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Article / Book Information

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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	化学工学 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Engineering)
学籍番号： Student ID Number		指導教員（主）： Academic Advisor(main)	吉川 史郎
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The goals of this study are: (1) to contribute an understanding of the phenomena governing the filtrate flux in cross-flow filtration of whey solution, and (2) to develop mathematical model which are capable of explaining experimental observation as well as provide a basic for the design and optimization of the filtration process. For these objectives, several related studies were conducted. First, different models of the membrane fouling which incorporate back flux for cross-flow system were extensively reviewed and examine for the applicability. From these knowledge, a new simple model which considers simultaneously pore blockage and compressive cake layer mechanisms for the permeate flux were developed. From the model, the steady-state permeate flux, an important parameter in crossflow filtration operation, were estimated. Dimensional analysis was conducted to correlate steady-state permeate flux and pore blockage parameter to the operating conditions. Next, the proposed model was applied to a simple optimization design problem base on economic analysis and energy consumption. The thesis itself is organized in six chapters as follows.

Chapter 1 Introduction describes the background of the research, including the history of whey production and utilization, the environmental impact as well as health benefit of whey. The explanation and mathematical model of membrane separation, an efficient process to make valuable product as well as prevent pollution, are also mentioned. From these backgrounds, the objective of this research was clarified.

Chapter 2 Filtration laws and the applicability to cross-flow filtration of protein solution. Classical fouling models may be generally classified into four types: pore blockage, intermediate blockage, pore constriction and cake filtration. However, in the ultrafilatrtion of a whey suspension, the protein cake layer was often compressible. Due to the existence of several mechanisms to analyze the filtration data, the purpose of this part is to examine the applicable of each model to describe the cross-flow ultrafiltration of whey protein solution for developing an appropriate model. Therefore, the deriving of the mathematical model for the four classical mechanisms as well as the compressive cake layer model was reviewed in both dead-end mode and the modification to cross-flow mode operation. The models were applied to

describe the experimental data and some conclusions was made from the comparison.

Chapter 3 Combination model for permeate flux in cross-flow ultrafiltration of protein solution. Instead of dividing whole process into two periods for sequential consideration, this study considers simultaneously the pore blockage and the compressive cake mechanisms. The permeation process is divided into three parts: the bulk phase which has the feed flow, the compressive cake layer and the membrane where the pore blockage occurs. In the cake portion, the compressive yield stress model based on the rheology was used. In the membrane, the pore blockage model is applied with modification. Two models are coupled to interpret the experimental data of protein suspension for validation. The pressure on the membrane is different from the applied pressure and iteration should be made at each step of calculation. Based on the comparison results, it was concluded that the combined usage of both models was able to explain the entire cross-flow filtration process.

Chapter 4 Estimation of steady state permeate flux in cross-flow ultrafiltration of protein solution. The steady state permeate flux plays an important role in cross-flow filtration in the aspects of operation, design and optimization. In this chapter, the model developed in Chapter 3 is applied to extrapolate the steady state permeate flux from the experimental data. After that, the empirical model using dimensional analysis is also proposed to predict the permeate flux from the operating conditions such as the trans-membrane pressure and the feed flow rate. The correlation between steady state permeate flux and cross-flow velocity in protein whey solution is also compared to current hydrodynamic models.

Chapter 5 Application in design and optimization problem. From the governing equation of permeate flux derived in Chapter 4, it should be possible to arrive at an optimal design for any given application. The optimal design will provide a basis against which existing membrane modules can be assessed, and the membrane system fabricator with the preferred module geometry. The approach used in this chapter to treat the design of a membrane module as multivariable optimization. The objective function is the annual cost. This includes an initial investment relating to the size of the core facilities and an operating component associated with energy usage. The core facilities of the membrane plant are classified into pumps, pipes and valves, instruments and controls, tank and frames and miscellaneous. The cost of each category is individually correlated to plant scale, specifically the membrane area. The configuration is assumed as feed and bleed operating mode and a model which incorporates the friction loss is introduced. The model is used to simulate the membrane plant and calculate the membrane area and energy usage, which directly relate to the total cost. The simple optimization routine (cyclic coordinate method) is used to determine the most cost effective module configuration.

Chapter 6 Conclusions and recommendations which has made general conclusions of the study and proposed some suggestions for additional work.