Process intensification of electrochemical processes by enhanced mass transfer using the rotor-stator spinning disc reactor

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Electrochemical processes play an important role in the chemical industry. Nowadays many chemicals are produced using an electrochemical route, for example: chlorine, sodium hydroxide, sodium chlorate, hydrogen, oxygen, aluminum, copper, magnesium, zinc, and adiponitrile [1]. In an electrochemical process, the process is limited by the rate of mass transfer at high current densities. The largest rate of the electrochemical reaction is reached at the limiting current density [2]. It is therefore desired to intensify the mass transfer rate in electrochemical reactors. An option for process intensification is the use of high shear forces that promote a rapid mixing of fluids and a high surface renewal rate. A type of rotating equipment that uses these principles is the rotor-stator spinning disc reactor (RS-SDR) [3]. The RS-SDR consists of a rotating disc in a cylindrical housing, with a typical gap distance between the rotor and the stator of 1 mm. The results reported by Meeuwse et al. [4] for gas-liquid and liquid-solid applications make this reactor a promising process intensification technology for single and multiphase electrochemical processes. In gas producing electrochemical reactions, an additional benefit of the spinning disc reactor is the high centrifugal force. This force rapidly removes gas bubbles from the electrodes which would become insulated by a gas layer under gravitational conditions. Several authors have studied the mass transfer to a rotating disc, in a rotor-stator configuration [4], or in a free disc configuration [5]. This work compares the mass transfer coefficient from the liquid to the rotor and to the stator of a RS-SDR, and evaluates the effect of electrolytic gas bubbles on the mass transfer in RS-SDR. The mass transfer coefficient at RS-SDR is determined at different rotation speeds using the limiting current density method. Measurements of the limiting current density are taken and used to calculate the liquid solid mass transfer coefficient as follows: $j_L/nF=k_{LS}C^{bulk}$. The reaction studied is the reduction of ferricyanide from an electrolyte mixture of ferro-ferricyanide ions in KNO_3, which is pumped around with 7 – 42 mL/s. The RS-SDR consists of a transparent PMMA with a rotating disc (13 cm diameter, rotational speeds from 20 to 1300 rpm) located at a small gap (1 mm) from the stator. The reactor configuration used in this study allows placing the working electrode on the rotor and on the stator respectively. Both working and counter electrodes are made of pure nickel. An Autolab PGSTAT30 is used for the potentiostatic control of the reactor. Results of the liquid-solid mass transfer without the influence of gas evolution showed that the mass transfer at the rotor disc surface is higher than the mass transfer at the stator. These results show that the mass transfer to the rotor and to the stator are enhanced by a factor 7 and 2 respectively (4.5 average) when compared to a non-rotating and a free rotating disc. Results of the influence of gas electrolytic bubbles on the mass transfer will be presented. Sh-correlations are established that correlate mass transfer to disc radius, rotation speed and gap distance. This work presents the opportunities of process intensification of electrochemical processes using the rotor-stator spinning disc reactor.

References

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