

Original Research Article

Simulation study based on the influencing factors of vibrating screen screening efficiency

ABSTRACT

Based on the vibrating screening simulation technology is an efficient technology to carry out research on sieving theory and sieving mechanism, which plays an irreplaceable role in promoting the rapid development of vibrating screen, the existing research direction of vibrating screening technology is introduced, the current status of research on the simulation method of the factors affecting the sieving effect in the vibrating sieving process and the current status of the application is elaborated, and the conclusions are summarized, and finally it is pointed out that the vibrating screen sieving efficiency simulation The future development direction of the research is: the combination of simulation technology and artificial intelligence, big data and other technologies will further promote the intelligent development of screening technology. The opportunities and challenges are: the simulation software will continue to improve, providing a more friendly user interface and more powerful computing power. Artificial intelligence technology will provide new solutions for parameter calibration, model simplification and result analysis.

Keywords: Screening efficiency, Material properties, Screen parameters, Vibration parameters .

1. INTRODUCTION

Vibrating screen is a kind of screening equipment widely used in mining, metallurgy, chemical industry, building materials and other industries, mainly used for screening, grading and removing impurities of materials. Its working principle is to loosen and stratify the materials on the screen surface through vibration, so as to realize the separation of different particle size materials^[1]. In the research of vibrating screen, prototype test and build imitation are really two main research means, complement each other and promote the rapid development of vibrating screen^[2]. Prototype test is a direct and effective performance inspection method, but the manufacturing cycle is long, the cost is high, and it is difficult to obtain test results^[3]. Modeling simulation, on the other hand, is low-cost, powerful, throughout the entire life cycle of vibrating screen research and development, and has become an efficient theoretical and mechanistic research tool^[4]. With the development of computer and virtual simulation technology, many scholars have achieved significant results in the simulation of the screening efficiency of vibrating screens, which promotes the design and structural optimization^[5]. However, due to the limitations of modeling and computational capabilities, simulation studies are usually simplified and processed, resulting in errors between simulation results and actual industrial screening results^[6]. Therefore, appropriate modeling methods and simulation ideas can reduce errors, improve simulation reliability and play a greater role^[7]. To this end, the authors of this paper from the impact of screening efficiency of the three research perspectives (material properties, screen parameters, vibration parameters), many vibrating screen simulation methods and application of the status quo to summarize, with a view to providing relevant researchers and industry practitioners with appropriate modeling methods and simulation ideas^[8].

2. METHODOLOGY

THE SCREENING MECHANISM OF VIBRATING SCREEN AND SIMULATION

Vibrating screen produces a certain vibration frequency and amplitude of the screen mesh through the vibration generated by the vibrating motor or exciter. The vibration makes the material jump and slide on the screen mesh, so as to realize the classification. The material is subjected to vibration on the vibrating screen, and the particles will move along the surface of the screen mesh. Smaller particles are able to pass through the pores of the screen mesh, while larger particles are left on the surface of the screen mesh, thus realizing grading. The aperture, material and structure of the screen mesh have an important influence on the screening effect^[9]. Suitable screen mesh can improve screening efficiency and precision. Characteristics such as particle size, shape, density and humidity of the material also affect the screening effect. Generally speaking, materials with regular particle shape and uniform density are easier to screen. The adjustment of vibration frequency and amplitude can optimize the screening effect^[10]. Appropriate vibration parameters can improve the passage rate of materials and screening efficiency. In the working process of vibrating screen, gravity and inertia force act together on the material to make it move on the surface of the screen mesh, and finally realize the classification. The research method of vibrating screen usually combines theoretical analysis, numerical simulation and experimental verification to carry out the research of vibrating screen performance^[11].

Theoretical analysis is mainly categorized into three aspects: analyzing the vibration characteristics of vibrating screen from the perspective of vibration, including vibration frequency, amplitude, vibration pattern, etc.; analyzing the mechanism of the screening process from the perspective of screening, including the movement of the particles, separation, delamination, etc.; analyzing the probability of the particles passing through the sieve from the perspective of probability, and establishing a mathematical model of screening efficiency^[12].

Numerical simulation is mainly studied from four modules: finite element analysis (FEA) is used to simulate the structural mechanical properties of the vibrating screen and optimize the structural design; discrete element method (DEM) is used to simulate the motion and interaction of particles and predict the screening efficiency; multi-body dynamics (MBD) is used to simulate the motion and dynamics of the vibrating screen, and optimize the motion parameters; and computational fluid dynamics (CFD) is used to simulate the Computational Fluid Dynamics (CFD) is used to simulate the fluid flow in the screening process and analyze the effect of fluid on screening^[13].

Simulation of vibrating screens requires the use of simulation software, which is mainly used to simulate the screening process, optimize the design of the screen machine, predict the screening efficiency, and help engineers better understand and improve the screening operation^[14]. These software programs are usually based on techniques such as finite element analysis (FEA), discrete element methods (DEM) or multi-body dynamics (MBD)^[15].

RESULTS AND DISCUSSION

3. RESEARCH ON THE INFLUENCE OF MATERIAL CHARACTERISTICS ON SCREENING EFFICIENCY

Material characteristics are the primary factors affecting the screening efficiency of vibrating screen^[16]. The particle size distribution, density, humidity and other characteristics of the material directly determines the fluidity and grading effect of the material in the screening process. The uniformity of particle size distribution and particle size will affect the trajectory and residence time of the material on the screen, thus affecting the screening effect. Density affects the settling speed of the material on the vibrating screen, and humidity may lead to material bonding, increasing the screening difficulty. Therefore, understanding and analyzing the material characteristics are crucial for optimizing the screening process. Zhang Luxia and Li Yunfeng through the study of material properties and screening efficiency concluded that: material bulk density, material particle composition, material size and the relative size of the sieve holes of the three factors have an impact on the screening efficiency, bulk material bulk density is easy to penetrate through the sieve screening efficiency is also higher; on the contrary, bulk density of smaller materials and powdered materials are not easy to penetrate through the sieve screening efficiency is also low. In order to improve the screening efficiency to be screened material gradation composition to determine the case of determining the vibrating screen sieve size so that difficult to screen materials (particle size of 0.7 ~ 1 times the size of the sieve material) accounted for the proportion of materials should be screened the smallest. The granularity of the mineral material should be strictly controlled within the scope of the technical parameters of the equipment granularity index is too large a difference will cause the production cycle to restrict the quality of the product and processing capacity. Material in the screening process through the screen probability affected by many factors of which the most direct and important factor is the relative size of the material particle size and sieve size. As shown in Figure 1, the particle diameter of d material each jump through the sieve probability.

$$C_{XD} = S_1 / S_2 = \frac{n(a-d+\psi\delta)^2}{n(a+\delta)^2} = \frac{(1-d/a+\psi\delta/a)^2}{(1+\delta/a)^2} \quad (1)$$

Area that can pass through the sieve holes

$$S_1 = n(a-d+\psi\delta)^2 \quad (2)$$

Total area of sieve surface

$$S_2 = n(a+\delta)^2 \quad (3)$$

In the formula

n --number of holes on the sieve surface; --number of holes on the sieve surface; --number of holes on the sieve surface, mm

a --Length of the side of the sieve holes, mm;

δ --diameter of the sieve wire, mm; --diameter of the sieve wire, mm

ψ --The coefficient that the material can still fall into the sieve holes after collision with the inner side of the sieve wire, <1.

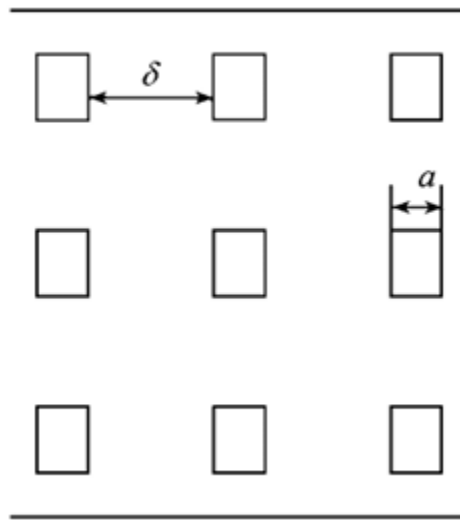


Fig. 1. The probability of the material falling vertically onto the screen surface to penetrate the screen.

Material particle size and sieve size ratio d/a is called the relative particle size. Relative particle size the smaller the probability of sieve penetration is higher when the relative particle size is close to 1 when the probability of sieve penetration tends to be close to zero, so the relative particle size of 0.7 ~ 1 is usually referred to as difficult to sieve the material or critical materials. The larger the content of difficult to screen materials in the screening material, the smaller the probability of sieve penetration screening efficiency will be lower; on the contrary, the higher the screening efficiency. In order to get a higher screening efficiency should try to reduce the content of difficult to screen materials in the aggregate. Therefore, the key holes of aggregate grading should be taken as the controlled holes of the crusher. In addition, the incoming aggregates should come from the same manufacturer to ensure the uniformity of the material size composition. The ratio of the screen area to the screen surface area (known as the effective area coefficient) is larger the higher the probability of screen penetration. Therefore, in the design of screening machinery should strictly control the gradation of aggregates and select the effective area coefficient of the larger screen surface, which is to improve the screening efficiency and speed up the screening process are of great practical significance.

In the process of vibrating screen screening wet fine-grained viscous materials bonded to each other into a group of loose difficulties, or adhering to the screen surface to block the sieve holes, so that the effective screening area of the screen surface is reduced, resulting in a decline in screening efficiency, the material group is not loose, not layered, the overall movement of the screening process is difficult to complete. In order to solve the above problems, Beijing Bo Hou Sieving Company has developed a new type of sieving machine suitable for sieving wet fine-grained materials - Bo Hou Sieving. As shown in Figure 2, the movement parameters and mechanical structure design of Bo Hou sieve not only meets the requirements of large-scale screening equipment, but also conforms to the screening law of wet fine-grained viscous materials. Sun Gang, Sun Chunbao, Zhang Wenming research and analysis on the screening mechanism of Bo Hou sieve, the traditional screening equipment are screen surface and screen box vibration together. Bo Hou sieve changed the mechanical structure of the traditional sieve using multiple sections of the screen surface vibration and screen box and frame does not vibrate the movement from the inlet to the discharge end of the multiple sections of the screen surface of

their own independent vibration each section of the screen surface amplitude, vibration intensity can be adjusted vibration intensity decreases step by step. Screen surface vibration and the screen box does not vibrate the structure of the sieve to reduce the vibration quality is easy to realize the optimization of movement parameters and screening equipment large-scale.

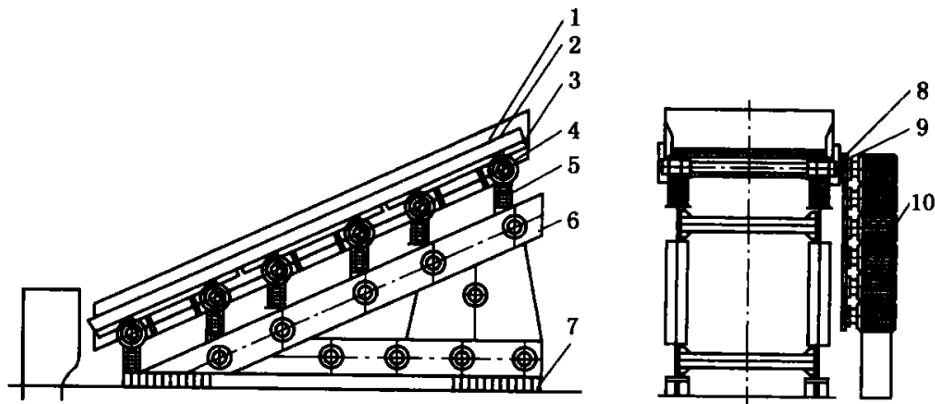


Fig. 2. Schematic diagram of the structure of Bo back sieve

Structure description: 1 - screen box for blocking material, not vibration; 2 - baffle plate: involved in the sieve vibration, used to block material and support the screen wire plate; 3 - screen surface, Bo after the sieve screen is fastened to the rectangular beam of the shaker, with the shaker synchronous vibration, the vibration direction is perpendicular to the screen surface, to realize the linear vibration. The size of the screen surface according to the site installation conditions and capacity requirements can be more free combination of segments, the screen surface of the screen wire arranged in the direction of the screening process, the screen wire has a secondary vibration function, the movement of materials on the screen surface has the ability to self-clean the screen surface; 4-connecting bridge, used to connect the two exciters to support the baffle plate and the screen wire plate; 5 springs, 6 -secondary damping frame, support the screen surface, cushioning the excitation force, through the secondary damping, the spring can further reduce the dynamic load; 7-secondary damping spring; 8-exciter, generating the excitation force, through the adjustment of the eccentric block can be adjusted to adjust the amplitude of the sieve and vibration strength, to meet the screening effect and processing capacity of the scene 9-soft connection, through the soft connection to the power transmission to the vibration exciter; 10-motor, motor mounted on the motor bracket, the motor does not participate in the vibration.

Material group movement has its own regularity in the material moisture is low due to the material between the material, the material and the sieve wire between the bonding force or bonding force is very small material group mobility is good particles as long as than the size of the sieve holes are smaller than the screen mesh and the screen mesh there is a relative movement between the screen can be through the sieve. When the material moisture increases between the material, the material and the screen between the bonding force increases when the screening process is divided into three stages of loose, layered and through the screen. A large number of different particle sizes, coarse and fine mixed bulk materials into the screen surface only part of the particles and the screen surface direct contact, and contact with the screen surface of this part of the material is not all smaller than the size of the screen hole of fine-grained materials, most of the smaller than the screen hole of fine-grained materials are distributed in the layer of the various parts of the material. But because of the relative movement of the material and the screen surface for the relative movement of the screen surface layer was loosened between the large particles there is a larger pore is further expanded small particles to take the opportunity to pass through the pore into the lower layer; due to the small particles of small particles can not pass through the small particles, so particles in the movement of the position of the rising. So the original chaotic arrangement of the material group after a period of time of separation according to the size of the formation of small particles in the lower part of the larger particles in the upper part of the more regular arrangement. This is smaller than the sieve hole of the fine particles get through the sieve to realize the separation of coarse and fine particles that complete the sieving process. The first condition of screening is to loosen the viscosity of the material increases so that the loosening becomes difficult and poor mobility, then it is necessary between the material and the material and the sieve mesh between the power is large enough that the sieve surface to give the layer of material is large enough energy material may be loosened. When the vibration force generated by the screen surface is greater than the bonding force between the material and the screen wire when the material will be separated from the screen wire material separation between the active up screen will not be blocked screening process can be effectively carried out. But the smaller the particles the greater the viscosity of the inertial force obtained by the smaller, so the small particles need to obtain a large acceleration in order to get rid of the large particles of the structure of the ordinary sieve box has been difficult to meet the requirements of the intensity of large vibration. Bo Hou sieve adopts large amplitude, large vibration intensity and elastic screen surface movement parameters maximum amplitude of 28mm is ordinary screening equipment amplitude of 3 times the maximum vibration intensity of 8 more than ordinary screening equipment vibration intensity of more than 2 times is

conducive to cutting off the bond between the material to force the material stratification. Bo Hou sieve emphasizes the rapid thin layer screening material into the sieve in the screen surface under the action of large vibration intensity of the material quickly spread along the screen surface to accelerate the relative movement speed between the material and the screen surface of fine-grained viscous material is easy to stratify the fine particles smaller than the size of the sieve holes can be obtained more opportunities for penetration of the sieve. The rapid screening process of the material is actually also a process of continuous cleaning of the screen holes moist fine-grained viscous materials difficult to bridge the screen wire networking screening process screen surface always maintains the maximum pore rate fully utilizes the entire screen surface, thus effectively solving the screening problem of difficult to screen materials in the process of industrial production.

4. STUDY ON THE EFFECT OF SCREEN PARAMETERS ON SCREENING EFFICIENCY

Screen parameters are important factors affecting screening efficiency. The aperture size and porosity of the screen directly determine the ability of the material to pass through the screen. Too small aperture may lead to material clogging, while too large aperture may not be able to effectively separate fine-grained materials. In addition, the screen material, surface treatment and its degree of wear will also affect the screening efficiency. Therefore, reasonable selection and design of screen parameters is the key to improve the performance of vibrating screen.

Duan Zhishan and Zhang Hong have more studies on the screen length, which is determined by the screening efficiency. Li Zhenliang, Men Wubin's research shows that with the increase of the screen surface length, the particle size of the screen separation particles become larger, only when the screen surface length is within a certain range, the screening efficiency will have the maximum value. Liu Dongpo's research on sieving efficiency in the sieve surface should be set to consider the particle size distribution of the screened material, when the particle size is small, the length of the screen surface should be shorter. Usually, the length of the screen surface affects the screening efficiency, and the width of the screen surface affects the productivity. The longer the sieve surface, the longer the material stays on the sieve surface, the higher the screening efficiency, the sieve surface length and width ratio is generally 2~3 is appropriate. Wang Na, Zhao Junkai and Li Menghong varied the length of the sieve surface from 20mm to 320mm by experimental research, with a gradient increase of 20mm. Plotting the relationship between sieve length and screening efficiency curve concluded that with the increase of sieve length, screening efficiency is a gradual increase in the trend, when the material particles are small, with the increase in the sieve length of the sieve efficiency increased rate is larger, when the increase in the sieve length over a certain range, the increase in screening efficiency is not obvious, the change is not significant.

Xiangdong Xie, Zelin Zhang, Zhiwei Zhang, and Yang Liu simulated the sieving process of sieve hole shape tending from square to round under different sieve mesh materials as shown in Fig. 3 based on the Discrete Element Method (DEM) and post-processed the simulated data by using the Discrete Element EDEM simulation software with a one-factor experiment with controlled variables. Dynamic sieving efficiency was adopted as the evaluation index, and the effects of the research factors on the sieving efficiency were analyzed based on the simulation data. The experimental results show that the square mesh shape has the best sieving efficiency and the octagonal mesh shape has a relatively low sieving efficiency in the case of the same screen material. At the same time, the experiments analyzed and compared the running speed of mineral particles on the sieve under different mesh shapes of four different materials, and the experimental results pointed out that the running speed of the mineral particles on the sieve under different factors was consistent with the trend of its sieving efficiency. In conclusion, the screen material and mesh shape affect the movement speed of mineral particles on the sieve, and indirectly affect the probability of sieve penetration by affecting the retention time of mineral particles on the sieve.

5. RESEARCH ON THE INFLUENCE OF VIBRATION PARAMETERS ON SCREENING EFFICIENCY

Vibration parameters are the core elements in the design of vibrating screen, including amplitude, frequency and vibration angle. The size of the amplitude affects the intensity of the movement of the material on the screen surface, and the appropriate amplitude can improve the fluidity of the material and promote the stratification and classification of the material. Frequency affects the residence time of the material on the screen surface, the appropriate frequency can improve screening efficiency. The adjustment of vibration angle can change the trajectory of the material on the screen surface, optimize the flow characteristics of the material. Therefore, the study of the impact of vibration parameters on screening efficiency can provide a theoretical basis for the optimal design of vibrating screen.

The process of screening is affected by a variety of factors, Li Hongchang used EDEM software to simulate and analyze the particles under different motion parameters, and the analysis shows that the particles' sieve penetration efficiency and the rate of clearing loss are affected by the structural parameters of the vibrating screen; Shi Xiudong chose the YD2000 vibrating screen as the object of study, and used orthogonal test method to study the motion state of the vibrating screen under different working parameters, and improved the type of vibrating screen's Maximum screening efficiency, so that the capacity of the screen increased by 21%; Wang Chengjun based on discrete element theory, the use of simulation software to study the screening efficiency of poplar particles, the study of comparative analysis found that the two-degree-of-freedom vibration mode can significantly improve the screening efficiency of poplar particles; Chen Yazhe using

ultrasonic waves for super vibration experiments, the results show that ultrasonic vibration can effectively break up the fine powder material particles agglomerates, to solve the sieve hole Liu Yilun to double-deck linear vibrating screen as the research object, the use of EDEM discrete element simulation software for different particle size particles in different parameters simulation, the results show that the particle movement speed with the amplitude and screen inclination angle increases and accelerates, the smaller the amplitude, the more conducive to the screening of small particles; Zhang Shun based on the discrete element method on the sieve structure and the shape of the material on the screening efficiency of the impact of virtual experiments. Zhang ship based on the discrete element method on the sieve surface structure and material shape on the sieving efficiency of the virtual experimental study, the sieve surface using round hole sieve, square hole sieve, the particles using complex particle shape material, the results show that the screening efficiency of the material with the increase in the sieve surface openings and gradually increase, and in the sieve surface opening rate is the same, the screening efficiency of the circular sieve is higher than that of the square sieve sieve screening efficiency; Yang Yang Gao based on the discrete element method on the impact of the vibration amplitude, vibration frequency and vibration direction angle on the efficiency of the screening of grain, using the principle of orthogonal test. Yangyang Gao studied the effect of vibration amplitude and vibration frequency and vibration direction angle on grain sieving efficiency based on discrete element method, and used orthogonal test principle to carry out simulation experiments on vibrating cleaning sieve, and the experimental results can provide a basis for analyzing the sieving efficiency of grain cleaning sieve and setting the parameters of equipment.

Xu Tianhao summarizes and reviews the relevant research results of vibrating screen through the literature method, based on the existing vibrating screen structure, sets up three layers of screen mesh, and the screen mesh holes are arranged in the order from big to small, the three layers of screen mesh holes are 21 mm, 15 mm, 11 mm, analyze the influence of vibration amplitude, screen surface inclination angle and vibration frequency on screening efficiency, set up a set of benchmark parameters, and use EDEM software to simulate the screening process of vibrating screen. Set a set of benchmark parameters, and use EDEM software to simulate the screening process of the vibrating screen, and at the same time, analyze and process the simulation results, plot the analyzed data into a curve and conclude that: the vibration amplitude, the angle of inclination of the screen surface and the vibration frequency of the vibrating screen screen screening efficiency of the various layers of the screen mesh increases first, and then decreases when it reaches the highest value, the upper layer of the screen mesh will affect the lower layer of the screen mesh, and from the first layer to the third layer of the screen mesh screening efficiency is gradually reduced. When the amplitude is 5 mm, the inclination angle is 6°, and the vibration frequency is 20 Hz, the overall screening efficiency of multi-layer linear vibrating screen is higher.

6. CONCLUSION

(1) Application status characteristics

Simulation technology has moved from academic research to industrial application, and more and more enterprises have begun to use simulation technology to optimize screening equipment and processes. Simulation results usually need to be verified with experimental results to ensure the accuracy and reliability of simulation. With the continuous development of simulation technology, multi-scale simulation (e.g., particle scale, equipment scale, process scale) has gradually become a research hotspot. The combination of simulation technology with artificial intelligence, big data and other technologies will further promote the intelligent development of screening technology.

(2) Challenges and opportunities

High computational cost, complex sieving process simulation requires a lot of computational resources and time. Difficulty in parameter calibration, DEM simulation requires a large number of parameters, and the calibration of these parameters is often difficult. Model simplification, in order to reduce the computational cost, it is usually necessary to simplify the actual sieving process, which may affect the accuracy of the simulation. With the continuous development of computer technology, the computational power will continue to improve, which will provide support for more complex sieving process simulation. Simulation software will continue to improve, providing a more friendly user interface and more powerful computing power. Artificial intelligence technology will provide new solutions for parameter calibration, model simplification, and result analysis.

Vibrating screen screening efficiency simulation has become an important tool that can help engineers better understand the screening process, optimize screening equipment and processes, and improve production efficiency and product quality. With the continuous development of simulation technology, its application prospects will be more broad. In the future, simulation technology will be more closely integrated with experiments, artificial intelligence and other technologies to make a greater contribution to the progress of screening technology.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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