Simulation analysis on the separation behavior and motion of particles in a hydrocyclone

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Highlights

- The dynamics analysis was carried out in Lagrangian frame to investigate the mechanism particle movement.
- Forces acting on particles and trajectories of particles were investigated.
- The properties of materials, and operation parameters were investigated systemically.

1. Introduction

Hydrocyclone [1] is known as a good device for separation and classification on the basis of densities and sizes. For its advantages such as simple structure, easy operation, space saving, and large treatment capability, hydrocyclone has been widely applied in various fields. Partition curve is used to characterize particle separation performance. Theoretically, the highest separation sharpness is accomplished which means all of the fine particles (smaller than cut size) are discharged through vortex finder, and the rest of the coarse particles (larger than cut size) are collected by spigot. However, it is hardly to realize in the actual industrial process. Furthermore, the hydrocyclone for particle separation and classification often have some deficiencies on low separation performance, including misplaced particles in both streams, and unsatisfactory sharpness of the particle classification [2]. Therefore, there is still a need to have a systematic study to accomplish a clearer understand of the motion trajectory of particle phase during the separation process. Only in this way could we better understand the separation mechanism and find an effective way to achieve high efficiency separation.

To understand the motion trajectories of particle phase during the separation process, a numerical study were presented in this paper. A comprehensive mathematical models were carried out to analyze the trajectories of different particles own the stochastic characteristic. The forces acting on particles were analyzed and the relationship between forces and trajectories of particles were obtained. The material properties and operation parameters effecting on separation efficiency were investigated as well. The circulation flow and the short circuit flow of particles were confirmed by analyzing the phenomenal trajectories. Through the aforesaid studies, the results can give a clear and useful understand on the particle motion behavior in the hydrocyclone and direction to improve its separation efficiency.

2. Methods

In this study, the Reynolds Stress Model has been applied to describe the rotating turbulent flow in the hydrocyclones. The interface between liquid phase and air phase was simulated by the Volume of Fluid Model. The Stochastic Lagrangian Model was used to track the motion behavior of solid phase.

3. Results and discussion

Figure 1 illustrated the particle distribution inside the hydrocyclone over time. When these typical particles injected into the hydrocyclone from the inlet, particles with various diameters showed different separation characteristic and motion trajectories. The coarse particles (34.30 μm, brown) gathered near the wall rapidly and were then collected on the spigot by the outer vortex under the effect of the centrifuge. While the fine ones (0.20 μm, blue, 4.36 μm, green and 7.20 μm, orange) showed a higher probability to pass through the locus of zero vertical velocity (LZVV) and were then taken to the vortex finder by the inner vortex. The

particles with cut size (18.50 μm) gave a uniform distribution on the both sides of LZVV, so they got equal chance to move to the overflow or underflow outlet.

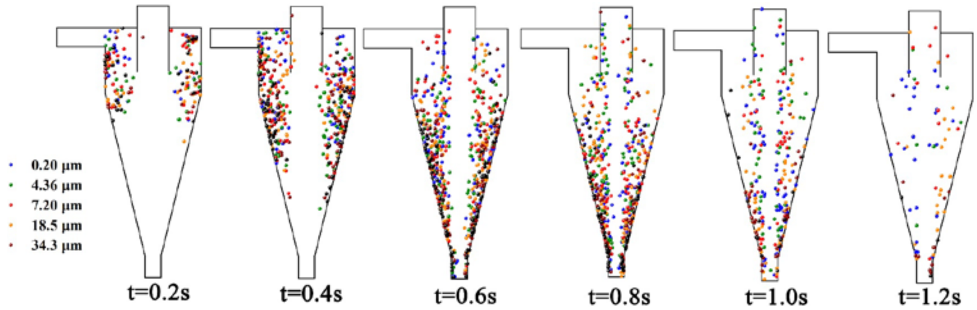

Figure 1. Distribution of particles phase verus to time.

The forces acting on the typical particles were studied, and Figure 2 showed the forces acting on a 0.20 μm particle in all directions.

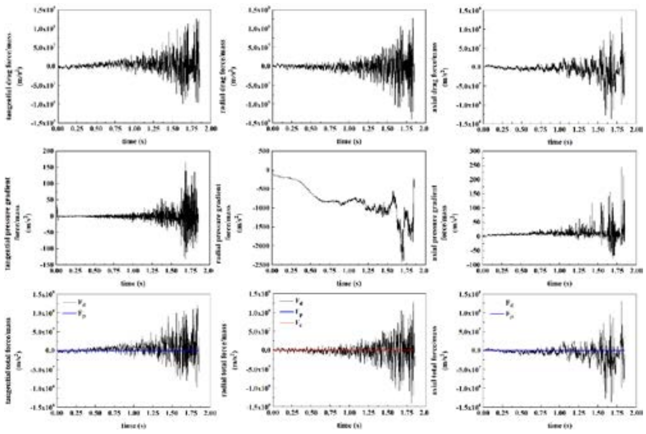

Figure 2. Analysis of force acting on a 0.20 μm particle.

4. Conclusions

To the particles with different diameter, the forces were shown different features. The drag force played a leading role in the movement of the 0.20 μm particles. And it could be known other forces became larger than these on the 0.20 μm particles though the drag force still played a leading role. This should be the reason why the separation efficiency of the 4.36 μm particle was the lowest. To the 7.20 μm, the drag force in the radial direction was no longer in absolute dominance, so that only 15% particles exited from the underflow. Meanwhile, the join forces on the 18.50 μm particles were approximately zero, leading to the separation efficiency being around 50%. Lastly, the pressure gradient force and the centrifugal force of the 34.30 μm particles became the control forces, who were much easier to move outwards in the radial direction, crossing the LZVV and being discharged from the underflow.

References

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[2] B. Wang; A. B. Yu, *AIChE J.* 56(2010) 1703-1715.

Keywords
Hydrocyclone, Separation characteristic, Particle motion