Dynamics analysis of the multiphase fluid field in the hydrocyclone with different cone angle

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Highlights

- Both Eulerian and Lagrangian methods are adopted for hydrocyclone CFD simulation and provide reliable prediction.
- Advice for cone angle alternative for different particle separation tasks is given based on simulation result.
- The effect of cone angle is analyzed with the calculation of radial acceleration, average relative velocity and residence time newly defined in Eulerian Frame.

1. Introduction

In chemical engineering process, particle classification is very common to get product with desirable characteristics. Hydrocyclones is such kind of device which is widely adopted for particle classification and solid-liquid separation in chemical engineering. The design of hydrocyclone geometrical has attracted many attention, for instance, the body size, vortex finder, spigot and inlet have been widely discussed in many works [1-3]. Several works have already investigated the effect of cone section on separation efficiency [4-5]. Therefore, for the small hydrocyclone designed for micron or submicron particles the influence of cone angle should be treated carefully. And more dynamics mechanism analysis is necessary to deeply understand this effect. In this paper, a serial CFD simulations for the75mm hydrocyclones with various cone angle design are carried out. Both Eulerian-Lagrangian and Eulerian-Eulerian method are applied to capture characteristics of multiphase flow. The effect of cone angle on separation performance of hydrocyclones is demonstrated and further dynamic analysis of particle phase based on Eulerian-Eulerian method is given to find out the underlying factors those determine the final separation performance.

2. Methods

The simulation of the multiphase flow in hydrocyclone is divided into two steps. First, the base fluid field of water phase and air core is established with Reynolds stress model (RSM) and Volume of Fluid (VOF). Then particle phase is introduced into the computation domain. In this step, both Eulerian and Lagrangian methods are applied. For Eulerian method, Mixture model which is a simplified Two Fluid Model (TFM) is adopted to replace VOF model for the description of multiphase including particles. For Lagrangian method, Lagrange Particle Tracking (LPT) model is adopted for particles based on the basic fluid field descripted by RSM and VOF model.

3. Results and discussion

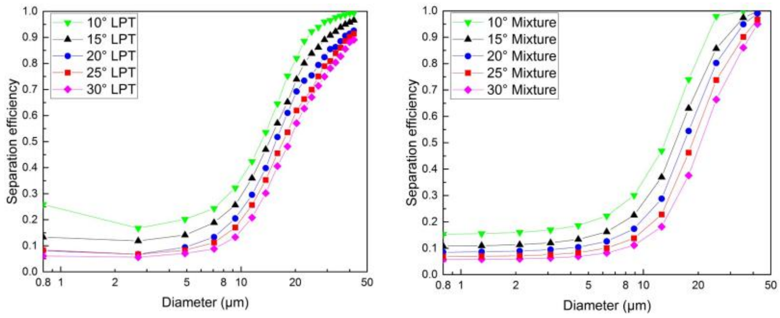

Figure 1. Effect of cone angle on separation efficiency of hydrocyclone by LPT model and Mixture model.

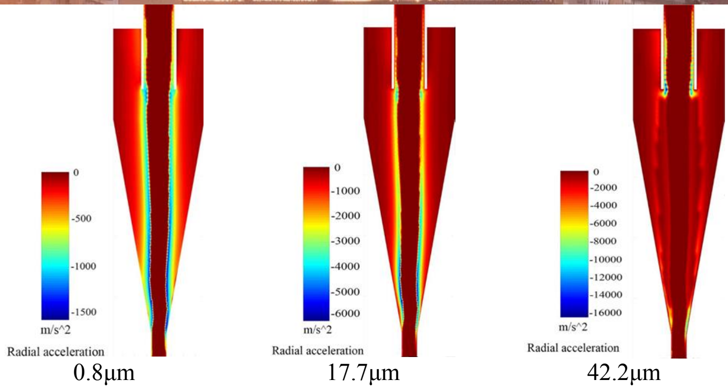

Figure 2. Radial acceleration distribution of typical particle size in Eulerian frame.

It can be found out that with the increase of cone angle the separation efficiency of particles with all sizes increase and that also reflects the probability of particle reported to the spigot becomes higher. (Figure 1.) Figure 2. shows overall radial acceleration profile of typical diameter particles. The distribution has the similar pattern for different particles: the value of acceleration is small near the wall and gradually increase toward the center. With the increase of cone angle, particle residence time increases. although the phase separation effect of radial acceleration is weaker than that in the hydrocyclone with large cone angle at single point, longer residence time may provide a higher final separation efficiency too. (Figure 3.)

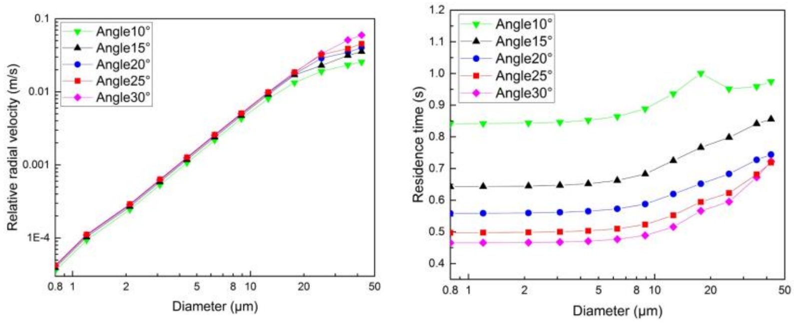

Figure 3. Average relative velocity and residence time of particle phase statistic with Mixture model.

4. Conclusions

(1) The simulation results imply that hydrocyclone with small cone angle provides higher separation efficiency which is desirable for water filtration. However, that may not be an acceptable alternative for particle size classification, since it introduces more ultra-fine particles into the underflow.

(2) Through the comprehensive analysis of stress state and residence time, the longer residence time in small cone angle hydrocyclone provides the higher overall separation efficiency rather than radial acceleration.

References

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Keywords
Hydrocyclone; Cone angle; Computational fluid dynamics; Dynamics analysis.