*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

# Research on Structure Optimization of Plow Discharger of Belt Conveyor Based on DEM

**Yang Mingliang[1]*, Yang Ning [1], Zhang Zhengwei[2]**
[1]School of Mechanical Engineering, Taiyuan University of Science and Technology, Taiyuan, Shanxi, China
[2]Department of Mechanical and Electrical Engineering, Shanxi Institute of Energy, Jinzhong, Shanxi, China
* Yang Mingliang

***Abstract:***

The belt conveyor is important equipment in the coal mine conveying system. During the conveying process, the plow discharger has problems such as spreading, clogging, and dust pollution. Aiming at these problems, a curved plow discharger head structure is proposed. Through EDEM simulation, the influence of different structural parameters on unloading efficiency is analyzed. The orthogonal test method is used to determine the effect of each parameter, and the optimal parameter combination model is obtained. The research results show that: changing the structural parameters of the plowshare can directly affect the unloading efficiency; the optimized structure of the plow discharger can effectively improve the problems of spreading, clogging, and dust pollution.

***Keywords****: EDEM simulation, belt conveyor, plow discharger, orthogonal test, structure*

*Optimization.*

## I. INTRODUCTION

Belt conveyor is an important bulk material conveying equipment, its performance directly affects industrial production efficiency. In the process of bulk material conveying, many occasions require multi-point unloading in the middle of the belt conveyor. In China, plow dischargers are mainly used for multi-point unloading in the middle. The plow discharger has the characteristics of simple structure, convenient use, and easy automatic control, which can greatly improve the conveying efficiency of the conveyor. However, due to the uneven instantaneous feeding of materials, the uneven particle size of materials, and the adhesion of materials with water, problems such as material leakage, blocking and dust pollution often occur, which reduces the safety, stability, and efficiency of material transportation. Based on this, the discrete element method is used to analyze the unloading process of the plow discharger, the influence of each parameter on the unloading efficiency is obtained, and the structure optimization scheme of the plow discharger is proposed.

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

The traditional plow discharger plowshare structure is designed based on engineering experience, and its unloading performance cannot be fully exerted in the actual application process. In 2017, Lu Zhongke proposed to change the front end of the plowshare of the plow discharger from a circular arc to a sharp angle to reduce the contact area with the coal flow, thereby reducing the accumulation of coal flow in front of the plow discharger, to reduce the amount of coal flow. To achieve the purpose of reducing material scattering, and at the same time install the eaves above the plowshares to improve the problem of turning over materials. This method has achieved good results in actual production, but the method is to transform the plow discharger that has been put into use, which makes the process more complicated and increases the equipment cost and manpower. In 2019, Wei Yi et al. proposed an optimized design scheme to optimize the angle between the unloading plowshare and the conveyor belt. The method used EDEM software to simulate the unloading process of the angle between the different plowshares and the conveyor belt, and compared the unloading process. The angle between the plowshare and the tape corresponding to the best unloading performance can be obtained from the trajectory and the unloading speed, which has a certain guiding significance for the design of the plow discharger plowshare. However, only optimizing the angle between the plowshare and the belt has certain limitations on the improvement of the discharge performance. In 2019, Yu Bo et al. proposed an improved design that changed the straight-line plowshare to a curved shape. The principle is that the material at the front end of the plowshare will be restrained by the curve when unloading so that the material will move in the direction of the guide plate and improve the material scattering phenomenon. However, no specific curve parameters were explored. For the above research status, this paper comprehensively considers the influence of three parameters, including the angle of the guide plate, the radian of the surface of the guide plate, and the radius of the surface of the guide plate, on the discharge performance. Determine the optimal parameter combination and verify its effect through simulation.

## II. THE ESTABLISHMENT OF THE SIMULATION MODEL

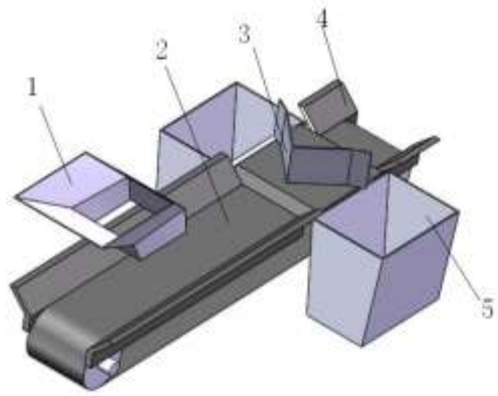
### 2.1 Establishment of Numerical Model for Middle Discharge of Belt Conveyor

Taking the multi-point unloading in the middle of a certain type of belt conveyor as the research object, the unloading simulation is carried out by EDEM software, and the motion state of the material during the unloading process is analyzed. The main data required for the simulation are as follows.

Material: coal; Bulk density: $2.4t/m^3$; Particle size: 50mm; Angle of repose: 45°; Conveying capacity: 1500t/h; Belt speed: 3.15m/s; Bandwidth: 1400mm; Elevation angle 0°.

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

As shown in Fig.1, a simplified three-dimensional model of the middle discharge of the belt conveyor is established with SolidWorks software.




1. Feeding hopper; 2. Conveyor belt; 3. Plow discharger head; 4. Rack; 5. Unloading hopper

Fig.1: 3D model of belt conveyor

2.2 Parameter calibration of material shape

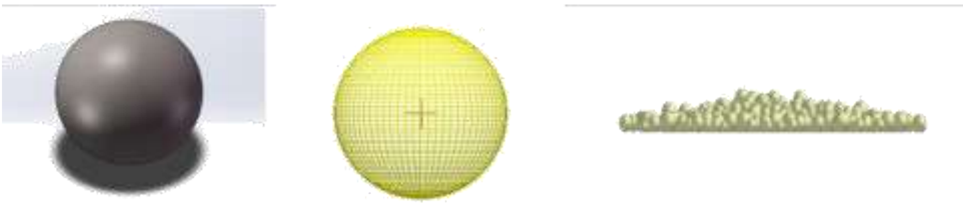
In the discrete element simulation software EDEM, the initial particle shape is spherical, which has a large deviation from the shape of the actual simulation material. To make the simulation parameters more realistic and the simulation results more credible, the simulation material is usually constructed by 3D modeling software. Appearance contour, and then save the appearance contour of the simulated material in a format that can be recognized by the EDEM software. In the method of filling the EDEM software with spherical particles, the shape of the simulated material particles can be constructed to simulate the actual bulk material shape to the greatest extent.

The approximate shape of the simulated material and the bulk material is a necessary condition to obtain its properties. During the stacking process of bulk materials, the material forms a cone on the horizontal plane, and the angle between the free surface of the cone and the horizontal plane is defined as the angle of repose. The angle of repose is closely related to the friction coefficient, viscosity, density, shape, and surface area of the material, and is the most basic property of the material. To make the shape of the simulated material as close to the real material as possible, the angle of repose formed by the natural accumulation of simulated materials is simulated by filling material particles of various shapes. Approaching a shape as a simulated material shape.

In this paper, coal is used as the simulated material. To obtain a simulated material shape that is closer to the real shape of the material, this paper conducts a simulation experiment on the angle of repose of four

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

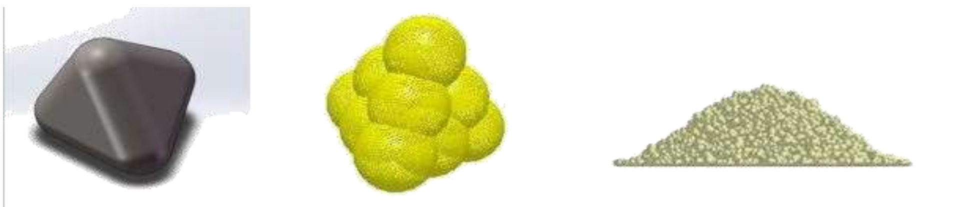
different shapes of materials and uses spherical particles to form the other four different shapes of materials. Because the more complex the shape of the material in the discrete element simulation software EDEM, the longer the simulation time will be. Considering the problem of simulation efficiency, four simple particle models of spherical, triangular-like, cube-like, and regular tetrahedral-like shapes are established and coal Perform angle of repose comparison. The filling and stacking effects of simulated materials of different shapes are shown in Fig.2.



(a) Filling and packing effects of spherical particles

(b) Filling and stacking effects of quasi-cubic particles

(c) Filling and stacking effects of triangular-like particles



(d) Filling and packing effects of tetrahedral-like particles

Fig. 2: Material filling and accumulation effect

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

The angle of repose of materials of various shapes is shown in Fig.3.The angle of repose of the material in the shape of a regular tetrahedron is 42.5°, and the angle of repose of coal is 45°. Therefore, the particle model of the quasi-regular tetrahedron is selected as the material for the unloading simulation in this paper.

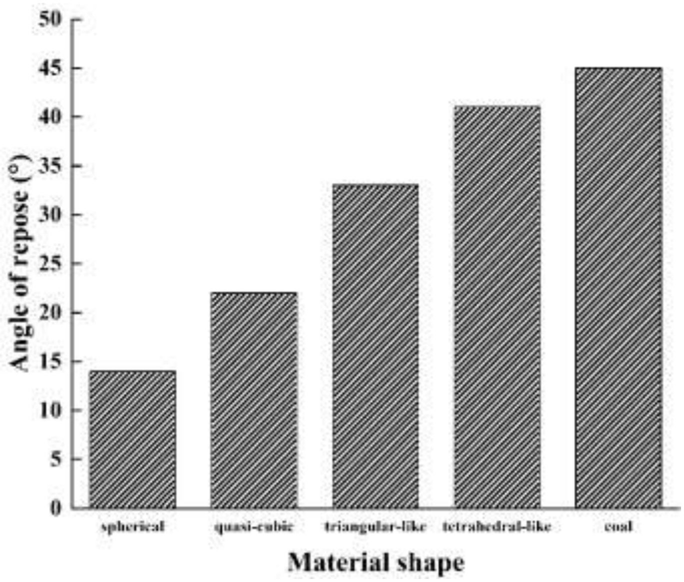
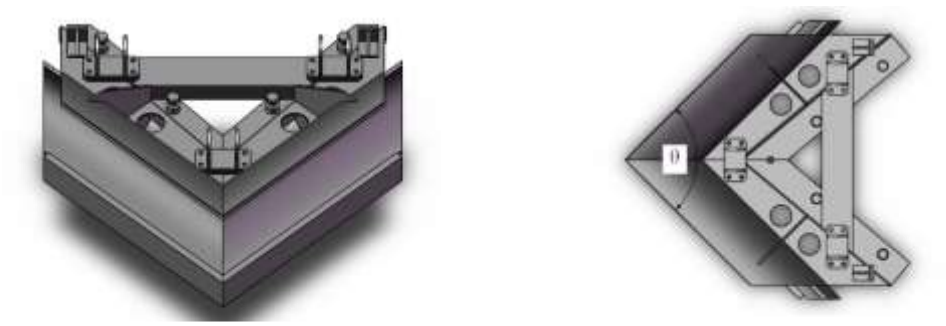


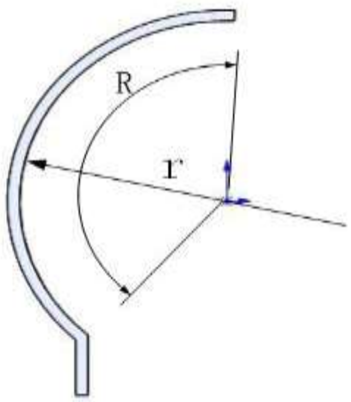

Fig.3: Angle of repose of materials of various shapes

The structure of the curved plow discharger is shown in Fig.4. It can be seen from Fig.4(b) that the plowshare part is formed by splicing two curved guide plates at an angle. From Fig.4 (c), it can be seen that the curved guide plate has a radius of r. It is composed of a semicircular arc surface with a radian of R.



(a) Curved plow discharger (b) The angle of the plow guide plate

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*




(c) Structural parameters of the curved surface of the plow discharger

Fig.4: Curved plow discharger Model

The plowshare consists of two guide plates. The guide plate is in the form of a curved surface. Due to the introverted curve of the front material, the material flows in the inclined direction, which can effectively improve the problem of material scattering; the upper part of the guide plate is curved inward, which can effectively squeeze the material when discharging. Pressing the material, destroying the material accumulation, can effectively improve the blocking phenomenon.

2.3 EDEM simulation parameters

The material parameters during the simulation are shown in TABLE I, and the contact parameters between the materials are shown in TABLE II.

**TABLE I. SIMULATION MATERIAL PARAMETERS**

| **PARAMETERS** | **POISSON'S RATIO** | **SHEAR MODULUS /PA** | **DENSITY/KG/$m^3$** |
|---|---|---|---|
| coal | 0.3 | $1.98\times10^{9}$ | 1540 |
| steel | 0.3 | $7.9\times10^{10}$ | 7800 |
| rubber | 0.47 | $2.67\times10^{6}$ | 1200 |

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

**TABLE II. CONTACT PARAMETERS OF EACH MATERIAL**

| CONTACT PARAMETERS | COAL - COAL | COAL-RUBBER | COAL-STEEL |
|---|---|---|---|
| Crash recovery factor | 0.5 | 0.4 | 0.5 |
| Static friction factor | 0.4 | 0.9 | 0.35 |
| rolling friction factor | 0.05 | 0.1 | 0.05 |

Save the 3D model of the unloading in the middle of the belt conveyor as “igs” file format, import it into the discrete element simulation software EDEM, and then set the material parameters, model material parameters, contact parameters, establish a suitable particle factory, set the appropriate simulation time and Raleigh time step, select the time interval for saving the simulation data, and finally start the simulation. The pellet factory generates material particles at the upper end of the feed hopper, then falls into the feed hopper at a certain initial speed, calves to the conveyor belt, and is transported to the unloading position through the conveyor belt. In the unloading hopper, the material completes the entire unloading process. Fig.5 is the EDEM discharge simulation model.

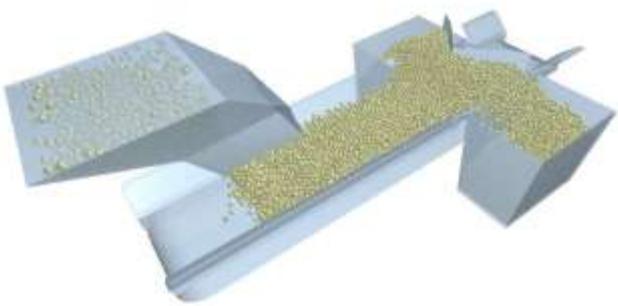


Fig.5: EDEM unloading simulation model

## III SIMULATION OF THE UNLOADING PROCESS OF THE PLOW DISCHARGER

### 3.1 Judgment indicators

To evaluate the performance of plow discharger during the unloading process, select the following three indicators:

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

(1) Material leakage quality: the weight of the material that did not fall into the unloading hopper due to various reasons during the unloading process. In the index of discharge performance, the quality of the material directly reflects the quality of the discharge performance.

(2) The speed of the material along the unloading direction: the higher the speed of the material along the unloading direction after contacting the plow discharger, the better, it can quickly fall into the unloading hopper, reducing the time for the material to accumulate on the conveyor belt, thereby effectively reducing the spread material and clogging problems.

(3) The speed of the material along the conveyor belt: the smaller the speed of the material along the conveyor belt after contact with the plow discharger, the better, the smaller the speed of the material along the conveying direction at the discharge port, the smaller the material flow section, the easier it is Falling into the unloading hopper, at the same time, the particles with smaller particle size are not easy to get out of the material flow, and the dust pollution will be improved to a certain extent.

The decomposition of the material velocity at the discharge port is shown in Fig.6.

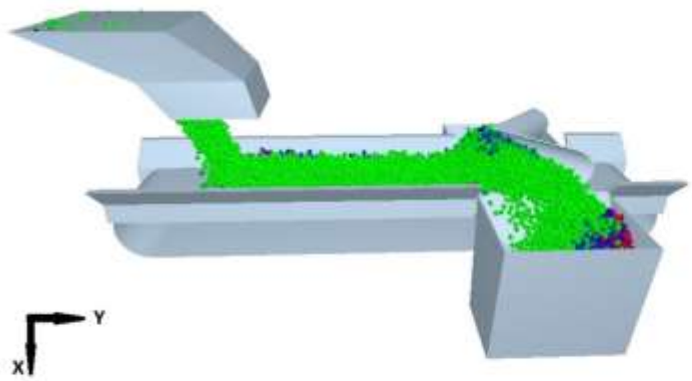
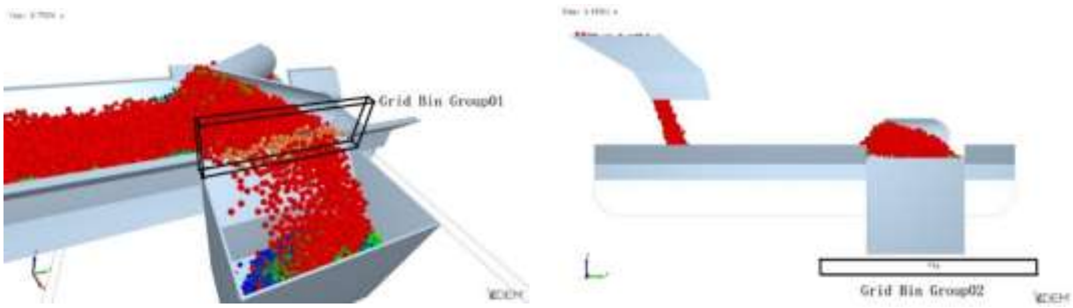



Fig.6: Schematic diagram of the speed decomposition of the discharge port

As shown in Fig.7, a Grid Bin Group monitoring unit is created at the discharge port to monitor the speed of the material at the discharge port, and a Grid Bin Group monitoring unit is established at the bottom of the belt conveyor to monitor the quality of the material during the discharge process.

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*




(a) Monitoring material velocity (b) Monitoring the quality of the leakage

Fig.7: Schematic diagram of the location of the monitoring unit

3.2 Influence of angle of the guide plate on the discharge performance

To obtain the variation law of the discharge performance with the included angle of the guide plate, the simulation was carried out at 5° intervals in the range of 80°~100°. The variation of the included angle is shown in TBALE III.

**TABLE III. CORRESPONDING EVALUATION INDEX VALUE OF GUIDE PLATE ANGLE**

| GUIDE PLATE ANGLE | SPEED IN X DIRECTION(M/S) | SPEED IN Y DIRECTION(M/S) | LEAKAGE QUALITY (KG) |
|---|---|---|---|
| 80° | 1.37667 | 1.17627 | 2.93898 |
| 85° | 1.37191 | 1.04828 | 0.30937 |
| 90° | 1.38036 | 0.88981 | 0.15468 |
| 95° | 1.37775 | 0.83481 | 0.30937 |
| 100° | 1.36870 | 0.71950 | 0.92810 |

It can be seen from Table 3 that with the increase of the included angle of the guide plate, the speed of the material at the discharge port along the X direction changes very little and maintains a stable state; the speed along the Y direction shows a decreasing trend; Small and then slightly increased. It shows that with the increase of the included angle of the guide plate, the speed of the material in the Y direction decreases when the material is unloaded, the cross-section of the material flow decreases, the material scattering, and dust pollution decrease, and the effect on the speed of the material in the X direction is small. Properly increasing the included angle of the guide plate can effectively improve the occurrence of material scattering.

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

3.3 Influence of radian of the curved surface on the discharge performance

To obtain the variation law of the discharge performance with the radian of the curved surface of the guide plate, in the interval of 130°~150°, simulation calculations are carried out at 5° intervals, and the speed along the X direction and the speed along the Y direction with the radian of the curved surface of the guide plate are obtained. The situation is shown in TBALE IV.

**TABLE IV. CORRESPONDING EVALUATION INDEX VALUE OF CURVED SURFACE RADIAN**

| CURVED SURFACE RADIAN | SPEED IN X DIRECTION(M/S) | SPEED IN Y DIRECTION(M/S) | LEAKAGE QUALITY (KG) |
|---|---|---|---|
| 130° | 1.37598 | 0.93332 | 0.30937 |
| 135° | 1.40954 | 0.95673 | 0.46405 |
| 140° | 1.39057 | 0.93818 | 0.30937 |
| 145° | 1.38235 | 0.95187 | 0.61873 |
| 150° | 1.36764 | 0.92762 | 0.46405 |

It can be seen from Table 4 that with the increase of the radian of the surface, the speed of the material at the discharge port along the X direction increases first and then decreases; the speed along the Y direction remains stable; the quality of the material has a certain range of change. It shows that with the increase of the radian of the surface, the speed of the material along the X direction is the largest at 135°, and the discharge performance is the best, while the effect on the speed of the material along the Y direction is small, and the quality of the material is leaked when the radian of the surface is 130° and 140°. close and minimal.

3.4 Influence of radius of the curved surface on Unloading Performance

To obtain the variation rule of the discharge performance with the radius of the curved surface of the guide plate, in the interval of 250~290mm, the simulation calculation was carried out at 10mm intervals, and the change of the speed of the material along the X direction and the speed along the Y direction with the radius of the curved surface of the guide plate was obtained. As shown in TBALE V.

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

**TABLE V. CORRESPONDING EVALUATION INDEX VALUE OF CURVED SURFACE RADIUS**

| CURVED SURFACE RADIUS(MM) | SPEED IN X DIRECTION(M/S) | SPEED IN Y DIRECTION(M/S) | LEAKAGE QUALITY (KG) |
|---|---|---|---|
| 250 | 1.38517 | 0.9178 | 0.15468 |
| 260 | 1.38362 | 0.95204 | 0.15468 |
| 270 | 1.4157 | 0.99554 | 0.15468 |
| 280 | 1.40643 | 1.00905 | 0.46405 |
| 290 | 1.43569 | 1.04471 | 0.46405 |

It can be seen from Table 5 that with the increase of the radius of the surface, the speed of the material at the discharge port along the X direction generally increases, but the change is not large; the speed along the Y direction shows an obvious increase trend; Increase after stability. It shows that with the increase of the radius of the curved surface of the guide plate, the performance of the material along the X direction during unloading is improved to a certain extent; but the speed of the material along with the Y direction increases, the material flow section becomes larger, and the dust pollution is aggravated. The radius of the curved surface is 250mm, 260mm, and 270mm, the spread quality is the same and minimal.

## IV. STRUCTURE OPTIMIZATION OF PLOW DISCHARGER

### 4.1 Orthogonal experiments

To determine the optimal combination parameters of the plowshare structure and the influence of each factor on the discharge performance, and to reduce the number of simulations, the above structural parameters were analyzed by orthogonal experiments. Establish the structure factors and level data table of the plowshare as shown in TBALE VI below.

**TABLE VI. STRUCTURAL FACTORS AND LEVEL DATA TABLE**

| FACTORS | GUIDE PLATE ANGLE(°) | CURVED SURFACE RADIAN(°) | CURVED SURFACE RADIUS(MM) |
|---|---|---|---|
| LEVEL 1 | 80 | 130 | 260 |
| LEVEL 2 | 90 | 140 | 270 |
| LEVEL 3 | 100 | 150 | 280 |

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

A reasonable selection of experimental factors and levels can quickly and accurately obtain the optimal combination, which is convenient for experimental processing. Select the orthogonal test table with three factors and three levels as shown in TBALE VII below.

**TABLE VII. $L_9$ ORTHOGONAL TABLE**

| TEST SERIAL NUMBER | A | B | C |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 |
| 3 | 1 | 3 | 3 |
| 4 | 2 | 1 | 3 |
| 5 | 2 | 2 | 1 |
| 6 | 2 | 3 | 2 |
| 7 | 3 | 1 | 2 |
| 8 | 3 | 2 | 3 |
| 9 | 3 | 3 | 1 |

According to the orthogonal experiment table in Table 7, three-dimensional models of different parameter combinations are established, and then imported into EDEM for simulation calculation, and the discharge performance parameters are obtained, including the speed of the material along the X direction, the speed along the Y direction, and the mass of the material. The experimental scheme and its corresponding experimental results are shown in TABLE VIII below.

**TABLE VIII. TEST PLAN AND TEST RESULTS**

| MODEL | A(°) | B(°) | C(MM) | SPEED IN X DIRECTION(M/S) | SPEED IN Y DIRECTION(M/S) | LEAKAGE QUALITY(KG) |
|---|---|---|---|---|---|---|
| 1 | 1(80) | 1(130) | 1(260) | 1.342 | 1.125 | 3.403 |
| 2 | 1(80) | 2(140) | 2(270) | 1.384 | 1.250 | 2.784 |
| 3 | 1(80) | 3(150) | 3(280) | 1.357 | 1.254 | 5.723 |
| 4 | 2(90) | 1(130) | 2(270) | 1.411 | 0.994 | 0.155 |
| 5 | 2(90) | 2(140) | 3(280) | 1.407 | 1.006 | 0.309 |

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 2(90) | 3(150) | 1(260) | 1.388 | 0.917 | 0.773 |
| 7 | 3(100) | 1(130) | 3(280) | 1.406 | 0.776 | 0 |
| 8 | 3(100) | 2(140) | 1(260) | 1.403 | 0.771 | 0.464 |
| 9 | 3(100) | 3(150) | 2(270) | 1.404 | 0.760 | 0.309 |

4.1.1 Range analysis

Range analysis is an intuitive analysis method to determine the influence of different levels of the same factor on test indicators. When analyzing a factor, the influence of other factors is considered to be balanced, and then the difference of each level of the factor is considered to be positive. caused by the factor itself. Analyzing the orthogonal test results by the range analysis method can obtain the order of the influence of each factor on the test index within the scope of the experiment; the changing trend of the experimental index with the change of each factor; at the same time, the obtained conclusions are discussed in a deeper level. The following table 9 is the X-direction speed range analysis table

**TABLE IX. X-DIRECTION SPEED RANGE ANALYSIS TABLE**

| **MODEL** | **A** | **B** | **C** |
|---|---|---|---|
| $T_1$ | 4.083 | 4.159 | 4.133 |
| $T_2$ | 4.206 | 4.194 | 4.199 |
| $T_3$ | 4.213 | 4.149 | 4.170 |
| $t_1$ | 1.361 | 1.386 | 1.378 |
| $t_2$ | 1.402 | 1.398 | 1.400 |
| $t_3$ | 1.404 | 1.383 | 1.390 |
| $R$ | 0.130 | 0.045 | 0.066 |
| EXCELLENT SOLUTION | $A_3$ | $B_2$ | $C_2$ |

in the table：

$$T_i = A_i + B_i + C_i$$

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

$$t_i = T_i / p$$

$$R = \max(T_i) - \min(T_i)$$

in the formula:

$T_i$—— the sum of the velocity values along the X direction at the $i$ level;

$t_i$——the average value of the speed along the X direction at the $i$ level;

$p$——number of factors;

$R$——range value.

TABLEIX shows the analysis table of the speed range of the material at the discharge point along the discharge direction. In the table, $T_i$ refers to the sum of the speed values along the discharge direction at the $i$ level, and $t_i$ refers to the speed value along the discharge direction at the $i$ level. The value of $T_i$ can determine the specific level under each test factor that can show the best discharge performance. In this test, the higher the speed of the material along the unloading direction (X direction), the better, so that the material can quickly fall into the unloading hopper to avoid accumulation, thereby effectively reducing the occurrence of material scattering and turning over, and maintaining high-efficiency unloading material process. In this experiment, the optimal parameter combination among the three factors of A, B, and C is $A_3B_2C_2$. At this time, the speed of the material along the unloading direction is the largest. The specific parameters are that the angle of the guide plate is 100°, the radian of the surface of the guide plate is 140°, and the radius of the surface of the guide plate is 270mm.

$R$ is the extreme difference value, which represents the difference between the maximum value and the minimum value of the discharge performance index value of any structural factor of the guide plate at different levels, that is $R = \max(T_i) - \min(T_i)$.The size of $R$ represents the ability of different factors to affect the discharge efficiency during the discharge process. The larger the value of $R$, the greater the influence ability of the factor on the test index, and the more important the factor is.

According to the range analysis in TABLEIX, it can be seen that the three factors of the plowshare structural parameters affect the speed of the material along the X direction in the order of A>C>B, that is,

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

the angle of the guide plate is the largest, the radius of the curved surface of the guide plate is second, and the radian of the curved surface of the guide plate is minimum.

The smaller the speed of the material along the conveyor belt direction (Y direction) at the discharge point of the unloading system, the better the unloading performance, the smaller the speed of the material along the Y direction, and the smaller the width of the material flow. Reduce the phenomenon of scattering and dust pollution. TABLEX shows the analysis table of the range of velocity variation of the material along the Y direction at the discharge port. The results of calculation and analysis can be obtained. The primary and secondary order of the influence of each factor on the velocity of the material along the Y direction is A>C>B, that is, the orientation The included angle of the plate is the largest, the radius of the curved surface of the guide plate is second, and the radian of the curved surface of the guide plate is minimum.

**TABLE X. Y DIRECTION SPEED RANGE ANALYSIS TABLE**

| **Model** | **A** | **B** | **C** |
|---|---|---|---|
| $T_1$ | 3.629 | 2.895 | 2.813 |
| $T_2$ | 2.917 | 3.027 | 3.004 |
| $T_3$ | 2.307 | 2.931 | 3.036 |
| $t_1$ | 1.210 | 0.965 | 0.938 |
| $t_2$ | 0.972 | 1.009 | 1.001 |
| $t_3$ | 0.769 | 0.977 | 1.012 |
| $R$ | 1.322 | 0.132 | 0.223 |
| EXCELLENT SOLUTION | $A_3$ | $B_1$ | $C_1$ |

The quality of the material in the unloading process simulation of the unloading system directly reflects the advantages and disadvantages of the unloading performance. The smaller the spread quality, the better, ensuring efficient discharge while maintaining a safe working environment. TABLE XI shows the visual analysis table of material quality. Through calculation and analysis, it can be obtained that the primary and secondary order of factors affecting material quality is A>B>C, that is, the angle of the guide plate is the

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

largest, the radian of the curved surface of the guide plate is second, and the radius of the curved surface of the guide plate is minimum.

**TABLE XI. Y DIRECTION SPEED RANGE ANALYSIS TABLE**

| MODEL | A | B | C |
|---|---|---|---|
| $T_1$ | 3.629 | 2.895 | 2.813 |
| $T_2$ | 2.917 | 3.027 | 3.004 |
| $T_3$ | 2.307 | 2.931 | 3.036 |
| $t_1$ | 1.210 | 0.965 | 0.938 |
| $t_2$ | 0.972 | 1.009 | 1.001 |
| $t_3$ | 0.769 | 0.977 | 1.012 |
| $R$ | 1.322 | 0.132 | 0.223 |
| EXCELLENT SOLUTION | $A_3$ | $B_1$ | $C_1$ |

4.1.2 variance analysis

Since the error may exist in the test, only the variation of each indicator cannot be accurately determined by range analysis, which is caused by the factors of the plow structure parameters or by the test error. In order to obtain a more accurate conclusion, the difference analysis method is verified. As a result, the analysis of variance is used for orthogonal test results, as shown in TABLEXII, which is shown in TABLE XII.

**TABLE XII. VARIANCE ANALYSIS TABLE**

| SOURCE OF VARIANCE | SUM OF SQUARE | DEGREES OF FREEDOM | MEAN SQUARE ERROR | $F$ VALUE | $F_\alpha$ | SALIENCE |
|---|---|---|---|---|---|---|
| FACTOR A | SSA | $f_A$ | MSA=SSA/ $f_A$ | MSA/MSE | | |

**Forest Chemicals Review**
**www.forestchemicalsreview.com**
**ISSN: 1520-0191**
**July-August 2022 Page No. 10-33**
**Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022**

| | | | | | | |
|---|---|---|---|---|---|---|
| FACTOR B | SSB | $f_B$ | MSB=SSB/ $f_B$ | MSB/MSE | | |
| FACTOR C | SSC | $f_C$ | MSC=SSC $f_C$ | MSC/MSE | | |
| ERROR | SSE | $f_e$ | MSE=SSE/ $f_e$ | | | |
| SUM | SST | $f_T$ | | | | |

$$SSj = p\sum_{i=1}^{m}(t_i - \bar{x})^2 = \frac{1}{p}\sum_{i=1}^{m}(T_i)^2 - \frac{1}{mp}\left(\sum_{i=1}^{m}\sum_{j=1}^{p}x_{ij}\right)^2$$

$$SST = \sum_{i=1}^{m}\sum_{j=1}^{p}(x_{ij} - \bar{x})^2 = \sum_{i=1}^{m}\sum_{j=1}^{p}x_{ij}^2 - \frac{1}{mp}\left(\sum_{i=1}^{m}\sum_{j=1}^{p}x_{ij}\right)^2$$

$$SSE = SST - (SSA + SSB + SSC)$$

$$f_T = n-1,\ f_A = f_B = f_C = m-1,\ f_e = f_T - f_A - f_B - f_C$$

in the formula:

$SSj$ ——Deviation Square,

$SST$ ——Total deviation square and,

$SSE$ ——The deviation between the test error and,

$MS_i$ ——Mean square,

$f_T$ ——Total degree of freedom,

$f_i$ ——The degrees of freedom of each factor,

$f_e$ ——experimental error degrees of freedom,

$m$ ——The degrees of freedom of each factor,

$p$ ——Factor number,

$n$ ——number of observations.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Use $F$ function to analyze the significance of various factors on the performance of unloading performance. According to the formula $F_\alpha(n_1, n_2)$, the confidence is set to 99%, 95%, that is, the critical value of $\alpha = 0.01$, $\alpha = 0.05$ as a significant test. When $\alpha = 0.01$, if $F > F_\alpha$, the ability to influence the test results is judged to be highly significant, When $\alpha = 0.05$; if $F > F_\alpha$, the ability to influence the test results is judged to be significant, If $F < F_\alpha$, it is determined that the influence on the test results is not significant, and this variance has no discrimination significance.

It can be seen from TABLE XIII below that the size of the included angle of the guide plate has a significant effect on the speed of the material along the X direction, while the radian and radius of the guide plate have no significant effect on the speed of the material along the X direction, indicating that the change of the included angle of the guide plate can make The material moves quickly along the discharge direction during unloading, thereby reducing the residence time of the material on the conveyor belt, effectively reducing the problems of material leaking and unsmooth unloading. Comprehensive analysis of the influence of various factors on the speed of the material along the X direction is the order of the angle of the guide plate, the radius of the surface of the guide plate, and the radian of the surface of the guide plate.

**TABLE XIII. X-DIRECTION VELOCITY VARIANCE ANALYSIS TABLE**

| SOURCE OF VARIANCE | SUM OF SQUARE | DEGREES OF FREEDOM | MEAN SQUARE ERROR | $F$ VALUE | $F_\alpha$ | SALIENCE |
|---|---|---|---|---|---|---|
| FACTOR A | 0.00356 | 2 | 0.001780 | 29.667 | $F_{0.05}(2,2) = 19$ | SIGNIFICANT |
| FACTOR B | 0.00037 | 2 | 0.000185 | 3.083 | $F_{0.01}(2,2) = 99$ | |
| FACTOR C | 0.00073 | 2 | 0.000365 | 6.083 | | |
| ERROR | 0.00012 | 2 | 0.000060 | | | |
| SUM | 0.00478 | 8 | | | | |

From TABLE XIV below, the size of the guide plate angle is highly significant on the material along the Y direction, while the radian and radius of the guide plate have no significant effect on the speed of the

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

material along the X direction, indicating the change in the guide plate angle. Make the material stream width during the discharge process, stably fall into the unloading hopper, which can effectively reduce the material leakage phenomenon and dust pollution. Comprehensive analysis of each factor on the rate of the material along the Y direction is from large to small, the guide plate angle, the surface radius of the guide plate, and the curved plate curve.

**TABLE XIV. Y DIRECTION VELOCITY VARIANCE ANALYSIS TABLE**

| **SOURCE OF VARIANCE** | **SUM OF SQUARE** | **DEGREES OF FREEDOM** | **MEAN SQUARE ERROR** | $F$ **VALUE** | $F_\alpha$ | **SALIENCE** |
|---|---|---|---|---|---|---|
| FACTOR A | 0.29186 | 2 | 0.14593 | 105.74638 | $F_{0.05}(2,2)=19$ | HIGHLY SIGNIFICANT |
| FACTOR B | 0.00310 | 2 | 0.00155 | 1.12319 | $F_{0.01}(2,2)=99$ | |
| FACTOR C | 0.00969 | 2 | 0.00485 | 3.51449 | | |
| ERROR | 0.00276 | 2 | 0.00138 | | | |
| SUM | 0.30742 | 8 | | | | |

The following TABLE XV shows the variance analysis table of the quality of the leakage. Since the mean square error of the error effect is larger than the mean square error of the factor C, the error effect and the mean square error of the factor C are calculated uniformly, and the unified mean square error is calculated again. The F test can make the degree of freedom of the analysis of variance larger, and the sensitivity is higher. When the error effect and the mean square error of the factor C are calculated uniformly, the corrected variance analysis table of the leaking quality shown in TABLE XVI below is obtained.

From Table 16, the size of the guide plate angle pair is highly significant on the quality of the springs, and the effect of the guide plate radian and the radius of the springs is not significant, indicating that the change in the guide plate angle can make the material unloaded The guarantees of the material are efficiently carried out while maintaining the safety of the working environment. Comprehensive analysis

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 10-33
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

of the influence of various factors on the quality of the material, from large to small, is the angle of the guide plate, the radian of the surface of the guide plate, and the radius of the surface of the guide plate.

**TABLE XV. LEAKING QUALITY VARIANCE ANALYSIS TABLE**

| SOURCE OF VARIANCE | SUM OF SQUARE | DEGREES OF FREEDOM | MEAN SQUARE ERROR | $F$ VALUE | $F_\alpha$ | SALIENCE |
|---|---|---|---|---|---|---|
| FACTOR A | 26.46233 | 2 | 13.231165 | | | |
| FACTOR B | 2.34361 | 2 | 1.171805 | | | |
| FACTOR C | 1.29178 | 2 | 0.645890 | | | |
| ERROR | 1.48429 | 2 | 0.742143 | | | |
| SUM | 31.58201 | 8 | | | | |

**Table XVI. Modified variance analysis table for leaking quality**

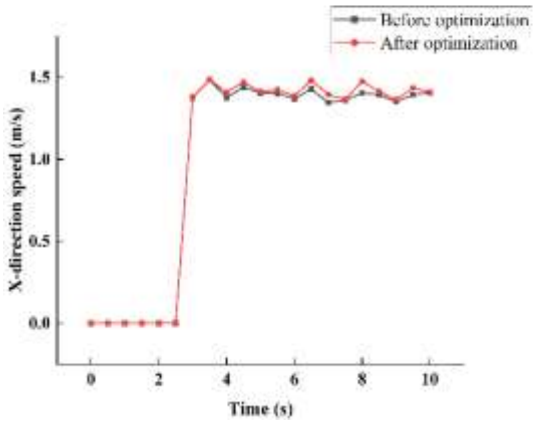
| SOURCE OF VARIANCE | SUM OF SQUARE | DEGREES OF FREEDOM | MEAN SQUARE ERROR | $F$ VALUE | $F_\alpha$ | SALIENCE |
|---|---|---|---|---|---|---|
| FACTOR A | 26.46233 | 2 | 13.23117 | 19.06454 | $F_{0.05}(2,4)=6.94$ | HIGHLY SIGNIFICANT |
| FACTOR B | 2.34361 | 2 | 1.17181 | 1.68844 | $F_{0.01}(2,4)=18$ | |
| FACTOR $C^*$ | 1.29178 | 2 | 0.64589 | | | |
| ERROR | 1.48429 | 4 | 0.69402 | | | |
| SUM | 31.58201 | 8 | | | | |

By comprehensively comparing the influence of the three factors on the speed of the material along the X direction, the speed along the Y direction, and the mass of the leakage, it can be found that the influence of each index has a certain similarity, and it can be found that the angle of the guide plate affects each The impact of indicators is the most significant.

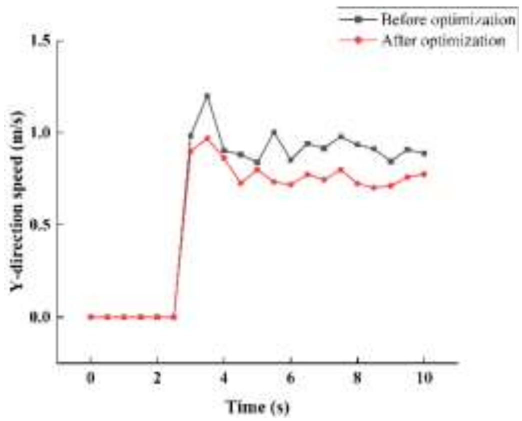
4.2 Optimization parameter rationality verification

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

Comprehensive consideration of the results of varying analysis and variance analysis, the optimal structure is combined into $A_3B_1C_1$, that is, the guide plate angle is 100 °, the surface radian is 130 °, and the surface radius is 260 mm. The two structures before and after optimization are modeled and the discharge simulation calculation is carried out. The simulation conditions, material parameter settings and contact attribute settings are all consistent. The conveying capacity is 1500t/h and the belt speed is 3.15m/s. The discharge port is obtained The speed of the material along the X direction, the speed along the Y direction and the quality of the material are shown in Fig.8 below. Comparing the simulation results data before and after optimization, it is understood by Fig.8(a). After the discharge state is stable, the optimized structure has a certain increase in the X direction during the discharge process, and the material will be rapid. Within the unloading tower, it will not be improved in the conveying band for a long time, blocking and unloading is not smooth. As can be seen from Fig.8 (b), the optimized structure is reduced in the Y direction during the discharge process, and the average speed is reduced from 0.93 m / s to 0.8 m / s, and the material is in the discharge process. The stream cross section is reduced, effectively improved dust pollution. As can be seen from Fig.8 (c), the mass of the leakage is reduced from 0.31 kg to 0.15 kg, and the unloading performance is improved.

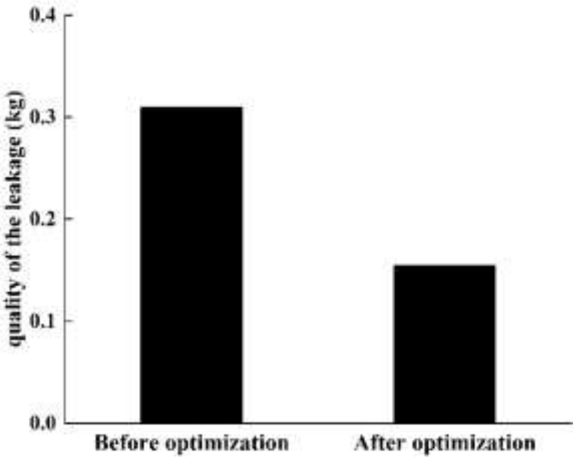



(a) Comparison of X-direction speed before and after optimization




(b) Comparison of Y-direction speed before and after optimization

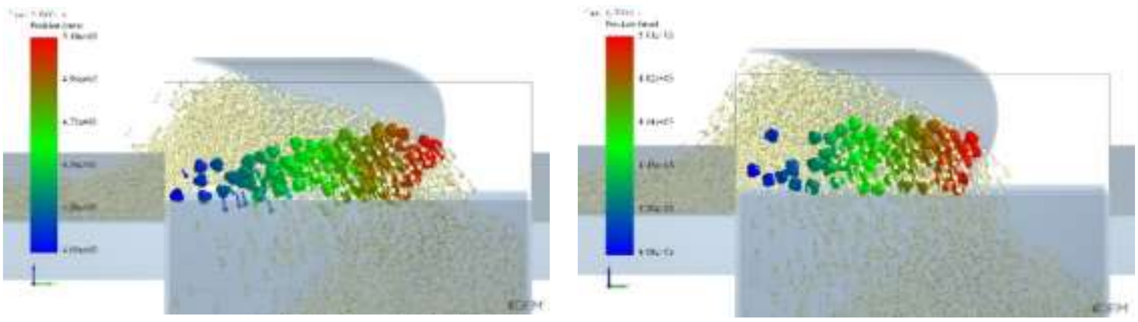
*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*




(c) Comparison of spreading quality before and after optimization

Fig.8: Comparison of parameters before and after optimization

As shown in Fig.9, the relative coordinates of the discharge port material along the transport direction of the discharge process is stabilized, and the maximum value is minimized, which is a stream cross section width, stream section. The smaller the width, the smaller the length of the discharge hockey, the less the situation is also the case; the degree of separation of fine particles and large particles during the material discharge is also reduced, and the problem of dust contamination is improved. From Fig.9 (a), the optimized front injection port stream cross section width is 1130 mm, and the width of the unloading port stream section is 930 mm after the optimization of Fig.9 (b). The width of the discharge port stream is reduced by 200mm, and it is visible to optimizing the structure of the plows and dust pollution problems has been significantly improved.



(a) Material section before optimization (b) Material section after optimization

Fig.9: Material section before and after optimization

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

## V. IN CONCLUSION

According to the structural parameters of the plow discharge, the guide plate angle, the curved radius, and the curved radian are each performed a single factor, and the influence of multi-factor on the performance of the unloading is explored, and the proposed improvement scheme is used to structural parameters Optimization. The main conclusions are as follows,

(1) In the case where the discharge conditions are unchanged, the structure of changing the plow discharge guide panel has a large impact on the performance of the discharge. The discharge performance will be improved with the change of the structural parameters of the plow discharge.

(2) Through orthogonal experiment, simulate the combination of nine sets of structural parameters, range analysis, variance analysis, and finally resulting in the main sequence of the evaluation index of the orthogonal test, A> C> B (guide plate angle > curved radius > curved radian). The optimal combination of the test range is $A_3B_1C_1$, that is, the guide plate angle is 100 °, the curved radian is 130 °, and the curved radius is 260 mm.

(3) By simulating the unloading process of the plow discharge before and after optimization, and comparing various performance indicators, it is found that the optimized unloading performance indicators are better than the structure before optimization, and the problems of material leakage, and dust pollution can be effectively improved. Therefore, it is considered that the optimized structural parameters of the plow discharge are more reasonable.

## REFERENCES

[1] Lu Zhongke. Retrofit of coal plow between coal bunker of 680MW unit. Electricity safety technology, 2017,19(04):52-54.

[2] Wei Yi, Song, Zhijie, Wang Jishi. optimization design of plow discharger based on DEM. Lifting transport machinery, 2019(11):71-73.

[3] Yu Bo, Zhang Ying, Luo Liangjun. Improvement design of plow discharger. Modern manufacturing technology and equipment, 2019(03):43-45.

[4] Wu Xi, Liang Baoying, Wu Weichen. Analysis and Improvement Design of Work Characteristics of Heavy Table Conveyor Head Cleansing. Mining machine, 2010,38(7):72-74 .

[5] Wang Cangzhu, Yang Xiaohong. Electric combined plow discharger optimization design. Mining machine,

*Forest Chemicals Review*
*www.forestchemicalsreview.com*
*ISSN: 1520-0191*
*July-August 2022 Page No. 10-33*
*Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022*

2002,30(8):4-5 .

[6] Xie Wujie. Improve measures for plow discharger on transport band wear. Huadian Technology, 2011,33(12):54-55.

[7] Zhang Yuan, Wang Jun, Zhang Zhe. Mechanical Analysis and Structure Opt-imization of Belt Conveyor Bi - side plow discharger. Coal science and technology, 2013,41(6):77–79.

[8] Teng Xiaoqiang, Huang Lizhi. Novel unloader with belt conveyor. Grain circulation technology, 2005 (4) :15-21.

[9] Liu Haoxuan, Gao Dianrong, Qin Yalu. Optimization Research of Structural Parameters of Curve Feed Tubes in Transit System. Journal of Chongqing University of Technology (Natural Science), 2020,34(07):149-155.

[10] Paul W. Cleary. DEM prediction of industrial and geophysical particle flow-s. Particuology,2010,8(02):106-118.

[11] P.A. Cundall. A Computer Model for Simulating Progressive, Large-Scale Movements in Block Rock Systems. Symposium of International Society of Rock Mechanics, 1971,1(ii-b): 8-11.

[12] P.A. Cundall. Formulation of a Three-Dimensional Distinct Element Model — Part I. A Scheme to Detect and Represent Contacts in a System Composed of Many Polyhedral Blocks. International Journal of Rock Mechanics & Mining Sciences & Geomechanics Abstracts, 1988, 25(6): 107–116.