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Solid Suspension and Mixing Time in a Torispherical-Bottomed Pharmaceutical Reactor under Different Baffling Conditions

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Abstract

In the pharmaceutical and specialty chemicals industries, partially baffled, torispherical-bottomed glass-lined reactors are often used because of their material compatibility with most reactants and their cleanability. These reactors are typically equipped with a retreat-blade impeller and a single baffle mounted from the top. The mixing performance of such reactors has received only limited attention in the literature, despite their ubiquitous presence in the pharmaceutical industry. In this work, the minimum agitation speed to achieve off-bottom solid suspension, N_{js}, and the mixing time required to achieve homogenization of an added tracer were experimentally determined. All experiments were conducted in a 60 L, scaled-down version of an actual industrial tank reactor having a torispherical bottom and equipped with a retreat-blade impeller. Different baffling configurations were studied, i.e., a fully baffled system with 4 standard vertical wall baffles, a partially baffled system with a single beavertail baffle placed midway between the shaft and the tank wall, and an unbaffled system. In the solid suspension experiments, spherical glass beads with an average size of 60 μm were used as the dispersed phase, while water was the continuous phase. N_{js} was experimentally determined using Zwietering's method, requiring that the solids do not rest on the tank bottom for more than 1-2 seconds. The value of N_{js} strongly depended on the type of baffling, and was highest in the unbaffled tank and lowest in the partial baffled system. As for mixing time, a conductivity method using sodium chloride (NaCl) as a tracer was one of the two approaches used here to determine mixing time. Experiments under unbaffled conditions were conducted by installing one or two probes in the mixing vessel (at the wall and midway between the wall and the shaft, respectively). The presence of the conductivity probe(s) had a significant impact on mixing time. Different mixing times were obtained with the conductivity method depending on the location of the probe(s) and the number of probes. A separate colorimetric method coupled with image processing was additionally used to determine the mixing time. Both methods produced similar results when two probes were present, probably because of the baffling effects introduced by the probes themselves. Results were also obtained with the partial baffling and full baffling arrangement. Experiments were performed when the agitation speed was varied in order to establish a correlation between mixing time and impeller speed under different baffling conditions. For the unbaffled system, different mixing times were obtained with the conductivity method depending on the location of the probe(s) and the number of probes. The colorimetric method produced results that were in agreement with the conductivity method only when two probes were used. The unbaffled system appeared to be extremely sensitive to minor geometric parameters, such as the presence or absence of the probes, their location and number, and the modality of the tracer addition. For the unbaffled system, mixing time results could not be interpreted using the conventional approach used for baffled systems. The mixing time in the fully baffled system was comparable to the mixing time obtained with other types of impellers in baffled systems and could be quantified in terms of the non-dimensional mixing time, $\theta_{95}{\cdot}N$. It was found that $\theta_{95}{\cdot}N$=24.2. The mixing time in the partially baffled system was intermediate between those of the unbaffled and baffled systems. In this system the non-dimensional mixing time $\theta_{95}{\cdot}N$ was not constant, implying that the use of a single beavertail baffle does not provide full baffling. This was confirmed by the formation of a small vortex at high agitation speeds in the partially baffled system.