Decolouration of highly viscous solutions using a rotating bed reactor and a stirred tank reactor

The performance of a SpinChem® rotating bed reactor (RBR) in the treatment of highly viscous solutions was compared to that of a conventional stirred tank reactor (STR). Both reactor set-ups were used for the removal of Allura red dye from a glycerol solution with a viscosity 116 higher than that of water at room temperature. The dye concentration for the STR stagnated at 1% of the start concentration after 25 hours, a concentration the RBR reached after just 7 hours. Overall, the RBR reached a 10 times lower dye concentration than the STR set-up, in just over 40 % of the time. This comparison underlines the efficient mass transfer and excellent mixing throughout the entire tank volume achieved with the SpinChem® RBR.

Keywords: Viscous solutions, Ion exchange, Decolouration, Technology, Fast reaction

Heterogeneous reactions in highly viscous media, common in the processing of functional foods, cosmetics and biofuels, face a number of obstacles. All heterogeneous reactions depend on efficient mass transfer in order for the different reactants to achieve contact at a reasonable rate, and highly viscous solutions put higher demands on the tools used to create the convective flow necessary to achieve this. When using a conventional stirred tank reactor (STR) in operations involving small particles and/or viscous media, the mixing of particles and solution is greatly decreased. This is due to the fact that the solid phase particles in an STR for such a case tend to follow their streamline closely, meaning low movement of the particle relative to the flow. This behaviour is related to a low Stokes number (*Stk*). The dimensionless Stokes number describes a suspended particle's response time relative to a moving fluid.

The SpinChem® rotating bed reactor (RBR) is an alternative to conventional techniques used for heterogeneous reactions, such as STRs and fixed bed reactors. The RBR consists of a hollow cylinder into which the solid phase material is packed. As the RBR is spun in solution, the fluid is forced through the packed bed of particles inside by the centrifugal forces created. Each fluid parcel makes multiple passages through the packed bed at high flow rates. The design of the RBR thus creates a strong convective flow of liquid to the particles, achieving efficient mass transfer, independent of the Stokes number.

Fig 1. An open SpinChem® rotating bed reactor (RBR) S3, filled with ion exchange resin after an uptake of Allura red dye.

In this application note, a high viscosity experiment was designed to compare the SpinChem® RBR S3 to a conventional STR in terms of mixing. A strong, macroporous base anion exchange resin (Purolite® A500MB Plus) was used to adsorb Allura red from a highly viscous solution comprised of glycerol and deionized water. The solution was cooled down to achieve a viscosity 116 times higher than that of water at room temperature. The RBR was packed with ion exchange resin and spun in the coloured glycerol solution. For the STR set-up, the same amount of ion exchange resin was suspended freely in the coloured glycerol solution, and stirred at the same rate using an impeller of the same diameter as the RBR. Samples were extracted over time and the change in dye concentration was monitored using a UV-Vis spectrometer.

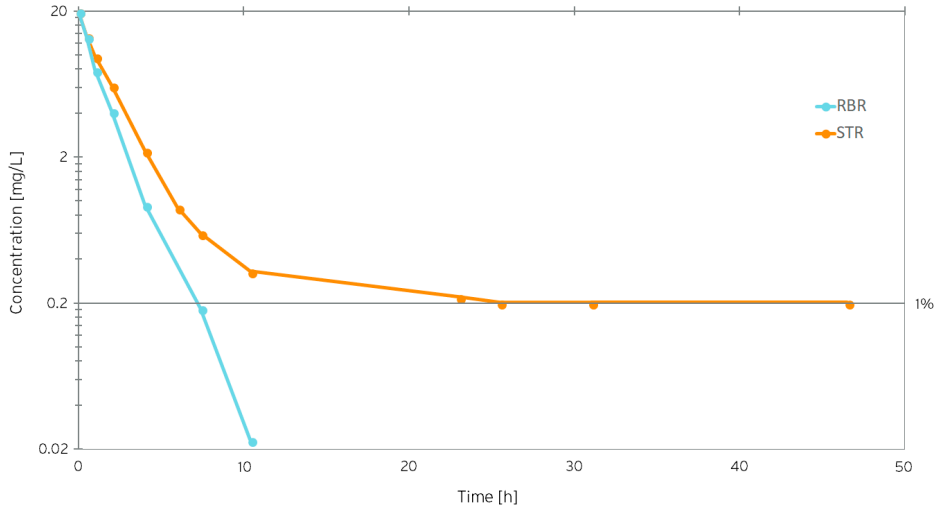


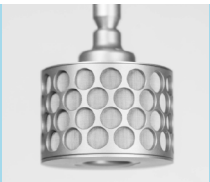
Fig 2. Graph showing the Allura red dye concentration over time for decolouration runs using a SpinChem® RBR S3 (blue) and a conventional STR set-up (orange). Glycerol (80 wt%) was mixed with deionized water and Allura red (20 mg/L). The mixture was kept in a flower-baffler SpinChem® vessel V3 at a temperature of 10 °C to achieve a viscosity of 1.16 · 10^{-4} m^2/s. A SpinChem® RBR S3 was filled with 41.6 g Purolite® A500 MB Plus, and spun in 1 L of the mixture at 400 rpm. For the STR experiment, 41.6 g of the same ion exchange resin was suspended in 1 L of the viscous dye solution, and stirred by means of an impeller of the same diameter as the RBR S3 at 400 rpm. Samples for absorbance measurements were analysed using UV-Vis spectrometry at 500 nm.

The RBR showed significantly better performance than the STR for treatment of viscous fluids, with a constant slope in the semilogarithmic plot of the dye concentration over time (Fig 2). The concentration of Allura red in the RBR set-up reached 0.02 mg/L after 10.4 h, after which the concentration was too low for the UV-Vis spectrometer to detect. For the STR, the dye concentration stagnated at 0.2 mg/L after 25.5 h, a value that was reached in just around 7.0 h using the RBR. This highlights the superior mass transfer efficiency of the RBR technology. The overall results obtained using the RBR was a 10-folds lower dye concentration after just 40.7% of the time, compared to the STR results.

The outstanding results obtained using the RBR technology can be explained by its clever design. As the RBR rotates, the solution is forced through the packed bed of particles, whose movement relative to the liquid is directly mediated by the movement of the RBR. This means that despite the high viscosity, the convective flow of solution to the solid phase particles is still high, meaning faster and more efficient dye adsorption. Following the extraction run, the solid phase in the RBR set-up was easily separated from the solution by simply removing the RBR from the reaction vessel. For the STR case, the run was followed by tedious and time-consuming filtration steps.

Conclusions:

- The RBR showed significantly better performance than the STR in highly viscous solution, with a dye concentration of 0.02 mg/L obtained after just 40.7% of the time it took the STR to reach 0.2 mg/L.
- The dye concentration in the solution processed by the RBR kept a constant slope throughout the entire run, while the concentration in the STR set-up stagnated at 0.2 mg/L.
- Using an RBR circumvents the tedious and time-consuming filtration steps needed to isolate the solid phase from the solution when using an STR.



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.

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

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