Optimizing the rotational speed of rotating bed reactors in baffled reaction vessels

The SpinChem® rotating bed reactor (RBR) can greatly increase rates and efficiency of heterogeneous reactions by enhancing mass transfer of reactants between the solution and the solid phase. This application note investigates the effect of rotational speed on reaction time and rate for a number of processes such as adsorption of a colorant onto activated carbon, neutralization by ion exchangers and biocatalyzed ammonolysis using an immobilized lipase enzyme. Fast reactions always benefitted from faster rotational speeds whereas a plateau in overall rate was reached when mass transfer efficiency exceeded maximum reaction rate. Overall reaction rates with SpinChem® RBR were higher under most conditions compared to traditional stirred tank reactors (STR).

Keywords: Technology, Activated carbon, Ion exchange, Immobilized enzymes

Heterogeneous reactions, which by definition involve the transfer of reagents to a solid surface, are often limited by the rate of mass transfer. This is especially evident in traditional stirred tank reactor (STR) batch processes and often cannot be solved even by vigorous stirring or excessive amounts of solid phase. The SpinChem® rotating bed reactor (RBR) overcomes this by delivering very efficient convective mass transfer.

During rotation of the SpinChem® RBR, the solution is aspirated from the bottom of the reaction vessel, efficiently percolated through the packed bed of solid phase within the RBR and finally redistributed towards the vessel walls (Fig 1). The rotational speed - plus other factors such as bed permeability - will affect the flow rate through the RBR. Optimization of RBR processes thus involve determining the rotational speed where the reaction time reaches a plateau or where further time savings will be limited.

In this application note we investigated the effects of rotational speed for the SpinChem® RBR on the performance of a number of heterogeneous processes and compared these to STR set-ups for some cases. First, we studied the adsorption of a food dye on activated carbon. Higher rotational speeds of the RBR gave faster and more efficient adsorption, reducing the dye concentration by a factor of 1000 at the highest speed tested (Fig 2).

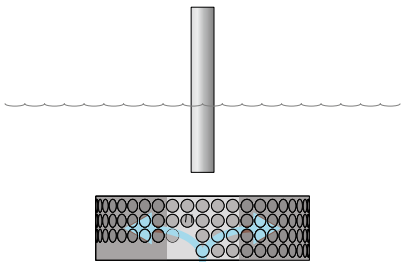

Fig 1. Schematic drawing of the SpinChem® rotating bed reactor (RBR) immersed in a reaction vessel. The arrows indicate liquid flow directions during rotation of the RBR.

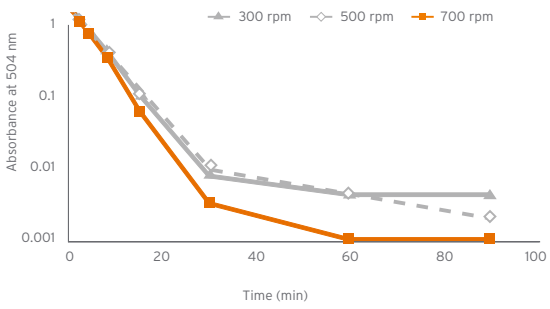

Fig 2. Adsorption of food dye Allura Red AC (1.75 mL) onto activated carbon (40 mL, 12-40 mesh) packed in SpinChem® RBR S311 operated at different rpms in 700 mL water within Radley's Reactor-Ready system (1 L) with baffles.

›le neutralization by a strongly basic
/as investigated (Fig 3a). We compared
ł in solution agitated by a traditional
STR setup, with an identical amount
. Trends of decreasing reaction times
:ational speeds were observed for both
icating mass transfer-limited reaction
nChem® RBR, however, reactions
ed 23-36% faster.

During neutralization by a strong acid cation exchanger (Fig 3b) we observed slightly slower reactions with the RBR at intermediate rotational speeds. At higher rotational speeds the STR reached a plateau in reaction rate due to limitations in mass transfer, whereas with the SpinChem® RBR the mass transfer and reaction rates continued to increase throughout the entire range studied.

When studying the activity of immobilized lipase packed into an RBR for ammonolysis (Fig 4), we observed that the reaction rate reached a plateau above 400 rpm. This indicates that enzyme kinetics rather than mass transfer efficiency, limited this reaction at higher rotational speeds. It is thus unnecessary to increase the rotational speed beyond this point.

Fig 4. Lipase activity during ammonolysis of dimethyl-3-hydroxy-glutarate (26.4 g) in SpinChem® RBR S221. CaLB-T1-XL high-activity beads (250 mg, 28 mL) and ammonia-saturated tert-pentanol (250 mL) within a baffled reaction vessel (250 mL).

:ime of acid (a) and neutralization rate of hangers (Purolite A500P and Amberlite pinChem® RBR S221 or dispersed with aced in a Mettler Toledo EasyMax 401 onditions; a) HCl (3%, 30 µL) in 450 mL urolite A500P (>700 µm, 0.4 g); b) NaOH mL water to change of phenolphthalein (5.2 99 (ca 500 µm, 28 mL).

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.

Sp en 48, SE-907 36 Umeå, Sweden
+46 (0)90 chem.com | www.spinchem.com

SPINCHEM®