of fertilizer shunt plate and evaluation model of fertilization effect was established. The influence of lift angle, distance between up and down, distance between left and right and distance from to top on the uniformity of fertilization on the uniformity of fertilization were analyzed, and the optimal results were obtained by orthogonal test. The results of fertilizer shunt plate under optimal structural parameters and original splitter plate showed that the variation coefficient of fertilization uniformity of chemical fertilizer particles was 17.2% and 12.7%, respectively. The effect of fertilization uniformity was improved by 35.4%. At the same time, it provides a feasible method for optimizing the different structural parameters of the fertilizer.

Keywords—the uniformity of fertilization; EDEM; fertilizer shunt plate; evaluation model of fertilization effect

I. INTRODUCTION

In recent years, with the improvement of national living standards and the change of consumption concept, people's demand for food has gradually decreased, and the demand for meat such as beef, mutton, eggs and milk has increased significantly. In 2016, Total production of meat (pig, cattle, sheep, birds) was 85.4 million tons in China, accounting for 27% of global production, and China has become the fourth largest dairy producer in the world [1-2]. From the overall trend, production of feed is increasing from 2000 to 2017, basically maintaining a doubling of development every five years[3]. Alfalfa is widely distributed in China. The yield level of China's alfalfa is 201-900 kg/hm². Compared with developed countries, the industry of alfalfa is still at a low level in China [4].

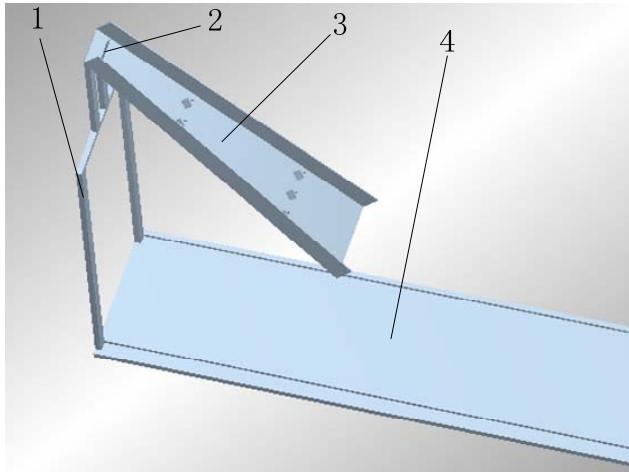
The growth of alfalfa requires chemical fertilizers. It is useful to increase the yield of alfalfa by applying some chemical fertilizers when planting alfalfa. Survey have shown that the uniformity of fertilization is of great significance for reducing the application rate of chemical fertilizers and increasing the yield of alfalfa [5-7]. Zuo Xingjian [8-9] et al. developed an accurate fertilizer control system based on real-time speed of work tools; Meng Zhijun [10-11] et al. developed a precise variable fertilization control system based on

prescription maps; Yuan Jin [12-13] et al. optimized the control algorithm of precision fertilizer; Zhu Qingzhen [14] et al. determined the law of influence. The law of influence is that the fertilizer performance is determined by the shape and parameters of slot wheel. Chinese researchers have made a lot of research on the precision fertilizer control system, this only solve the problem of fertilization precision, but can not solve the problem of uniformity of fertilization [15-16].

II. ESTABLISH A SIMULATION MODEL

A. Simulation Model of Fertilizer Shunt Plate

Fertilizers are ball-like particles with a sphericity of more than 90%. Therefore, the fertilizer particles can be replaced by spherical particles in the simulation model. The Poisson's ratio is set to 0.3, the shear modulus is 10⁶ Pa, the density is 1000 Kg/m², and the equivalent diameter is 2 mm. Fertilizers are generated by virtual factories in dynamic form. The virtual factory is set to 50mm long and 20mm wide according to the size of the actual area of the fertilization port. The virtual factory generates a total of 1000 chemical fertilizers with a production rate of 100 per second. According to the relevant literature, the coefficient of restitution, the coefficient of static friction and the coefficient of rolling friction between chemical fertilizer particles are 0.01, 1.25, 1.24 [17].



1. translational bracket 2.the factory of chemical fertilizer particles
3. fertilizer shunt plate 4. virtual soil

FIGURE I. SIMULATION MODEL OF FERTILIZER SHUNT PLATE

As shown in Fig.1, simulation model of the fertilizer shunt plate is established, which mainly includes the translational bracket, the factory of chemical fertilizer particles, the fertilizer shunt plate and the virtual soil. The translation bracket can simulate the traveling speed of the fertilizer, and the speed is set to 0.1m/s. The translational bracket is hinged with fertilizer shunt plate. Lift angle of fertilizer shunt plate can be adjusted in this way. The coefficient of restitution, the coefficient of static friction and the coefficient of rolling friction between chemical fertilizer particles and fertilizer shunt plate were 0.41, 0.32, and 0.18, respectively [18]. The virtual soil is convenient for counting the number of chemical fertilizer particles, and the coefficient of restitution, the coefficient of static friction and the coefficient of rolling friction between the chemical fertilizer particles and the soil are 0.02, 1.25, 1.24, respectively [19].

B. Evaluation Model of Fertilization Effect

Different evaluation indexes lead to different uniformity of fertilization, obviously. In order to accurately evaluate the uniformity effect of different structural parameters of the fertilizer shunt plate in the EDEM simulation test. As shown in Fig. 2, a sampling space of 200 mm × 200 mm × 20 mm randomly selected in the fertilization area is divided into 100 grid units (each grid unit size is 20 mm × 20 mm × 20 mm), and each unit is numbered.

	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	3	4	5	6	7	8	9	10	1
3	3	4	5	6	7	8	9	10	1	2
4	4	5	6	7	8	9	10	1	2	3
5	5	6	7	8	9	10	1	2	3	4
6	6	7	8	9	10	1	2	3	4	5
7	7	8	9	10	1	2	3	4	5	6
8	8	9	10	1	2	3	4	5	6	7
9	9	10	1	2	3	4	5	6	7	8
10	10	1	2	3	4	5	6	7	8	9

Note: 1~10 represent row and column No. of grid cells respectively

FIGURE II. DATE COLLECTION IN SAMPLING AREA

After the simulation, the number of fertilizers per grid unit is counted. Using formula (1), the average number of chemical fertilizer particles in the grid unit is solved separately.

$$\begin{cases} \bar{x}_i = \frac{1}{m} \sum_{j=1}^m x_{ij} \\ \bar{x} = \frac{1}{n} \sum_{i=1}^n \bar{x}_i \end{cases} \quad (1)$$

In the formula: \bar{x}_i represents the average number of chemical fertilizer particles for all grid units in the i-th row. \bar{x} represents the average number of chemical fertilizer particles in each column of grid units. x_{ij} represents the number of chemical fertilizer particles in the grid units of the i-th row and the j-th column. m represents the number of grids per row, m = 10. n represents the number of grids per column, n = 10.

Using formula (2), the standard deviation of the chemical fertilizer particles for all cells in the sampling area was calculated.

$$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (2)$$

In the formula: S represents the standard deviation of the chemical fertilizer particles in the grid unit of the sampling area.

Using formula (3), the variation coefficient of fertilization uniformity σ was calculated.

$$\sigma = \frac{S}{\bar{x}} \times 100\% \quad (3)$$

In the formula: σ is the variation coefficient of fertilization uniformity, %.

The variation coefficient of fertilization uniformity σ was selected as a parameter to evaluate the stability and the uniformity of fertilization. In the fertilizer applicator, the smaller the σ is, the better the effect of stability and uniformity is. According to the variation coefficient of fertilization uniformity σ , the performance of fertilizer shunt plate with different structural parameters was analyzed.

III. ORTHOGONAL EXPERIMENT

By analyzing the influence of differences of lift angle, distance between up and down, distance between left and right and distance from to top on the uniformity of fertilization. The structural parameters of the fertilizer shunt plate were optimized. In the orthogonal experiment, the optimal fertilizer shunt plate under different structural parameters was found by the variation coefficient of fertilization uniformity. The test factors and levels are shown in Table 1.

TABLE I. EXPERIMENTAL FACTORS AND LEVELS

Levels	A/ (°)	B/ (mm)	C/ (mm)	D/ (mm)
1	40	200	15	150
2	45	225	20	175
3	50	250	25	200
4	55	275	30	225
5	60	300	35	250

According to relevant data and experiments, there is no interaction between the various factors. This is an orthogonal experiment with 4 factors and 5 levels, so orthogonal table L25 (45) should be selected. The variation coefficient of fertilization uniformity σ of each experiment can be obtained by EDEM simulation, as shown in Table 2.

TABLE II. EXPERIMENTAL RESULTS

source	A	B	C	D	$\sigma/\%$
1	1	1	1	1	1.88
2	1	2	2	2	2.12
3	1	3	3	3	1.58
4	1	4	4	4	1.38
5	1	5	5	5	1.33
6	2	1	2	3	1.53
7	2	2	3	4	1.76
8	2	3	4	5	1.35
9	2	4	5	1	1.47
10	2	5	1	2	1.61
11	3	1	3	5	2.07
12	3	2	4	1	1.88
13	3	3	5	2	1.54

14	3	4	1	3	1.6
15	3	5	2	4	2.1
16	4	1	4	2	1.78
17	4	2	5	3	1.27
18	4	3	1	4	1.7
19	4	4	2	5	1.34
20	4	5	3	1	1.51
21	5	1	5	4	1.28

TABLE II. CONTINUE

22	5	2	1	5	1.65
23	5	3	2	1	1.82
24	5	4	3	2	1.8
25	5	5	4	3	1.7

As shown in Table 3, the primary and secondary factors affecting the uniformity of fertilization by the range analysis are obtained as C>A>D>B. The effect of fertilization uniformity is the best, when the C factor is the fifth level, the A factor is the fourth level, the D factor is the third level, and the B factor is the fourth level. Since the influence factor of B is the least, it has little effect on the overall effect, when any level of B is taken. Therefore, the B factor was taken to the second level, and the 17 sets of tests were optimized.

TABLE III. RANGE ANALYSIS

	A	B	C	D
K1	8.29	8.54	8.44	8.56
K2	7.72	8.68	8.91	8.85
K3	9.19	7.99	8.72	7.68
K4	7.6	7.59	8.09	8.22
K5	8.25	8.25	6.89	7.74
k1	1.66	1.71	1.69	1.71
k2	1.54	1.74	1.78	1.77
k3	1.84	1.6	1.74	1.54
k4	1.52	1.52	1.62	1.64
k5	1.65	1.65	1.38	1.55
Range	0.32	0.22	0.4	0.23
Best plan	4 level	4 level	5 level	3 level

IV. CONCLUSION

This paper describes a method for optimizing the uniformity of fertilization through EDEM simulation. The effect of fertilization uniformity is decided by factors such as lift angle, distance between up and down, distance between left and right and distance from to top. Simulation model of fertilizer shunt plate and evaluation model of fertilization effect was established through EDEM. The optimal fertilizer shunt plate under different structural parameters was determined by orthogonal experiment (DOE). Compared with the existing

fertilizer shunt plate, the variation coefficient of fertilization uniformity was 12.7% and 17.2%, respectively. The effect of fertilization uniformity was improved by 35.4%, as shown in Fig.3. At the same time, it provides a feasible method for optimizing the different structural parameters of the fertilizer.

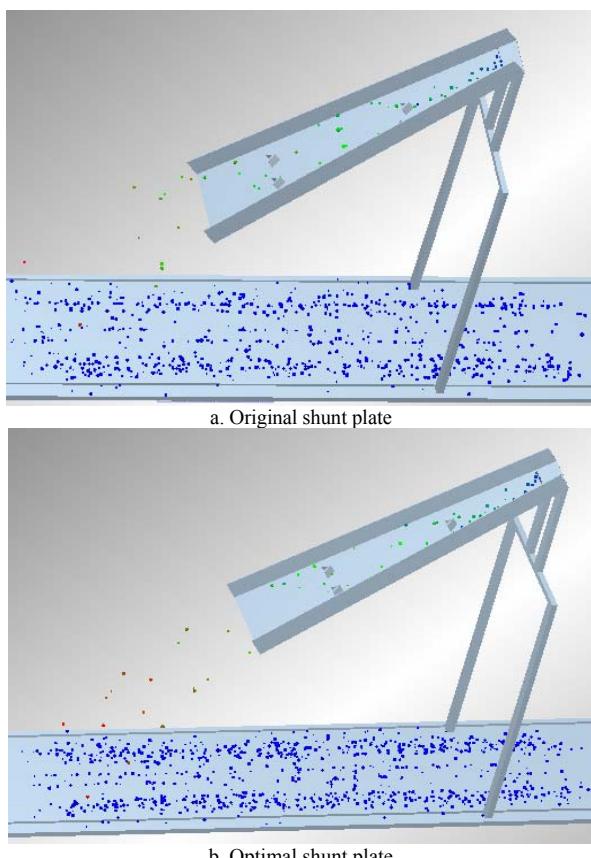


FIGURE III. RESULTS OF SIMULATION

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