Intensification of electrochemical processes by enhancing the mass transfer and promoting efficient bubble removal using the rotor-stator spinning disc reactor

INTENSIFICATION OF ELECTROCHEMICAL PROCESSES BY ENHANCING THE MASS TRANSFER AND PROMOTING EFFICIENT BUBBLE REMOVAL USING THE ROTOR-STATOR SPINNING DISC REACTOR

Congress: ECCE10
Topic: Electrochemical Engineering (workshop)

Presenting author: P. Granados Mendoza
Authors and affiliations : P. Granados Mendoza:Department of Chemical Engineering and Chemistry,Technische Universiteit Eindhoven,Eindhoven,Netherlands|T. de Groot:Industrial Chemicals,AkzoNobel B.V.,Amersfoort,Netherlands|J. T.F. Keurentjes:Department of Chemical Engineering and Chemistry,Technische Universiteit Eindhoven,Eindhoven,Netherlands|J. C. Schouten:Department of Chemical Engineering and Chemistry,Technische Universiteit Eindhoven,Eindhoven,Netherlands|J. van der Schaaf:Department of Chemical Engineering and Chemistry,Technische Universiteit Eindhoven,Eindhoven,Netherlands

Abstract:
Electrochemical processes are limited by the rate of mass transfer at high current densities. It is therefore desired to intensify the mass transfer rate in electrochemical reactors. An option for this 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) [1]. This reactor consists of a rotating disc in a cylindrical housing, with a typical gap distance between the rotor and the stator of 1 mm. Due to the small reactor volume, the RS-SDR offers a fast start-up and shut down which is beneficial when intermittent production is required, e.g. at peak electricity production by wind or solar energy. This work presents the opportunities of process intensification of electrochemical processes using the rotor-stator spinning disc reactor. Measurements of the mass transfer coefficient to a rotating disc and a rotating mesh have been taken using the limiting current density method. Experimental results obtained with the hexachloroiridate(IV)/(III) redox couple show that the mass transfer to a rotating disc increases from ~10-5 m/s at 0 rad/s to ~10-4 m/s at 135 rad/s. It is also shown that using a mesh electrode enhances even further the mass transfer, up to 2 times higher compared to a flat disc [2]. These results indicate that the RS-SDR can achieve current densities up to 10 times higher than conventional cells [3]. Moreover, often these electrochemical processes involve gas evolution, such as Cl2, H2 and O2. At high current densities the blockage of the electrode area by the bubbles formed at the electrode is an important limitation. The RS-SDR gives an additional benefit in this case due to the high centrifugal force. This force rapidly removes gas bubbles from the electrodes which would become insulated by a gas layer under gravitational conditions. Experimental results about the dynamics of gas evolving electrodes show that gas bubbles remain attached to the electrodes with an attaching force of up to 10-2 µN at normal gravity conditions with bubble sizes of up to 200 µm of diameter and detachment time of up to 30 s. The centrifugal force exerted by the rotation of the disc of a RS-SDR is in the order of 10-3 µN. Based on experimental growth curves of electrolytic bubbles, the detachment time of gas bubbles in a RS-SDR is less than 1 s. Therefore, blockage of the electrode due to the attached gas bubbles is prevented. Obtained results and advantages of the RS-SDR make it a very good option for intensifying electrochemical processes.

Reference 1:
Reference 2 : 1. Van der Schaaf, J. & Schouten, J.C. High-gravity and high-shear gas–liquid contactors for the chemical process industry. Curr. Opin. Chem. Eng. 1, 84–88 (2011).
Reference 3 : 2. Daguenet, M. Etude du transport de matiere en solution, a l'aide des electrodes a disque et a anneau tournants. Int. J. Heat Mass Transf. 11, 1581–1596 (1968).
Reference 4 : 3. Botte, G. G. Electrochemical Manufacturing in the Chemical Industry. Electrochem. Soc. Interface 49–55 (2014).

Highlight 1: Novel type of rotating reactor that uses high shear forces promoting high surface renewal
Highlight 2: Due to enhanced mass transfer, the limiting current density is increased up to 10 times
Highlight 3: Centrifugal force rapidly removes gas bubbles from the electrode preventing its blockage