INNOVATIVE DESIGN AND DEM ANALYSIS OF ENERGY-EFFICIENT VIBRATING SCREENS FOR INERT MATERIAL PROCESSING

Muzafarov Ezozjon
Navoi State University of Mining and Technologies, Navoi, Uzbekistan
E-mail: mirjonovfayzulla@gmail.com
Toirov Murtoza
Navoi State University of Mining and Technologies, Navoi, Uzbekistan
E-mail: murtoza.toirov@mail.ru

Abstract: This study focuses on the development and analysis of energy-efficient and environmentally friendly vibrating screen technologies used for processing inert and granular materials. A spring-based screen design powered by compressed air is proposed, offering advantages such as low noise levels, elimination of electrical energy consumption, and convenient application in road construction, maintenance operations, and coal screening. In addition, the performance of a "banana-shaped" vibrating screen with multiple inclination angles was investigated. Using the Discrete Element Method (DEM), the influence of geometric and operational parameters on screening efficiency was modeled, providing practical recommendations for improving screen design and optimizing resource-efficient industrial processes.

Key words: Pneumatic vibrating screen, Banana-shaped screen, Deck inclination angle, Screening efficiency, Discrete Element Method (DEM), Energy-efficient, Inert material processing.

Annotatsiya: Ushbu tadqiqot inert va granulali materiallarni qayta ishlashda qo‘llaniladigan energiya tejamkor va ekologik toza vibratsiyali elak texnologiyalarini ishlab chiqish va tahlil qilishga qaratilgan. Siqilgan havo yordamida ishlaydigan, prujinalarga asoslangan elak konstruksiyasi taklif etildi. U past shovqin darajasi, elektr energiyasidan foydalanmaslik va yo‘l qurilishi, ta’mirlash ishlari hamda ko‘mirni saralashda qulaylik kabi afzalliklarga ega. Shuningdek, bir nechta qiyalik burchaklariga ega bo‘lgan “banan” shaklidagi vibratsion elakning ish samaradorligi ham o‘rganildi. Diskret elementlar usuli (DEM) yordamida geometrik va ekspluatatsion parametrlarning saralash samaradorligiga ta’siri modellashtirilib, elak konstruksiyasini takomillashtirish va resurs tejamkor sanoat jarayonlarini optimallashtirish bo‘yicha amaliy tavsiyalar ishlab chiqildi.

Kalit so‘zlar: Pnevmatik vibratsion elak, Banan shaklidagi elak, Elak qavati qiyalik burchagi, Saralash samaradorligi, Diskret elementlar usuli (DEM), Energiya tejamkor, Inert materiallarni qayta ishlash.

ISSN 3030-3907

Аннотация: В данном исследовании рассматривается разработка и анализ энергосберегающих и экологически безопасных технологий вибрационных грохотов, применяемых для переработки инертных и гранулированных материалов. Предлагается конструкция грохота на пружинах, работающего на сжатом воздухе, обладающая такими преимуществами, как низкий уровень шума, отсутствие потребления электрической энергии и удобство применения в дорожном строительстве, при выполнении ремонтных работ и сортировке угля. Кроме того, была изучена эффективность работы вибрационного грохота «банановой» формы с несколькими углами наклона. С помощью метода дискретных элементов (DEM) смоделировано влияние геометрических и эксплуатационных параметров на эффективность сортировки, что позволило дать практические рекомендации по совершенствованию конструкции грохота и оптимизации ресурсосберегающих промышленных процессов.

Ключевые слова: Пневматический вибрационный грохот, Грохот банановой формы, Угол наклона деки, Эффективность сортировки, Метод дискретных элементов (DEM), Энергоэффективный, Переработка инертных материалов.

Introduction

Efficient screening of inert materials is a crucial technological stage in many industrial sectors, including mining, road construction, building materials production, and coal processing. The quality of the screening process directly affects not only production efficiency but also energy consumption, equipment service life, and the quality of the final product. Therefore, modern industrial enterprises increasingly demand energy-efficient, environmentally friendly, and high-performance screening equipment. Although traditional electric-motor-driven vibrating screens have been widely used for many years, they still suffer from high operating costs, elevated noise levels, and significant energy consumption. Moreover, in conditions where power supply is limited or where mobile operation is required, such equipment becomes less practical. From this perspective, pneumatic vibrating screens powered by compressed air are emerging as a modern technological solution. They do not require electrical energy, offer low maintenance costs, and are considered environmentally friendly. Screening efficiency depends not only on the vibration source but also on the screen geometry, particularly the inclination angles of multi-segment decks. In recent years, “banana-type” vibrating screens have become widely used in high-capacity processing lines because their variable inclination angles ensure rapid material stratification and improved passage through screen apertures. However, determining the optimal combination of inclination angles through experimental methods is both complex and costly. For this reason, the Discrete Element Method

ISSN 3030-3907

(DEM) provides an effective means of accurately modeling particle dynamics on the screen, including bounce amplitude, stratification, and passage through apertures. By evaluating the performance of banana-type screens with different geometric configurations using DEM, it becomes possible to identify optimal design parameters and scientifically improve the screening process. The purpose of this study is to develop a pneumatic vibrating screen for inert material classification, analyze the performance of a multi-segment banana-shaped screen with various inclination angles using DEM, and identify the optimal parameters for the screening process. The results have practical significance for implementing energy-efficient, environmentally friendly, and highly efficient screening technologies in industrial operations. Modern industries—such as metallurgy, mining, road construction, and building materials production—require equipment that is energy-efficient, reliable, and cost-effective in operation. Pneumatic vibrating screens powered by compressed air represent an efficient and economically advantageous technology for screening inert materials, especially in locations with limited or unavailable electrical infrastructure. Multi-inclination banana-type vibrating screens are widely used in high-capacity screening processes, where their effectiveness depends mainly on deck inclination, vibration parameters, and the characteristics of the material flow. [1]The Discrete Element Method (DEM) allows for accurate modeling of particle motion, separation behavior, and aperture passage processes, enabling optimization of screen design. By combining compressed-air-driven systems with optimized multi-segment screen geometries, it is possible to enhance screening efficiency, reduce energy consumption, and minimize environmental impact.

Materials and Methods

Pneumatic vibrating screens represent an efficient, energy-saving, and environmentally friendly solution for industrial processing operations. In coal mining, they enable effective separation of fine coal particles, directing them to conveyor systems for subsequent briquetting. These screens can operate in both stationary and mobile configurations, offering high adaptability to different mining sites. When necessary, pneumatic screens can be deployed at any location and powered by mobile compressors such as the PR-10 or VVP 6/7. Their operating principle is straightforward: vibration is generated by the rotation of a rotor under compressed air pressure of 0.5–0.7 MPa. This ensures long-term operation, low maintenance requirements, and consistent performance.

Results and Discussion

The performance of the screen was analyzed using the Discrete Element Method (DEM). The study examined the following parameters:

- Screen surface area: 1200 × 640 mm

ISSN 3030-3907

- Aperture size: 10 mm
- Particle diameter: 2–15 mm
- Material composition:
  - 80% — readily passable material (d/a = 0.2–0.7)
  - 15% — difficult-to-pass material (d/a = 0.7–1.0)
  - 5% — non-passable material (d/a = 1.0–1.5)

Four geometric configurations of the multi-segment "banana" screen were tested. Each screen was divided into five equal segments, starting with a base inclination of 10°, with subsequent segments increasing by Δα = 3°, 4°, 5°, and 6°. For the banana-type screen, the obtained throwing index (Kv > 2.08) confirmed continuous particle bouncing, which is essential for effective separation. [2]While increasing the deck inclination improved throughput capacity, it also reduced particle stratification, indicating a trade-off between material flow rate and separation quality.

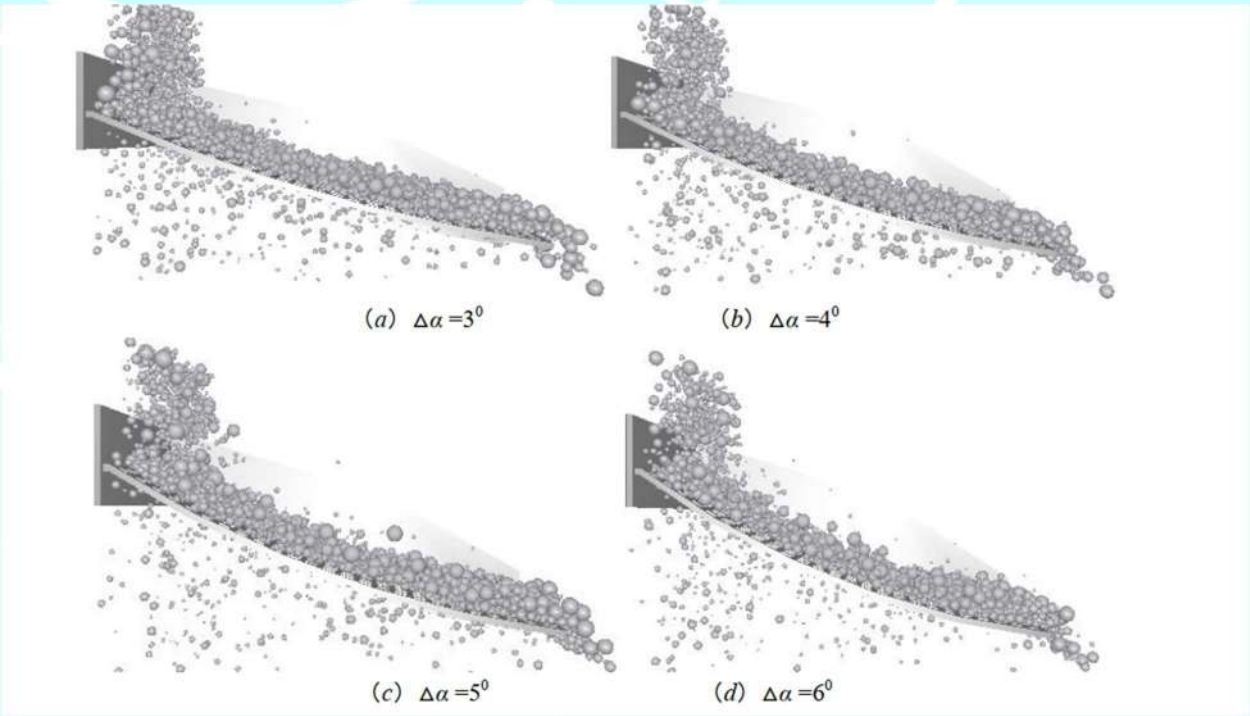


Fig. 1. Screen model with variable deck inclination angles [3]

The experiments showed the following trends:

- At **Δα = 3–4°**, the screening efficiency was initially high and stabilized after approximately 2 seconds.
- At **Δα = 6°**, excessive particle velocity prevented proper stratification, resulting in the lowest efficiency.
- At **Δα = 5°**, performance improved slightly but did not reach optimal levels.

The best results were observed in the **Δα = 3–4°** range, where particle stratification, passage through the screen apertures, and overall screening efficiency were maximized.

Conclusion

ISSN 3030-3907

Pneumatic vibrating screens reduce energy consumption, lower operational costs, and minimize environmental impact compared to conventional electric motor-driven systems. Their mobile, adaptable, and low-maintenance design makes them suitable for a wide range of industrial applications. DEM-based studies indicate that the screening efficiency of banana-shaped screens largely depends on the gradation of deck inclination angles. Optimal performance was observed at inclination increments of 3–4°, while excessive angles significantly reduced efficiency. Overall, integrating pneumatic vibrating systems with optimized multi-segment screen geometries offers a promising solution for developing highly efficient, environmentally friendly, and resource-saving industrial technologies.

REFERENCES

1. Guo Nian Qin and Kuang Yong Jiang. Research & development of, screen home and abroad. *Nonferrous Metals of the World*, China 2009, 5, 26-27

2. Zhao Yue Min and Liu Chu Sheng. Advances in coal dry screening theory and equipment. *China Academic Journal*, 2008, 2, 15-18.

3. N. V. Xo, “Study on the effect of deck inclination angle on the screening efficiency of banana-shaped vibrating screens applying discrete element method (DEM),” *IOSR Journal of Engineering (IOSRJEN)*, vol. 10, no. 4, pp. 58–62, Apr. 2020.

ISSN 3030-3907