

사각파 펄스전원을 이용한 전기투석 공정에서의 막오염 저감효과에 대한 연구

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A study on membrane fouling mitigation in electro dialysis process using square-wave pulse power

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1. Introduction

Fouling of ion exchange membranes in electro dialysis (ED) has been recognized as one of the greatest concerns of their application. Fouling is essentially caused by the deposition of foulants such as organics, minerals, colloids, biomass, and particles on the membrane surface or inside the membranes. The foulants cause to deteriorate membrane performance, which is indicated by a decline in the flux and an increase in the electric resistance. When the energy cost makes the operation uneconomical due to the increased resistance, the operation is interrupted to clean reversibly fouled membranes in place or to disassemble the stacks to replace irreversibly fouled membranes.

Many approaches have been examined to minimize fouling during electro dialysis. These include pretreatment of the feed solution, the turbulence in the compartments, the optimization of process conditions such as pH and flow rate, and the modification of the membrane properties. Although all the methods reduce fouling to some extent, cleaning-in-place (CIP) is still needed in practical processes. Several cleaning methods have been used effectively, including hydraulic and chemical cleaning methods. These methods, however, require additional chemicals or instruments resulting in an increase in the installed cost

as well as the operating cost.

The objective of this study is to reduce the fouling rate of ion exchange membranes in electro dialysis using the electric pulses as driving force so that the system can be operated during the extended time period without CIP. In this study pulse power source such as the square-wave power with 30 Hz and DC power were used to investigate the effects on the membrane fouling. The feasibility of the concept was examined experimentally in electro dialysis of sodium chloride solution with an artificial foulant, humic acid.

2. Experimental

A reference power source was DC power generated by a regulated rectifier (6632A, Agilent) consisting of filtering and regulation circuits. The pulsed electric power was supplied as a square-wave form. The square-wave pulse power was a modified DC power source with a triple-output regulated rectifier (UP-100D, UNICORN), a function generator (33210A, Agilent), and a power transistor. During the desalting experiment of sodium chloride solution, the wave form for pulse power source was observed by an oscilloscope (54600B, Agilent). Images of wave forms for the membranes were captured via RS-232. The voltage drop across two cell pairs was measured by connecting the platinum wires inserted in between total cell pairs to a digital multimeter (34401A, Agilent) logged to a computer via RS-232.

To observe the fouling phenomena, two cell pairs of CMX & AMX (NEOSEPTA, Tokuyama Corp., Japan) were assembled in TS-1 electro dialysis stack (Tokuyama Corp, Japan). The effective membrane area was 100 cm². The initial diluate solution was 1.0 L of 0.01 M NaCl containing 100 mg/L of sodium humate (Cat. # H1,675-2, Aldrich, USA), and the diluate solution 1.0 L of 0.01 M NaCl. Conductivity of the solutions were measured with a digital conductivity meter (model 124, Cole-Parmer). The current density applied was 1 mA/cm².

3. Results and Discussion

Fig. 1 shows square-wave power monitored over a membrane by the oscilloscope in the desalting operation. The skewed waveform in Fig. 1

results from the electrical response of unknown equivalent circuit of the electro dialysis module.

The pulsation of power applied is observed in measurement of cell voltage as shown in Fig. 2. The filled circles in Fig. 2 are cell voltage drop measured at maximum and minimum moment of square waveform. The increase in difference between upper and lower part of the filled circles with time is due to an increase in the membrane resistance by the depletion of ions in diluate compartment of ED cell. In order to compare cell voltage drop between DC and pulse power ED operation, the average cell voltage (empty circle) was measured by a digital multimeter as $3\frac{1}{2}$ digits of resolution (DM-312, Goldstar). It is observed that the voltage (empty circles) measured by the multimeter indicates the average cell voltage of the square-wave pulse power as shown in Fig. 2.

In the desalting experiment of sodium chloride solution in the presence of humic acid, cell voltages in both DC power ED and pulse power ED operation with time show the similar trend, but one in latter operation shows a little faster sharp increase at the end of each batch experiment as shown in Fig. 3. This might be due to an increase in the response voltage of the pulse power, while response DC power is the same as the input one.

One of the major organic foulants is humic acid which refer to the fraction of humic substances that is not soluble in water under acidic conditions ($\text{pH} < 2$) but is soluble at higher pH [1]. The fouling of AEM by humic acid was dominantly caused by H^+ ion that are generated by even minimal polarization at the membrane surface because an insoluble acidic colloid precipitates on the membrane surface facing the diluate [2]. The precipitate forms a composite membrane on the AMX and, due to the increased resistance, more H^+ ions are generated [3]. As a result the more the precipitate forms, the harder salt ions pass through AMX. After 1st batch operation, on the AMX surface, more precipitate was formed because the pH of the diluate sharply decreased at the end of 1st batch experiment due to water splitting on the AMX surface facing the diluate. However, Fig. 4 shows that the increase in conductivity of concentrate becomes more significant in the second batch of the pulse power ED. It indicates that the square-wave pulse power is effective for desalting in the presence of foulant such as humic acid, which may precipitate due to their lower

mobility and lower solubility.

4. Conclusion

The square-wave pulse power giving turbulence effect of electrical power might be effective for desalination when insoluble precipitates was formed on the surface of AEM.

Acknowledgement

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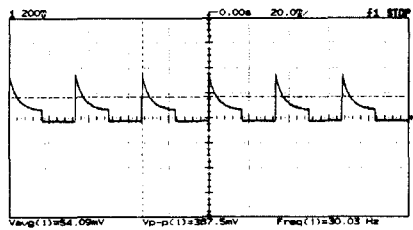


Fig. 1. Square-wave pulse power.

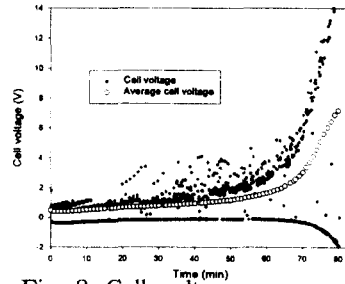


Fig. 2. Cell voltage measurement in square-wave pulse power.

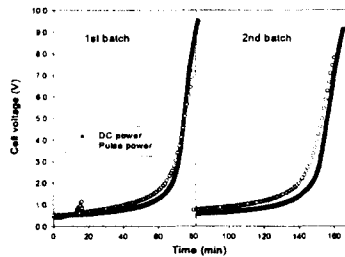


Fig. 3. Cell voltage drop in DC power and pulse power ED.

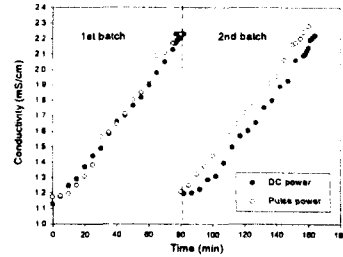


Fig. 4. Conductivity variation in DC power and pulse power ED.