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Influences of solid physical properties on the performances of a slurry external airlift loop reactor integrating mixing and separation

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1. Introduction

Gas-liquid-solid slurry airlift loop reactor has been widely applied in Fischer-Tropsch synthesis, hydrogenation, and microbial fermentation due to its excellent mixing and mass/heat transfer characteristics [1]. In order to obtain clear liquid products after the multiphase reaction, continuous and efficient separation of the liquid from the slurry is one of the main challenges in the industrial processes. By combining the liquid-solid separation in the hydrocyclones and the directional flow in the airlift loop reactor, an external airlift loop reactor (EALR) was first proposed and established to realize the process intensification of mixing, mass transfer, and liquid-solid separation in 2019 [2]. With the existence of solid particles, the hydrodynamics and mass transfer properties become complicated because of their multiple influences on the bubble coalescence/breakup, bubble rising velocity, gas holdup, and flow regime transition. Contradictory conclusions of the solid effects have been obtained by different researchers due to different solid concentrations and physical properties of the employed solid particles [3,4]. In this reactor, our previous study showed that gas holdup, liquid circulating velocity, mass transfer rate decreased with increasing the solid concentration [2]. For the purpose of better understanding the underlying mechanisms and enlarging the application scope of this promising type of reactor, further investigations of the solid physical properties on the reactor performances should be conducted. In this work, the impacts of solid density and size distribution on hydrodynamics, flow regime transition, mass transfer, liquid-solid separation, and solid axial distribution will be performed to give guidance of further design, optimization, and scale-up of this slurry EALR.

2. Methods

The overall gas holdup in the reactor was measured by the traditional manometric method, i.e., measuring the pressure drop between two levels through differential pressure sensors. Two electromagnetic flowmeters (XFE025Y16F1BM1R, Henan Xinhang Flow Instrument Co., Ltd.) installed below the

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hydrocyclones were applied here to measure the slurry circulating flow rate, with the correction of a classical response technique. The classic Na_2SO_3-air oxidation method [2] was applied to measure the overall volumetric mass transfer coefficient. Axial distribution of solid particles was investigated by a sampling method through four taps of 10 mm diameter installed in the riser column at different axial positions.

3. Results and discussion

Two types of aluminum oxide particles with medium diameter of 101.0 μm and 61.78 μm, whose true density of and bulk density were respectively 3800 kg/m^3 and 1660 kg/m^3, were applied as the solid phase to investigate the influences of solid diameter. It was demonstrated that the initial and final particle size distribution of both two types of solid particles almost overlapped, indicating that the solid particles can be commendably retained in the working system. The amount of solid particles with medium diameter of 101.0 μm discharged from overflow of hydrocyclones after 4 h circulation was less than that of solid particles with medium diameter of 61.78 μm, which could be attributed to the higher separation efficiency with increasing solid diameter. Different solid particles, i.e., silica sand with the Sauter diameter of 125.1 μm and FCC catalyst of 71.1 μm, were also applied to investigate the influences of solid density and diameter on the hydrodynamics, mass transfer, and separation efficiency in this EALR. It was found that solid axial uniformity increased with decreasing the solid density and diameter.

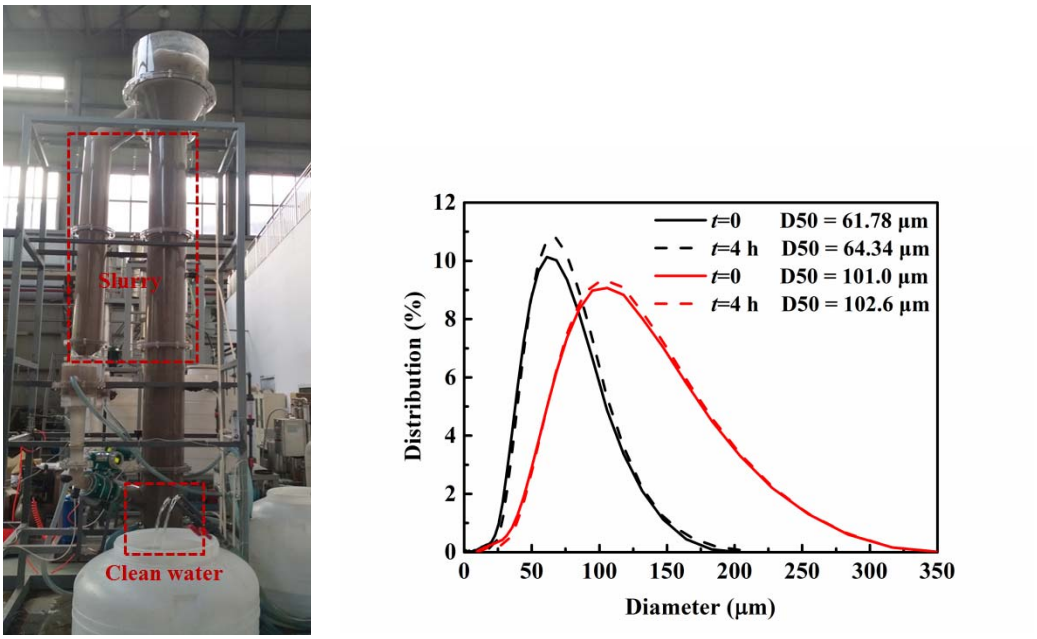

Figure 1 (a) Illustration of experimental process; (b) Comparison of size distribution for different solid particles.

4. Conclusions

In the new type of EALR integrating mixing and liquid-solid separation, the influences of solid density and diameter on the hydrodynamics, mass transfer, axial particle distribution, and separation efficiency have been thoroughly conducted. Experimental results demonstrated that the discharge amount and solid axial uniformity decreased with increasing solid diameter and density.

References

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