Biomedical Testing & Sensing
2025, VOL. 4, NO. 1, 55-58
DOI: 10.47297/wspbtsWSP2755-952110.20250401

EDEM Simulation Modeling of Particle Shape Factor In Screw Conveying Process

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ABSTRACT

With the advancement of granular material conveying technology, particle shape characteristics significantly influence conveying performance and operational processes. As a widely-used equipment in various industrial fields, screw conveyors have been extensively applied. This study investigates the impact of particle shape factors on screw conveying processes through EDEM simulation software, establishing a correlation model between particle morphology and conveying performance. By analyzing conveying characteristics of particles with different shape factors through simulations, this research explores the operational patterns influenced by particle geometry. Results demonstrate that particle shape factors substantially affect material flowability, conveying efficiency, and uniformity during screw conveyance. Irregularly shaped particles are particularly prone to causing blockages and reduced operational efficiency during transportation.

KEYWORDS

Particle shape factor; Screw conveying; EDEM simulation; Particle flow; Conveying efficiency

1 Introduction

As a widely-used material conveying equipment, screw conveyors are extensively applied in mining, chemical, and agricultural industries. However, the shape characteristics of granular materials significantly influence conveying efficiency, effectiveness, and flowability during transportation. While traditional studies on granular conveying primarily focus on factors like particle size and density, the impact of shape parameters has not been sufficiently investigated. EDEM simulation technology, as an advanced tool for modeling dynamic granular material behavior, effectively simulates and predicts flow characteristics during conveying processes, providing scientific support for optimized design and practical applications.

2 Influence of particle shape factor on screw conveying process

2.1 Definition and influence of particle shape factor

The shape factor of particles is typically an dimensionless parameter used to characterize their geometric morphology. Common shape factors include roundness, aspect ratio, and specific surface area. These parameters reflect characteristics such as surface smoothness, angularity, and irregularities. In screw conveying processes, particle shape directly influences flow dynamics between screw blades. Irregularly shaped particles often result in increased friction, causing uneven movement during transportation and consequently affecting conveying efficiency and stability. Through EDEM simulations, precise motion state modeling can be achieved to better understand how shape factors influence particle behavior during material transfer.

2.2 EDEM Simulation Technology Introduction

EDEM (Discrete Element Method) is an advanced simulation technology that models particle behavior in conveying systems. By establishing mechanical models of particle interactions, it simulates phenomena such as collisions, friction, and flow. EDEM not only tracks particle trajectories but also captures contact mechanics between particles and equipment, enabling more realistic and precise simulations of particle conveying processes. When conducting particle conveying simulations, EDEM software allows users to customize parameters like particle shape, size, and surface properties to create environments matching actual equipment configurations. The key advantage of EDEM lies in its capability to analyze dynamic particle-level behaviors—something traditional computational methods cannot achieve. For instance, EDEM can handle particles with varying shape factors and observe their flow patterns in screw conveyors. Through simulations of particles with different shapes, researchers can investigate how shape factors specifically influence particle movement. EDEM not only simulates contact forces between particles and screw blades but also calculates collisions, sliding, and friction between particles, further revealing the flow mechanisms during conveying processes. In this way, EDEM simulation provides crucial tools for optimizing particle shapes and offers robust support for engineering design and equipment improvement.

2.3 The influence mechanism of particle shape factor on transportation process

During screw conveying, the shape factor of particles significantly impacts material flowability, efficiency, and stability. Variations in particle shape factors directly influence contact patterns, motion trajectories, and interactions with screw blades. Spherical particles with regular shapes typically exhibit better flowability during conveyance. Their geometric symmetry reduces contact area with blades, minimizes friction, and ensures uniform distribution within the conveyor system, preventing particle locking and accumulation. Spherical particles glide smoothly along screw blades, enabling efficient material transfer. Conversely, irregularly shaped particles like elongated, flattened, or angular forms generate excessive friction due to rough surfaces and larger contact areas. These irregular particles are prone to getting stuck or accumulating between blades, causing flow resistance and equipment blockages that ultimately reduce overall conveying efficiency.

3 EDEM simulation modeling method

3.1 Establish particle shape model

In EDEM simulations, establishing particle geometry models is the first step in studying how shape factors influence screw conveyor behavior. Shape factors can be modeled by adjusting geometric characteristics of particles, including common forms like spheres, rectangles, cubes, and ellipses, as well as more complex irregular shapes. In practical applications, particles often exhibit intricate geometries, necessitating more refined modeling techniques to describe external features such as aspect ratios, surface roughness, and roundness. EDEM provides multiple modeling approaches for particle shapes, with the most commonly used being particle swarm-based geometric approximation models. For complex particle configurations, polyhedral models or particle composite models can be employed. This method divides irregular particles into smaller segments, which interact through contact force models to simulate overall morphology. Such modeling enables precise mechanical simulations of irregularly shaped particles, further revealing their dynamic behaviors. By adjusting parameters like surface roughness and internal structures, researchers can study compression, fragmentation, and inter-particle interactions. During simulations, changes in shape factors directly affect particle trajectories and interactions with others. For instance, regular spherical particles have smaller contact areas and lower friction coefficients, while irregularly shaped particles may encounter greater flow resistance in screw conveyors due to larger surface contact areas and complex frictional mechanics. Therefore, the establishment of accurate particle shape model can help to better simulate the dynamic behavior of particles in the screw conveying process.

3.2 Construction of spiral conveyor simulation model

The modeling of screw conveyors is a critical component in EDEM simulations, as its accuracy directly impacts the precision of simulation results. In EDEM, the geometric configuration of screw conveyors can be established by defining key parameters such as blade dimensions, thickness, rotation angles, and rotational speed. To ensure simulation accuracy aligns with real-world conditions, precise specifications must be applied to blade materials, surface roughness, and particle contact characteristics. In kinematic modeling of screw conveyors, blade rotation trajectories and speeds are crucial factors influencing particle transportation. Different rotational speeds directly affect both the movement velocity and distribution patterns of particles along the blades during conveyance. By setting appropriate blade rotation angles and speeds, engineers can simulate particle transport behavior under various operating conditions. For instance, high-speed rotation may cause particles to deviate from normal trajectories due to centrifugal forces, while low-speed rotation tends to slow particle movement, increasing the likelihood of accumulation. Additionally, the contact force model between particles and blades is essential. EDEM typically employs multiple mechanical models—including friction, elasticity, and adhesion—to describe interactions between particles and blades. Friction between particles and blades influences sliding, rolling, or bouncing behaviors, thereby affecting smoothness during conveyance. By adjusting particle shape factors and friction coefficients between particles and blades, engineers can simulate conveying processes under different conditions, providing theoretical foundations for design optimization.

3.3 Simulation and experimental verification

While EDEM simulations provide precise modeling of granular flow, experimental validation remains essential to ensure accuracy. This verification typically involves operating actual screw conveyors under real-world conditions, comparing simulation results with experimental data to assess model reliability. Researchers conduct conveying experiments using particles with varying aspect ratios, tracking trajectories, conveying speeds, and accumulation patterns. For instance, representative particle shapes (spherical, elongated, angular) are tested under identical conditions to measure key parameters like conveying efficiency, bulk density, and material uniformity. By cross-verifying experimental and simulation data, engineers can fine-tune the simulation model by adjusting aspect ratio coefficients, ensuring alignment with physical processes. Moreover, experiments reveal critical details unobservable in simulations—such as particle fragmentation, wear, or other physical phenomena. Analysis of experimental data provides calibration parameters and practical insights for EDEM, enhancing the model's real-world applicability. Ultimately, this integration of simulation and experimentation not only validates how aspect ratios influence conveying processes but also offers scientific foundations for optimizing screw conveyor designs.

4 Influence of particle shape factor on transportation performance

4.1 Changes in particle flowability

Granular fluidity is a critical factor affecting screw conveyor performance, directly determining whether particles can move smoothly through the system. Poorly fluidized particles are prone to accumulation, clogging, or blockage, leading to reduced efficiency. In EDEM simulations, fluidity is closely related to particle friction, collision characteristics, and shape factors. Spherical particles, due to their symmetry, exhibit lower friction and generally better fluidity. Their stable motion paths along screw blades and minimal inter-particle interactions allow smooth sliding. However, when particles become irregularly shaped—such as elongated, flattened, or angular forms—the increased contact surface area significantly raises friction. This dramatically reduces fluidity and may cause particle clogging or accumulation. Additionally, irregular shapes create more contact points between particles and blades, intensifying friction and slowing movement. Elongated particles often demonstrate high stability and anti-slip properties, but are prone to interlocking between blades. Such irregularities not only increase system load but also risk equipment failures like blockages and damage. Therefore, optimizing particle shape factors, reducing inter-particle friction, and enhancing fluidity are key to improving screw conveyor efficiency.

4.2 Improvement of transportation efficiency

Screw conveying efficiency is directly influenced by particle shape factors. Particles with more regular shapes exhibit better flowability during transportation, enabling more efficient passage through the screw conveyor. Regularly shaped particles like spherical ones can be evenly distributed between spiral blades, reducing friction and resistance to enhance conveying efficiency. Conversely, irregularly shaped particles such as angular or elongated ones tend to cause inter-particle blockages due to their uneven surfaces and sharp angles, which increase friction coefficients. This results in slower particle movement during conveyance, thereby reducing overall system efficiency. The impact becomes particularly pronounced with high-density materials or frequent conveying operations, potentially causing frequent jams and equipment damage. EDEM simulations of different particle shapes reveal that spherical particles generally demonstrate higher conveying efficiency under identical working conditions compared to irregular ones. To improve conveying performance, designers should prioritize regular-shaped particles with smooth surfaces and optimize spiral blade angles and rotational speeds in equipment design to better accommodate particle flow characteristics, ultimately enhancing the system's overall conveying capacity.

4.3 Improvement of particle uniformity and stability

The uniformity and stability of particles in screw conveyors significantly impact production efficiency and material distribution consistency. Poorly uniform material conveying often leads to issues like stratification, agglomeration, or uneven dispersion during final processing stages, which compromise product quality and operational effectiveness. Regularly shaped particles such as spherical ones typically maintain better uniformity and stability. Their geometric symmetry ensures even distribution across screw blades during conveyance, effectively preventing irregular particles from causing accumulation or stratification. Conversely, irregularly shaped particles may exhibit uneven distribution due to shape variations or surface roughness inconsistencies, resulting in material stratification or buildup. This not only affects conveying quality but also reduces material flowability during transportation. Therefore, strategically selecting particle aspect ratios and optimizing their distribution during conveyance can substantially improve material uniformity and stability. This holds particular significance for industries with strict requirements on particle distribution, such as chemical and pharmaceutical manufacturing. EDEM simulations analyzing particle mobility and distribution patterns under different aspect ratios provide scientific foundations for shape optimization design, ultimately enhancing both conveying efficiency and product quality.

5 Conclusions

This study employs EDEM simulation technology to investigate the impact of particle shape factors on screw conveying processes. The research demonstrates that particle shape significantly affects fluidity, conveying efficiency, and uniformity. Regularly shaped particles exhibit better flow characteristics and higher conveying efficiency during operation, whereas irregularly shaped particles tend to generate resistance, compromising smoothness. Therefore, optimizing particle shape factors in screw conveyor system design can substantially enhance conveying performance. Future research could further explore the influence of various particle shape factors through combined experimental and simulation approaches, providing theoretical support for practical engineering applications.

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