Topic: 旋轉反應器在光觸媒的應用之製程特性與規模放大

3-2-4 Comparison with Batch Reactor
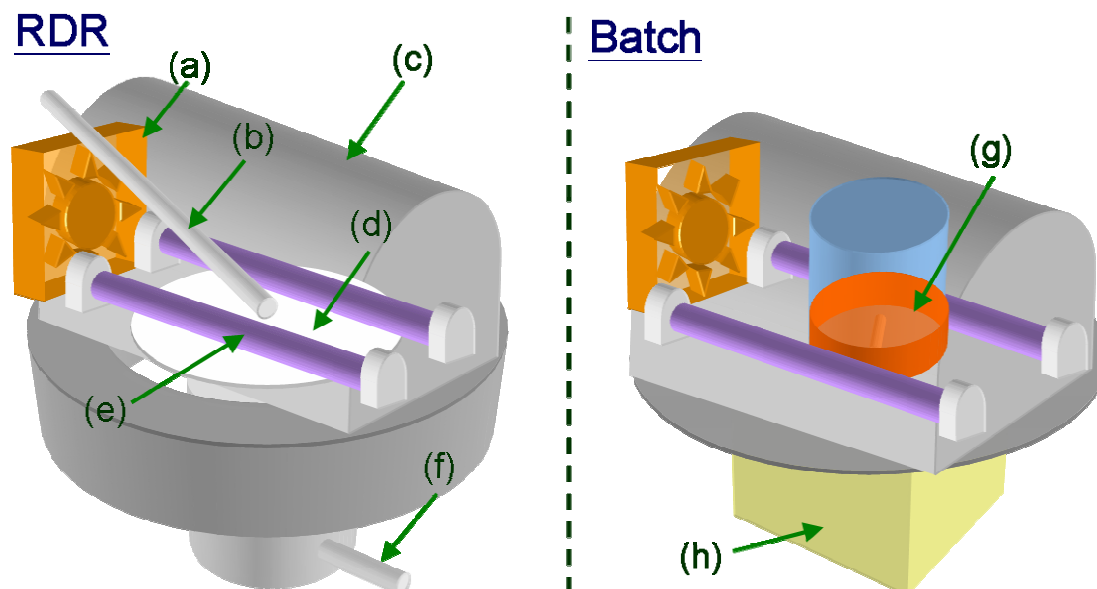

Fig. 3-3. Schematic of experimental apparatus of RDR and batch reactor. (a) Fan (b) Inlet of test solution (c) Aluminum foil (d) TiO_2-coated disc (e) Ultra Visible lamps (f) outlet of test solution (g) TiO_2 suspension solution with organic material. (h) Stirrer.

Table 3-4. Comparable table for RDR and batch reactor.

RDR		Batch reactor	
TiO_2 (P25)	0.03g	TiO_2 (P25)	0.03g (0.6g/l) 0.004g (0.08g/l) 0.002g (0.04g/l)
Methyl orange	50ml $4×10^{-5}$M	Methyl orange	50ml $4×10^{-5}$M
Two UV lamps	254nm 4W	Two UV lamps	254nm 4W

Temperature	RT	Temperature	RT
Operation time	5min (10ml/min)	Operation time	5min
	10min (5ml/min)		10min
	17min (3ml/min)		17min
Rotating speed	600rpm		

The purpose of this experiment is to see whether the performance of RDR could be comparable to that of batch reactor. Some parameters have been fixed for the sake of having more meaningful results. These involve *amount of TiO₂, volume and concentration of the methyl orange*, *intensity of UV light source* and *operating temperature.*

From calculation, the amount of TiO$_2$ on the disk is 0.03g. The detail algorithm for estimating the quantity of TiO$_2$ is presented in Appendix A.

Both the apparatus of RDR and batch reactor are shown in Fig. 3-3, while the compared table of various parameters for these two reactors also display in Table 3-4. It should be mentioned that the rotating speed of disc selected to compare with the batch reactor is 600rpm, which shows the optimum conversion of MO at various volume flow rate in the following parts.

4-3-5 Kinetics Model of Rotating-Disk-Reactor

In this section, the objective is to offer an appropriate kinetics model for rotating-disk-reactor (RDR) in decomposition of organic contaminant of water. As far as kinetics model of rotating-disk-reactor is concerned, considering the organic material solution flow through the TiO$_2$-coated discs which was illustrated in Fig. 4-10, we could reasonably derive the kinetics model of RDR from general model balance equation:

$$F_A(V) - F_A(V + \Delta V) + \int^V (-r_A)dV = -\frac{dN_A}{dt}$$

Where, $F_A(V)$:   Molar flow rate of A into volume ΔV (mole/s)

$F_A(V+\Delta V)$:   Molar flow rate of A out of the volume ΔV (mole/s)

r_A: Rate of reaction (mol/(L×s))

N_A: the amount of moles of A in the ΔV at time t (mole/s)

Some assumptions could be established below: (1) The apparatus is operated at steady-state; (2) Within each subvolume ΔV, the reaction rate may be considered spatially uniform. Hence, we could reasonably derive the kinetics model of RDR and yield

$$-\frac{dF_A}{dV} = -r_A$$

Eq. (4-11) could be rewritten as that of the function of concentration and radius, as shown in follows:

$$-\frac{QdC_A}{2\pi rhdr} = -r_A \tag{4-12}$$

Substituting the expression of liquid film thickness from Eq. (4-5) into Eq. (4-12), after rearranging the kinetics model of RDR as the function of radial location may be expressed as:

$$-0.2035\frac{Q^{2/3}\Omega^{2/3}}{v^{1/3}r^{1/3}}\frac{dC_A}{dr} = -r_A \tag{4-13}$$

On the other hand, the kinetic model of RDR also can express as a function of average residence time. Replacing the derivation term in the left hand with concentration of MO versus average residence time, and substituting Eq. (4-8) into this form reveals simpler expression:

$$-\frac{dC_A}{dt} = -r_A \qquad\qquad (4\text{-}14)$$

The general kinetic form of RDR from design equation Eq. (4-14), is employed for determining the photocatalytic reaction order of organic material in the following section.
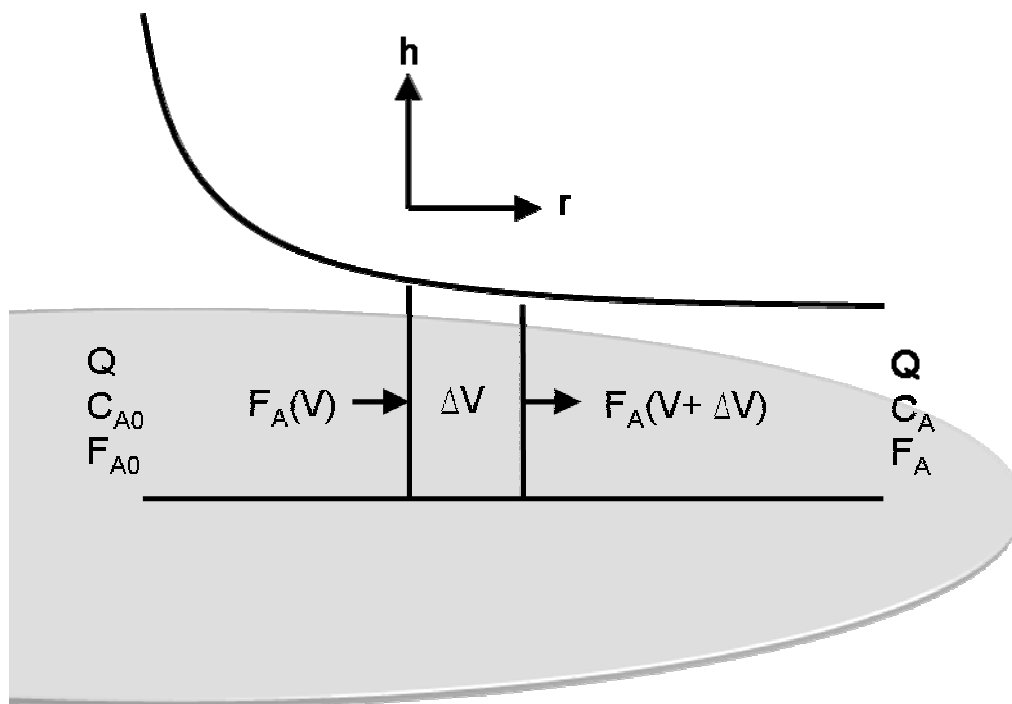

Fig. 4-10. Schematic of rotating-disk-reactor system.

4-4-2 Model of Photocatalytic Reaction Limitations

It is demonstrated from the preceding data that a reduction of film thickness not only can enhance the flux of incident light exposed to the reaction interface, but also can accelerate the mass transfer rate by steeping the concentration gradient of contaminants. Therefore, it would be more

noteworthy to discuss whether the overall photocatalytic process is located in the photoreaction limitation region or that in the mass transfer limitation region of RDR system.

For the case of photocatalytic reaction limitation ($C_{As} = C_A$), as illustrated in Fig. 4-14 (a), a number of studies have applied Langmuir-Hinshelwood model to discuss this condition [3,5-7,9,17,18,31,57]

$$-r_A = \frac{k_r K C_{As}}{1 + K C_{As}} \approx \frac{k_r K C_A}{1 + K C_A} \qquad (4\text{-}15)$$

Where, r_A: Reaction rate of species A (mol/(L×s))

k_r: Reaction rate constant

K: Adsorption coefficient

C_A: Concentration of the compound A in bulk phase (mol/L)

C_{As}: Concentration of species A at the surface of the catalyst (mol/L)

Considering that the low intensity of light would lead the overall reaction rate to locate at photocatalytic reaction rate limitation region, it could be supposed that the reaction rate constant (k_r) would have a proportional relationship to intensity of light source, which shown as follows:

Based on this phenomenon, RDR indeed shows no mass transfer restriction and even can improve the conversion of organic matter with relative high intensity of incident light. It is one of the essential advantages that most of other type reactors don't possess.

Chapter 5 Conclusion

With increasing angular velocity of rotating disc at the same residence time, the photocatalytic reaction is greatly improved by light penetration only through the micro-scale liquid film.

From the present study it may be concluded that rotating disc reactor has the potential to be used as a photocatalytic reactor, the possibility of scale-up have discussed in our research. Based on our proposed model, the optimal condition of photocatalytic process could be simply attained by adjusting several parameters, including flow rate, rotating speed, disc size and light intensity. Future prospects for this research are to evaluate the degradation of other pollutants and industrial solvents, to investigate the effect of different UV wavelengths on the degradation of various compounds and to investigate if the same process efficiency can be attained in the case of natural contaminated waters. **We think that with the help of Materials Studio and Gaussian software, we can predict the reaction products and conversion of different reactants, and thus reduce the unnecessary usage of chemicals.**