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Proceeding Paper

Investigation of Mixing Dynamics of a Pilot-Scale Twin-Paddle Blender Containing Non-Spherical Particles †

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Abstract: An in-depth analysis of the flow patterns and mixing dynamics in a twin-paddle blender with bi-disperse non-spherical particles was investigated using the discrete element method (DEM) and experiments. This study aimed to explore the mixing efficiency of a twin-paddle blender containing two different shapes of non-spherical particles. The study focussed on the demonstration of the applicability of the GPU-based DEM model. To achieve this, calibration tests were performed using a classical rotary drum to validate the accuracy of the DEM model. The next step was to examine the impact of various operating parameters on the mixing performance, such as impeller rotational speed. The relative standard deviation (RSD) was employed as a measure of mixing performance. Results revealed that the rotational speed of the impellers had a significant impact on the mixing performance.

Keywords: particulate flow; non-spherical particle; mixing dynamics; discrete element method (DEM); double paddle blender

1. Introduction

The mixing of granular materials is a critical process in various industries, including energy, food, pharmaceuticals, and chemicals. When designing processing units like mixing systems, it is essential to understand the mechanical behavior of the granular materials. However, predicting their behavior under various operating conditions can be challenging due to the random and complex particle interactions. This task becomes even more challenging when particles have different sizes, shapes, and physical properties. To tackle this issue, researchers have developed the discrete element method (DEM) approach [1], which tracks individual particle motion and provides comprehensive particle-level information about the system. While the DEM approach has proved effective in simulating various mixing systems [2–5], it has some challenges, including long computational times and high processing power requirements. Consequently, models often simplify the system by using monodisperse size distributions and spherical particles [6]. However, this approach does not address the complexity of the particle shapes in industrial applications. To overcome this shortcoming, practical studies are necessary to model the particles accurately and develop effective solutions that can be implemented in real-world engineering applications. Such studies will improve our understanding of irregular particles' behavior in various mixing scenarios. Thus, the objective of this research is to explore the mixing behavior of a blend of two non-spherical particle shapes (cubical and cylindrical particles) in a pilot-scale mixer using DEM. The effect of impeller rotational speed on the mixing performance of two non-spherical particles in a twin-paddle blender is discussed in this paper.

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2. Modeling and Simulations

GPU-enhanced DEM via EDEM 2022 was used to study the mixing behavior in a double-paddle blender. The DEM is a comprehensive numerical method that considers the movement and interaction of all particles in a mixing system. This method utilizes Newton's equations of motion to determine the translational and rotational velocities, positions, and orientations of individual particles based on their contacts with other particles and walls. Various contact models have been developed to estimate and evaluate particle interactions [7,8]. The geometry of the twin-paddle blender and the formulas used to determine the contact forces and torques are available in our prior research and are not included in this paper for the purpose of being concise [6,9]. Additionally, in the simulations, the polyhedral method was applied to represent non-spherical particles.

3. Results and Discussion

Initially, image analysis was employed to collect experimental data from a rotary drum that had a mixture of cylindrical and cubical particles. Then, the GPU-based DEM solver (EDEM v2022 commercial software) was utilized for the modelling of the same experiments. The experimental data were then used to calibrate the DEM model. The calibrated DEM model was used to investigate how the mixing performance is affected by the operating parameters once it is calibrated. Figure 1 shows different snapshots of the simulated mixer at a constant vessel fill level and particle number ratio ($Number_{cubical}/Number_{cylindical}$), captured from various views after commencing 20 s of mixing process. The figure demonstrates that increasing the rotational speed of the paddles from 10 to 100 RPM improved the mixing performance.

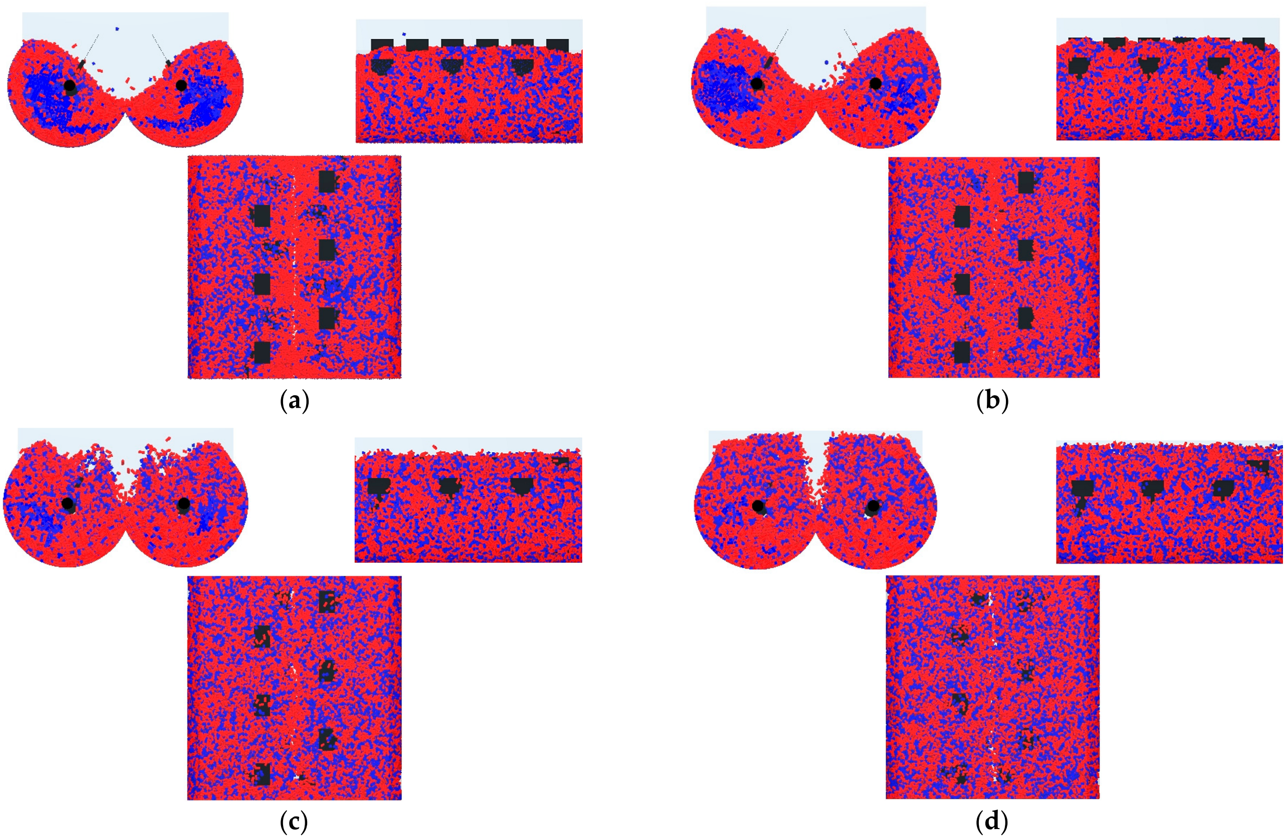

Figure 1. The impact of the impeller rotational speed on mixing at a fill level of 50% and particle number ratio of 1 under different paddle rotational speeds: (**a**) 10 RPM, (**b**) 40 RPM, (**c**) 70 RPM, and (**d**) 100 RPM.

The use of 100 RPM resulted in increased momentum transfer from impellers to particles. However, when the paddles rotated at higher speeds (100 RPM), the particles were less likely to move in bulk along the length of the vessel. On the other hand, a lower impeller rotational speed (70 RPM) allowed particles to move and mix more easily along the mixer's shaft than a higher impeller rotational speed (100 RPM), leading to almost similar mixing performance at both speeds. These findings are consistent with previous studies that have reported an overall improvement in mixer performance with increasing impeller rotational speed for the spherical particles [3,10]. The results suggest that the choice of impeller speed should be carefully considered in order to achieve optimal mixing performance in specific applications. When choosing the impeller speed for optimal mixing performance, the mixing objectives such as achieving homogeneity, reducing particle agglomeration, or maximizing mass transfer should be considered. Moreover, the operational constraints such as power consumption and shear sensitivity should also be taken into account.

4. Conclusions

This study used numerical analysis to examine the flow and mixing process of bi-disperse non-spherical particles in a horizontal twin-paddle blender. The accuracy of the DEM model was verified by comparing it to the experimental data obtained from a rotary drum. This study also examined the effect of adjusting operating parameters on mixing performance. The findings demonstrated that the rotational speed of the paddle had the most substantial effect on the blender's mixing ability. Enhancing the paddle's rotational speed led to a notable improvement in mixing performance.

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