Effects of channelling on flow rates through rotating bed reactors and fixed bed reactors

The performance and robustness of the rotating bed reactor (RBR) technology was examined and compared to a fixed bed reactor (FBR) using fluid dynamics simulations in ANSYS Fluent. By means of flow simulations through loosely packed beds, the RBR was found to be extremely robust with respect to the density of the packed solid phase bed within. Adverse effects of channelling that can occur in non-optimally packed fixed beds had very little impact on the performance of the RBR. The FBR was found to be affected negatively by channelling, with very poor performance for non-optimally solid phase packing. This explains why the SpinChem® RBR can be used with great results even when not fully packed, something that generally entails major problems for an FBR set-up.

Keywords: Simulation, Technology, Easy handling

A common issue faced with when utilizing fixed bed reactors (FBR) for heterogeneous reactions is a phenomenon known as channelling. This is caused by uneven packing of the solid phase material in the column. In parts of the column where the solid material is loosely packed, the liquid being pumped through will experience less resistance, leading to a higher flow rate. This means that the liquid parcels will favour this route over one containing more densely packed material. The liquid will thus pass through void regions in the bed rather than in the proximity of the packed material, greatly reducing the performance of the set-up.

The rotating bed reactor (RBR) technology is an innovative alternative to conventional methods, such as FBRs, for heterogeneous reactions. The RBR consists of a hollow cylinder into which the solid phase is packed and contained. As the RBR is rotated in solution, the centrifugal forces created by the rotary movement will drive the flow of liquid through the filters of the RBR and the packed bed within repeatedly at high flow rates.

In this application note, simulations were carried out in ANSYS Fluent to determine the impact that channelling in a section of the RBR had on flow performance of the reactor set-up, relative to that of an FBR. For an equitable comparison, the same geometry and flow rate were used for simulations of a spinning RBR and a stationary FBR. The flow rate determined for the RBR at optimal packing was

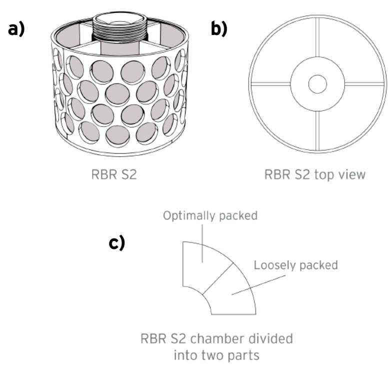


Fig 1. a) SpinChem® rotating bed reactor, model S2, open at top. b) RBR S2, open at top, top view. c) One compartment of the RBR divided into two parts, used as the geometry for the packed bed in the flow simulations. One half was simulated as optimally packed, and one half was simulated with varying degrees of packing.

pumped through the FBR for all degrees of packing. This represents a typical FBR operation at fixed flow rate. The simulated bed was in both cases split into two halves so that a loosely packed region could be modelled alongside an optimally packed region. By simulating alternations in the packing density in the loosely packed half, and observing the flow rate in the optimally packed half, the effect of channelling could be monitored for the different reactor types. Different packing densities were simulated by changing the relative permeability coefficient of the loosely packed half of the bed.

It was found that the volumetric flow rate through the optimally packed half of the solid phase bed in the RBR decreased by <0.1% when the specific permeability coefficient of the loosely packed half of the bed was increased to 133% of the reference value. This was done to simulate the effect of moderate channelling, and the corresponding value for the FBR was a 15% decrease in flow rate. The specific permeability coefficient in the region with channelling was also increased to 200% with respect to the reference value, corresponding to severe channelling. In this case the volumetric flow rate in the optimally packed region of the RBR was <0.5% lower than in the reference case, while the corresponding flow rate for the FBR dropped by 33% compared to the reference value.

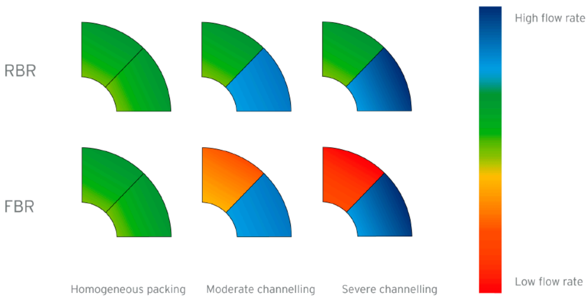
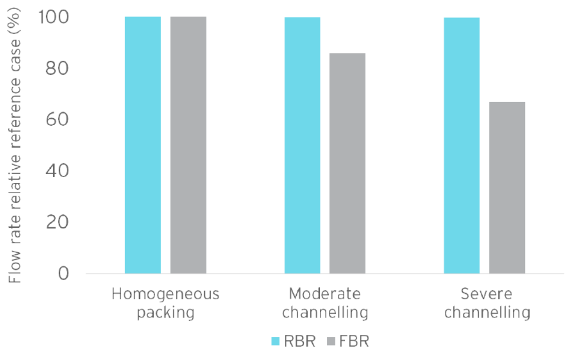


Fig 2. Schematic representation of flow rates in the two halves of the simulated bed for an RBR and an FBR at different levels of packing. One half was simulated as optimally packed (top half in figure), while one half was simulated with varying degrees of packing (bottom half).

The optimally packed half of the simulated bed for the RBR was not affected by the higher flow rate through the loosely packed half. For the FBR, the flow rate through the optimally packed half of the bed decreased as the flow rate through the other half increases due to looser packing of material. The differences observed for the RBR and FBR implies that the performance of the RBR will not be significantly affected by the level of flow channelling, while the FBR is greatly affected. This can be explained by the fact that the overall flow through an RBR will increase as channelling occurs, meaning that the flow through a specific point



Level of channelling	Relative specific permeability	Relative volumetric flow rate RBR	Relative volumetric flow rate FBR
None	100%	100	100
Moderate	133%	>99	85
Severe	200%	>99	67

Fig 3. Diagram and table showing the effect of channelling on the flow rate through a packed bed inside an RBR and FBR, respectively. Homogeneous packing was simulated by assigning the region a specific permeability coefficient corresponding to that of an ion exchange resin of uniform particle size. This value served as a reference value for the simulations, and corresponds to a pressure drop of 0.054 bar/m for water at 20°C with a linear velocity of 1 mm/s. Moderate and severe channelling was assigned specific permeability values corresponding to 133% and 200% of that of the reference, respectively.

of the optimally packed bed will stay unchanged even as the flow rate through the loosely packed half increases. For the FBR, the overall volume flowing through the bed is constant, and will thus be redistributed over all the points of the bed as channelling occurs. A higher specific permeability in one part of the bed due to channelling will lead to lower flow rate in parts with a lower specific permeability.

Conclusion:

- The performance of an RBR is very robust and will not be significantly affected by channelling due to a loosely packed bed, while the performance of an FBR set-up is significantly diminished by channelling.

The SpinChem® rotating bed reactor (RBR) technology 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.

SpinChem AB, Tvistevägen 48, SE-907 36 Umeå, Sweden
+46 (0)90 19 25 01 | info@spinchem.com | www.spinchem.com

SPINCHEM®