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SHORT COMMUNICATION

Mass transport in a rotating parallel plate cell

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1. Introduction

Parallel plate electrodes form the basis of most classical electrochemical reactors but problems may be encountered in their efficient design and operation due to non-uniform concentration, current and potential distribution effects [1]. Such problems arise in stationary cells where fresh feed electrolyte enters at one end of the electrode channel and depleted electrolyte leaves at the trailing end. Thus the present authors have suggested the use of a rotating stack of electrodes as shown in Fig. 1 in order to achieve a spatially even supply

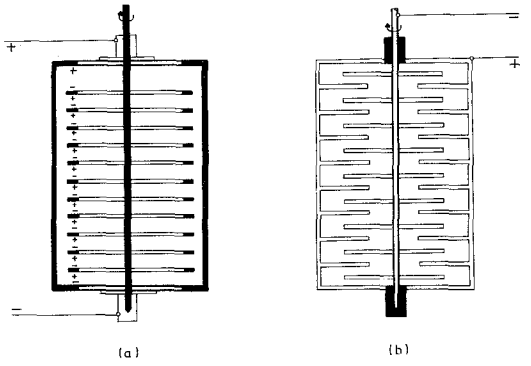

Fig. 1. Schematic representation of two types of rotating stack reactors: (a) bipolar reactor; (b) monopolar reactor.

of reactant to the electrode [2]. The work reported here was carried out in order to observe the effects of electrode diameter and inter-electrode gap on mass transfer rates.

2. Experimental

Rotating cylinders of the type shown in Fig. 2 have been made of different diameters (24, 30, 38 and 50 mm), each fitted with a platinum foil disc electrode at its base. A plastic disc was made to face the electrode; it could be fixed at different distances, its support being screwed into the body of the plastic cylinder. Mass-transfer on to the rotating electrode has been investigated by immersing the electrode into 5×10^{-2} M ferric/ferrous cyanide solution in 1 M KOH (as a supporting electrolyte) and measuring the limiting current using a standard polarographic technique (i.e. by continuously changing the potential of the disc with respect to a SCE brought near to the disc via a Luggin capillary and by monitoring the current passing between the disc and the platinum wire ring around it).

In each experiment the polarographic wave was obtained initially in the absence of the plastic disc, to check the result at different speeds of rotation against the Levich rotating-disc theory. The disc was then mounted and the measurements repeated at decreasing distance between it and the electrode surface, for the same set of speeds of rotation.

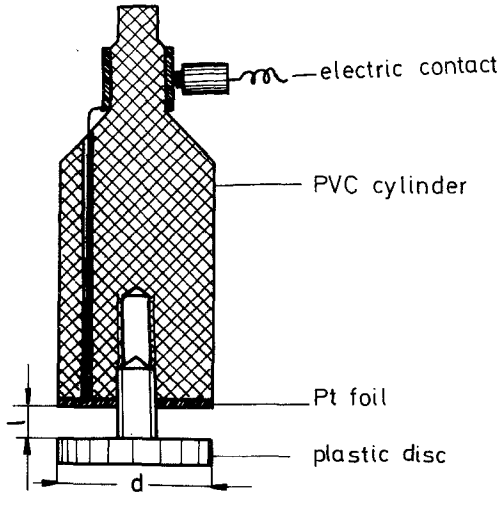

Fig. 2. Experimental arrangement for investigating mass-transfer between two rotating discs.

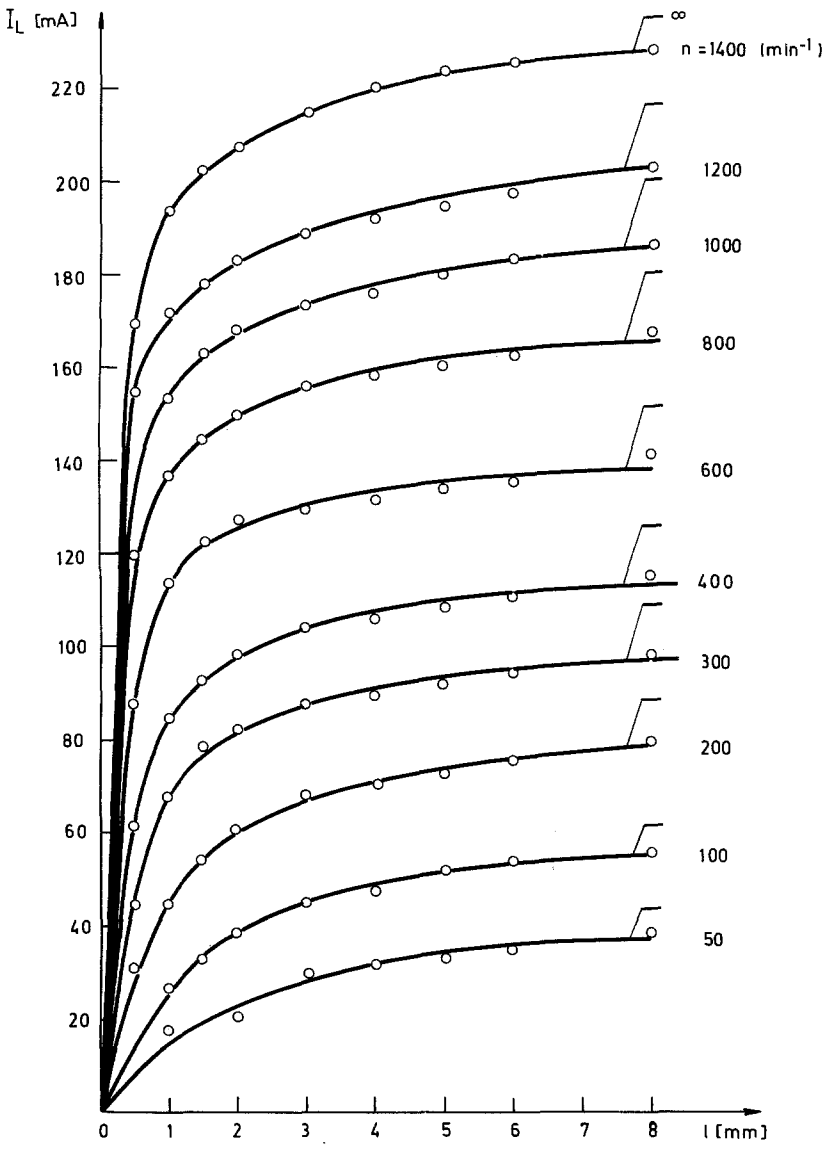

Fig. 3. Diffusion limiting current on the disc electrode as a function of inter-electrode distance at different constant speeds of rotation (n).

3. Results and discussion

A typical set of dependences of the limiting current, I_L, on the distance between the disc electrode and the plastic disc facing it, at different speeds of rotation is shown in Fig. 3 for the electrode of 30 mm in diameter. The figure also shows the limiting values $I_{L,\infty}$ obtained in the absence of the plastic disc. All other electrodes gave similar results. Least-square analyses of the dependences of $I_{L,\infty}$ on $\omega^{1/2}$ gave the slopes and standard deviations shown in Table 1.

The corresponding values of the diffusion coefficient, D, are also shown, calculated assuming the validity of the Levich equation [3]

$$I_{L,\infty} = 0{\cdot}62zFSD^{2/3}\nu^{-1/6}C_0\omega^{1/2} \qquad (1)$$

with $C_0 = 5 \times 10^{-5}$ mol cm^{-3} and the kinematic viscosity $\nu = 10^{-2}$ cm^2 s^{-1}. S is the electrode surface area and ω the rotation speed ($= 2\Pi n$).

The results of all the measurements made at different inter-disc distances, l, different disc diameters, d, and different rotation speeds are summarized in Fig. 4, where the relative deviations of the

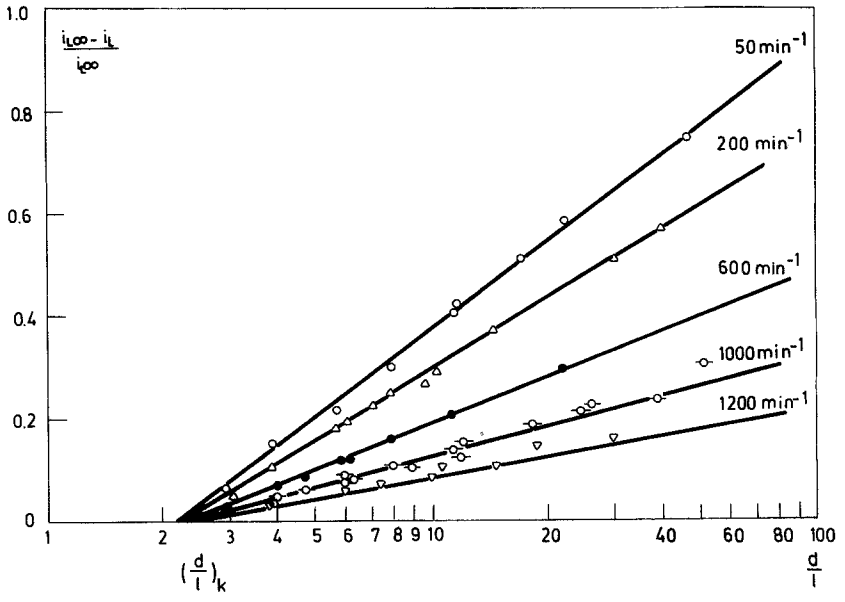

Fig. 4. Relative deviation of the diffusion limiting current as a function of the dimensionless parameter (d/*l*).

Table 1. Calculated values of D depending on the measured slopes according to the Levich equation

Disc diameter (mm)	*Slope* (mA s$^{1/2}$)	*Standard deviation* (mA)	*D (calc.) (Equation 1)* (cm^2 s^{-1})
24	28·7	1·3	$3{\cdot}7 \times 10^{-5}$
30	49·1	1·3	$3{\cdot}9 \times 10^{-5}$
38	76·6	1·8	$3{\cdot}6 \times 10^{-5}$
50	122·1	0·8	$3{\cdot}1 \times 10^{-5}$

limiting current under given conditions from the Levich limiting current in the absence of the plastic disc are plotted in a semi-log system against (d/*l*).

They are seen to follow linear relationships which could be described by the equation

$$\frac{I_{L,\infty} - I_L}{I_{L,\infty}} = k[\log(d/l) - \log(d/l)_k] \qquad (2)$$

with a common intercept (d/*l*) falling at about 2. The slope, *k*, of this relationship is found to be dependent on the rotation speed in the way shown in Fig. 5.

From the above results it is clear that an undisturbed and even supply of the reacting material to the rotating electrodes, following a flow suggested by the model in Fig. 6(a), is obtained only at distances between electrodes equal to or slightly

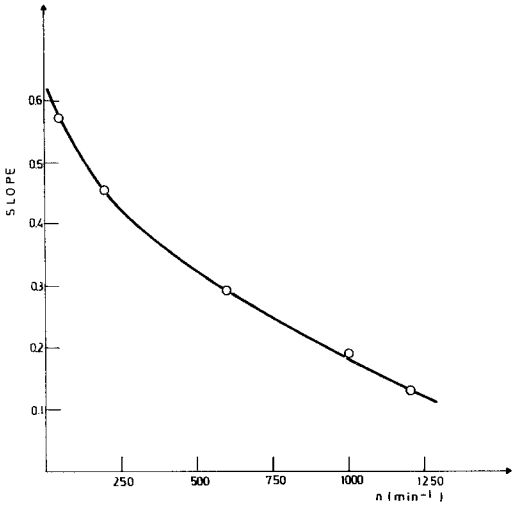

Fig. 5. Slope of the relationship shown in Fig. 4 as a function of rotation speed.

smaller than their radii. Such a rotating stack arrangement would be impractical for building electrochemical reactors of significant current capacity. For, if the electrodes were in a bipolar arrangement, for example, the electrolyte resistance would hardly allow larger electrode distances than about 5 mm. At smaller inter-electrode distances the electrolyte probably follows the flow pattern shown in Fig. 6(b).

However, Fig. 4 and Equation 2 show that at

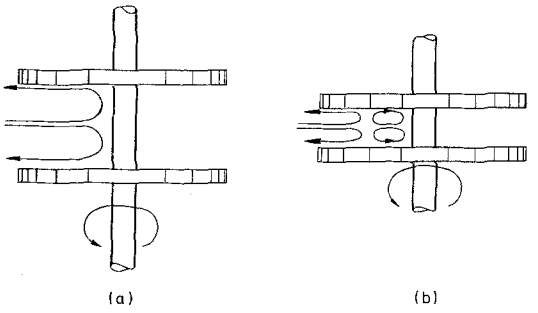

Fig. 6. Patterns of fluid flow between the discs in a rotating stack: (a) at a sufficient distance for the Levich flow to be maintained; and (b) at a relatively small distance.

rotating speeds which are not prohibitively high (e.g. 1200 rev min^{-1}) the deviation from the ideal behaviour is not larger than 20% for a 100-fold larger disc than the inter-electrode distance. Hence, discs of, for example, 100 mm in diameter at 1 mm spacing are likely to give a satisfactory operation at rotation speeds larger than 10^3 rev min^{-1}.

References

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[3] I. V. G. Levich, 'Physicochemical Hydrodynamics', Prentice-Hall, Englewood Cliffs, N.J. (1962).