Comparing rotating bed reactor and fixed bed reactor for adsorption purification

The use of a SpinChem® rotating bed reactor (RBR) can streamline purification of large liquid volumes by decreasing the time and amount of solid phase material required to process a given liquid volume. In this application note, we investigated adsorption of methylene blue dye onto activated carbon using a SpinChem® RBR and a fixed bed reactor (FBR) column. It was found that the RBR technology could significantly reduce the processing time and required amount of solid phase material compared to the conventional FBR column set-up. At identical material volumes, the SpinChem® RBR finished the processing after 40% of the time compared to the FBR and was still somewhat faster when only 50% of the adsorbent material was used. The adsorption patterns within the two different reactor types suggest that the RBR has a more optimized utilization of the solid phase compared to the FBR.

Keywords: Technology, Activated carbon, Decolouration, Fast reaction

Heterogeneous reactions involve reactants in different phases; usually a substrate dissolved in a liquid, and a solid catalyst or adsorbent. As diffusion is a slow process, different techniques are applied to achieve contact between the reactants in the two different phases. One approach is to pack the solid phase into a column through which the liquid phase is pumped, a set-up known as a fixed bed reactor (FBR). However, the typical speed of this process is limited as the mass transfer efficiency decreases with increasing particle size, and often also with increasing flow rates. The FBR generates high back pressures at high flow rates, which might damage the solid phase particles, or require high-pressure equipment, thus restricting the viable flow rate.

When using a SpinChem® rotating bed reactor (RBR), the solid phase is kept inside a rotating stainless steel cylinder. As the cylinder spins, solution is repeatedly flushed through the packed bed within by centrifugal forces (Fig 1). This allows every liquid parcel to do multiple passages through the bed at high flow rates, without exposing the solid particles to pressure or stress.

In this application note we compared a SpinChem® RBR and a conventional FBR for removal of dissolved methylene blue dye from an aqueous volume. The two different reactors were loaded with equal amounts of granulated activated carbon. Each reactor was then used to process a fixed volume of dye solution until the dye concentration was below 0.5% of the start value. The FBR was investigated at different flow rates, whereas the amount of adsorbent material was varied in the RBR.

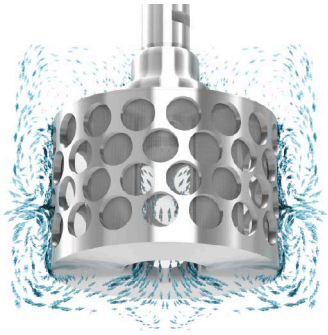

Fig 1. Vector plot from computational fluid dynamics simulation of a SpinChem® rotating bed reactor (RBR), immersed in a SpinChem® flower-baffled reaction vessel. The arrows indicate liquid flow directions in one plane during rotation of the RBR.

With the FBR, the effluent reached the defined breakthrough criterium within 18 min, and allowed processing of the entire liquid volume within 20 min at a moderate flow rate of 50 mL/min (Fig 2) and a back pressure of about 0.5 MPa. At higher flow rates (75 mL/min and 100 mL/min), the breakthrough limit of the effluent from the FBR was reached after processing only fractions of the total liquid volume (50% and 30%, respectively), and the concentration of the pooled effluent also exceeded the concentration limit of 0.5%.

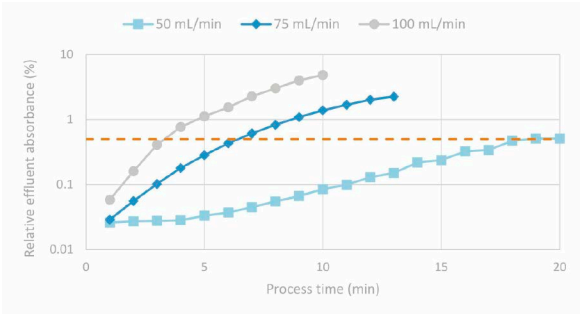

Fig 2. Relative absorbance of column effluent from the FBR acquired at different flow rates during processing of 1 L aqueous solution containing 400 mg/L methylene blue using 48 mL of 20/50 mesh activated carbon packed into a 9 x 2.6 cm column. Samples for absorbance measurements were collected every minute and divided by the initial absorbance level. The dashed line indicates the defined limit of 0.5% of initial concentration.

When the SpinChem® RBR was used to process the corresponding volume of dye solution, the purity limit of 0.5% of the initial concentration was reached after only 8 min (Fig 3), thus being 2.5 times faster compared to the FBR. The reduction of adsorbent material to 75% and 50% resulted in processing times of 12.5 min and 17.5 min, respectively. Thus, even with half the amount of activated carbon used, the RBR was significantly faster than the FBR column.

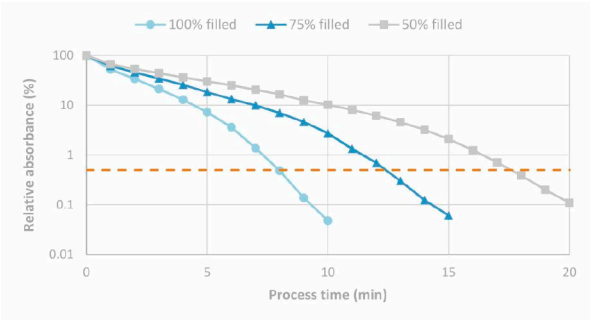

Fig 3. Relative absorbance of the liquid processed by spinning a SpinChem® RBR S311 containing 48 mL, 36 mL or 24 mL (100%, 75% and 50% filled, respectively) of 20/50 mesh activated carbon at 800 rpm within a SpinChem® flower-baffled vessel V321, containing 1 L water containing 400 mg methylene blue. Confer Fig 2 for additional information.

Attempting to visualize the adsorption patterns of the two different reactors, we used a white, polymeric adsorbent (XAD 1600N) under the same experimental conditions. The FBR showed a distinct colour gradient from inlet to outlet of the packed bed, whereas the particles within the RBR were all evenly coloured, thus indicating a more efficient use of the material in the SpinChem® RBR.

In summary, the RBR technology can significantly reduce the processing time and amount of solid phase material compared to a FBR column (Fig 4). The process with the SpinChem® RBR required only 40% of the time at equal material amounts, or 62% and 88% of the time with 75% and 50% of the material quantities, respectively.

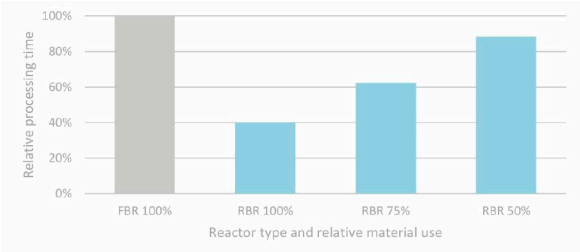

Fig 4. Relative processing time of a traditional FBR column set-up compared to SpinChem® RBR technology at different levels of filling. Data extracted from Fig 2 and Fig 3.

Conclusions:

- The SpinChem® RBR technology can significantly reduce the processing time, and/or the amount of material required for purification processes.
- With a SpinChem® RBR, the purification process was accomplished in 40% of the time needed for a conventional FBR setup, using the same amount of material.
- The SpinChem® RBR required less than 50% of the material, compared to an FBR, to accomplish the same level of purity within a fixed processing time.

The SpinChem® rotating bed reactor (RBR) is revolutionizing mass transfer in heterogeneous reactions where solid phases are used for catalysis, enzymatic reactions, adsorption, scavenging and other processes. The convenience of a protected bed within an RBR significantly reduce the need for post-reaction work-up. The SpinChem® RBR concept is fully scalable from laboratory to production, thus providing both more efficient reaction development and improved production economy.

Products: SpinChem® RBR S311 (1311-001), SpinChem® Vessel V321 (2321-001)

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