

A METHOD AND A SYSTEM FOR SCALING CONTROL IN MEMBRANE SYSTEM OPERATION

FIELD OF THE INVENTION

The invention relates to a membrane system operation, and more particularly to a method and a system for scaling control in a membrane system operation.

BACKGROUND

Membrane technology includes all process engineering measures for the transport of substances between two fractions with the help of permeable membranes. It finds practical applications in membrane system operations involving membrane process, such as but not limited to Reverse Osmosis (RO), Ultra Filtration (UF), Microfiltration (MF), etc.

Raw seawater contains sparingly soluble salts, such as carbonate scale, sulfate scale, bio-scale etc which have very low solubility thereby constituting a very high specific potential for scaling on membrane surface of the permeable membranes used in the membrane system operations. The concentration of these salts in reject water increases with the extent of removal of product water. The high concentration of low solubility salts causes precipitation and crystallization of salts on membrane surface. This phenomenon is known as membrane scale formation. Similarly the organic salts and microorganism in the feed water also gets deposit on the membrane surface and on the spacers, and this phenomenon is known as membrane fouling. Membrane fouling / scaling causes a higher energy use and a shorter life span of the membranes, because of the more often need for cleaning.

Inorganic salts such as calcium carbonate, barium sulfate etc which are water insoluble can become oversaturated and causing them to precipitate. Hence the feed water to membrane process is treated with scaling control chemicals to avoid precipitation of these salts on membrane surface. These scaling control chemicals are called as antiscalants. The antiscalants adsorb onto growth sites of the scales and prevent further growth, crystallization and precipitation of scalants. The type of antiscalant chosen governs the extent of diffusion kinetics reaction between the scalant and antiscalant. Also, in order to avoid deposition of organic content on the membrane surface, the feed water is treated with alkaline solution as antiscalant. Hence

the choice of antiscalant and its dosage is very important in scaling/fouling control of membranes for better membrane performance and operation.

Currently, the type of antiscalant used and its dosage is determined based on recommendation from membrane manufacturers, chemical suppliers, consultants and the feed water quality. The scale deposited in the membrane could be predominantly either carbonate scale, sulfate scales, bio-scale etc, depending on the feed water quality. In industrial application, antiscalant is suggested based on the type of component which is dominantly present in the feed water. For example, sodium hydroxide is suggested for sulfate scales and organic fouling, hydrochloric acid is suggested for carbonate scale etc. The antiscalant recommended will dissolve only that particular component and may not dissolve all the components present in the scale. Hence, it may be necessary to use mixture of antiscalants with particular composition, in order to dissolve and remove all the components present in the scale.

The antiscalants are dosed along with feed water to maintain their concentration at a specific value in the reject stream. Since some of the antiscalants are not measureable by available sensors in the market, a fixed excess amount of antiscalants are dosed to prevent membrane scaling and subsequent damage. This technique is based on rule of thumb and has some disadvantages like excess use of antiscalants which are highly expensive, it does not consider the current condition or status of membrane to estimate the amount of antiscalants required to dissolve existing scale precipitates and crystals at membrane surface. It has to be noted that, even though in practice a fixed excess amount of antiscalants are dosed, the amount of antiscalant present in the product water and reject stream should be within allowable limits as recommended by World Health Organization (WHO) such that it does not require any post-treatment operations to remove these antiscalant chemicals.

The invention is aimed at choosing proper antiscalants and its optimal dosage. The membrane cleaning chemistry and its kinetics are vital in deciding the proper choice of antiscalant while the dosage of antiscalants is estimated based on membrane fouling status.

OBJECTS OF THE INVENTION

It is an object of the invention to provide a method for scaling control in which antiscalants required for the membrane system operation is selected appropriately.

It is another object of the invention to provide a method for scaling control in which the composition of antiscalants required for the membrane system operation is estimated appropriately.

It is also an object of the invention to provide a method for scaling control in which the optimal dosage of the estimated composition of antiscalants required for the membrane system operation is determined.

Yet another object of the invention is to provide a system for performing the method for scaling control in accordance with the invention, in a membrane system operation.

SUMMARY OF THE INVENTION

Accordingly the invention provides a method for scaling control in a membrane system operation. The method performed by a model in the control system of a plant. The method comprises the steps of selecting one or more antiscalant corresponding to one or more components of the scale. This is based on one or more of feed water condition, membrane material, membrane fouling status and kinetic study relating to the reaction between the antiscalants and the components of the scale. Estimating the composition of one or more selected antiscalant based on the overall scaling rate constant. Administering the dosage of the said estimated composition of one or more antiscalant.

Accordingly the invention also provides a system for scaling control in a membrane system operation in accordance with the method of the invention. The system has a control system having a model, and comprises one or more sensors to obtain plant data. The system of the invention in which, an antiscalant selector unit is provided for selecting one or more antiscalant corresponding to one or more components of the scale. An antiscalant estimation unit is provided for estimating the composition of one or more selected antiscalant. An antiscalant dosage control unit is provided for administering and / or controlling the dosage of the said estimated composition of one or more antiscalant. The control system corresponds to a Distributed Control System, Programmable Logic Controller or any other microprocessor based embedded system. The model of the system caters to one or more of antiscalant selector unit, antiscalant estimation unit and antiscalant dosage control unit.

BRIEF DESCRIPTION OF THE DRAWING

With reference to the accompanying drawings, in which:

Fig. 1 shows a system for scaling control in a membrane system operation.

DETAILED DESCRIPTION

With reference to a non exhaustive exemplary embodiment in which, Fig. 1 depicts a system for scaling control in a membrane system operation. The method of the invention is coextensively described in conjunction with the system of the invention.

The system (100) has a control system and such control system corresponds to a Distributed Control System, Programmable Logic Controller or any other microprocessor based embedded system. The control system has a model for performing the method for scaling control in a membrane system operation. Primarily, the method and system of the invention are aimed at scaling control through proper selection of antiscalant, appropriate composition of the selected antiscalants and through administering optimal dosage of antiscalant.

The system (100) has atleast one sensor for obtaining the relevant plant data. The plant data referred herein include one or more of feed flow rate, feed pressure, feed concentration, reject flow rate, reject pressure, product flow rate, product concentration etc. The system also has antiscalant selector unit, antiscalant estimation unit and antiscalant dosage control unit.

The antiscalant selector unit (101) is provided for selecting one or more antiscalant. The antiscalants are identified from the list of antiscalants provided by the membrane manufacturer, and that correspond to the components present in the scale. Such selection is not made based on rule of thumb. Rather, the selection of one or more antiscalants accordingly, is based on the kinetic study. The kinetic study relates to the reaction between the antiscalants and the components of the scale.

Apparently, with regard to the kinetic study referred here above, the rate of reaction (R_c) and its kinetics of the reaction between the antiscalant and scale deposits in feed water is derived based

on shrinking core model. The shrinking core model herein considers chemical reaction control and solid particle mass transfer diffusion control.

$$R_c = -k'' C^a \quad (1)$$

$$C = C_{init} \exp\left(\frac{F_m}{k''}\right) \quad (2)$$

$$\frac{1}{k''} = \frac{1}{k_c} + \frac{1}{k_m} \quad (3)$$

$$k_c = k_0 \sqrt{T} \exp\left(-\frac{184000}{RT}\right) \quad (4)$$

$$k_m = \frac{D_m}{d_p} \left[2 + 0.6 \left(\frac{d_p u \rho}{\mu} \right)^{1/2} \left(\frac{\mu}{\rho D_m} \right)^{1/3} \right] \quad (5)$$

where,

R_c is rate of reaction, kg/m² s;

C is antiscalant concentration, kg/m³;

C_{init} is inlet concentration of fresh antiscalant chemical, kg/m³;

k_c is chemical reaction rate constant;

k_m is solid particle mass transfer diffusion control rate constant, m/s;

u is cross flow velocity of antiscalant, m/s;

μ is viscosity of the antiscalant chemical, kg/(m.s);

ρ is density of the antiscalant chemical, kg/m³;

D_m is molecular diffusion coefficient, m²/s;

a is reaction order, (-);

T is temperature, °C;

d_p is equivalent diameter of the particle, m

Using offline plant measurements such as water quality, antiscalant flow rate and its concentration, the overall rate constant (k'') is calculated. The antiscalant selector unit (101) makes use of the value of the overall rate constant (k'') in selecting the antiscalant.

The antiscalant is selected such that it gives high overall rate constant value k'' . The value of k'' indicates the extent of reaction that takes place between the antiscalant and the scale material. The higher the value of k'' , higher the chances of antiscalant chosen is correct. If the value of k'' for a particular antiscalant is less than some threshold value (k''_{thresh}), then that particular antiscalant is not chosen. For example, as shown in Fig. 1, list of antiscalants suggested by the membrane manufacturer are AS_1 , AS_2 and AS_3 . If the k'' value of antiscalants AS_1 and AS_2 are greater than k''_{thresh} and k'' value for antiscalant AS_3 is less than k''_{thresh} , then the antiscalants AS_1 and AS_2 are selected from the list.

The antiscalants so selected in respect of the components of the scale required to be mixed in an appropriate fraction so as to form the correct composition of antiscalants. This is because of the fact that certain antiscalant can dissolve only certain or its corresponding component in the scale. Hence, there is a need for such mixture of antiscalant catering to its relevant or corresponding component in the scale. It is not trivial to have an appropriate mixture of antiscalants with correct composition.

An antiscalant estimation unit (102) is provided for estimating the composition of one or more selected antiscalant to form an appropriate and required mixture of antiscalants. Here, the mixing fraction of the set of antiscalants selected as described before is estimated. For example, antiscalants AS_1 and AS_2 are selected as stated before and the percentage of AS_1 and AS_2 needs to be mixed needs to be decided. The antiscalant estimation unit (102) makes use of the value of the overall rate constant (k'') to estimate the mixing fraction. The value of k'' estimated is compared with the theoretical value of the k'' and mixing fraction is selected such that the error between the estimated and theoretical value of k'' is minimized. For the example considered, this unit estimates the X_1 % of AS_1 and X_2 % of AS_2 . The k'' is estimated using offline plant

measurement, and the theoretical value of k corresponds to the rate at which complete removal of scale material takes place.

Further, the estimated composition of antiscalants needs to be administered for the membrane system operation. This includes determining the optimal dosage of the estimated composition of antiscalants. The antiscalant dosage control unit (103) is provided for administering and / or controlling the dosage of the estimated composition of one or more antiscalant. This is done based on the value of membrane fouling status. The membrane fouling status is estimated using first principles model for membrane separation process. The model estimates membrane transport parameters such as hydrodynamic permeability (A) and solute permeability (B). Only membrane transport parameters are affected by membrane fouling. These membrane transport parameters are estimated by using plant data such as feed flow rate, feed pressure, feed concentration, reject flow rate, reject pressure, product flow rate, product concentration etc.

The change in hydrodynamic permeability over time with respect to different antiscalant flow rate is given by

$$\frac{dA}{dt} = -A_0 + k \times F_{in} \quad (6)$$

where,

A_0 is initial hydrodynamic permeability obtained from membrane performance solution;

k is scaling rate constant, which could be obtained from the past history of hydrodynamic permeability and antiscalant flow rate data;

F_{in} is flow rate of antiscalant, m^3/hr

The flow rate of the estimated composition of antiscalants is adjusted to minimize the error between current & required value for membrane fouling status (hydrodynamic permeability value) as given in equation 6. In this control strategy, the membrane fouling status is sent to a membrane performance controller (MIC) which in turn determines the set point for the flow controller (FIC) for dosage chemicals ie. for dosing the estimated composition of antiscalants.

The estimated composition of selected antiscalants and its dosage is determined by formulating an objective function as given below:

$$Obj = \min_{x_i, F_{in}} \left\{ (k''_{est} - k''_{theo})^2 + \sum_{l=0}^T F_{in} * T * C_c + (A - A_{req})^2 \right\} \quad (7)$$

where,

A is current hydrodynamic permeability obtained from membrane performance solution;

A_{req} is required hydrodynamic permeability provided by the user/customer;

C_c is cost per kg of antiscalant;

k''_{est} is estimated value of overall rate constant from offline measurement data, m²/s;

k''_{theo} is theoretical value of overall rate constant corresponding to the complete removal of scale material, m²/s;

x_i is estimated antiscalant % mixing composition;

Subjected to constraint

$$F_{in,min} \leq F_{in} \leq F_{in,max}$$

where,

F_{in,min} & F_{in,max} are minimum and maximum allowed flow rate of antiscalants, m³/hr

The first term in the objective function relates to estimating the composition of antiscalants selected i.e. estimating the mixture of the selected antiscalants thereof. The second term in the objective function minimizes the cost of antiscalant and the third term selects the antiscalant flow rate as described in administering or controlling the dosage of the estimated composition of antiscalants.

The invention is not restricted by the preferred embodiment described herein in the description. It is to be noted that the invention is explained by way of exemplary embodiment and is neither exhaustive nor limiting. Certain aspects of the invention that not been elaborated herein in the description are well understood by one skilled in the art. Also, the terms relating to singular form used herein in the description also include its plurality and vice versa, wherever applicable. Any relevant modification or variation, which is not described specifically in the specification are in fact to be construed of being well within the scope of the invention.

WE CLAIM:

1. A method for scaling control in a membrane system operation, by a model in the control system of a plant, wherein the method comprising the steps of:

selecting one or more antiscalant corresponding to one or more components of the scale, based on one or more of feed water condition, membrane material, membrane fouling status and kinetic study relating to the reaction between the said antiscalants and the said components of the scale;

estimating the composition of one or more selected antiscalant based on the overall scaling rate constant;

administering the dosage of the said estimated composition of one or more antiscalant, for scaling control in a membrane system operation.

2. The method as claimed in claim 1, wherein selecting one or more antiscalant from the list of antiscalants provided by the membrane manufacturer.

3. The method as claimed in claim 1, wherein selecting one or more antiscalant based on kinetic study relating to the reaction between the said antiscalants and the said components of the scale includes ascertaining the values of kinetic parameters based on one or more of chemical reaction control, film diffusion and solid particle mass transfer diffusion control.

4. The method as claimed in claim 1, wherein estimating the composition of one or more selected antiscalant includes calculating the overall scaling rate constant using offline plant measurements such as water quality, antiscalant flow rate, antiscalant concentration etc.

5. The method as claimed in claim 1, wherein administering the dosage of the said estimated composition of one or more antiscalant is based on the membrane fouling status.

6. The method as claimed in claim 1 or 5, wherein the membrane fouling status is determined based on the estimation of time varying physical parameters of membrane such as

hydrodynamic permeability of membrane, solute permeability and reflection coefficient of membrane.

7. The method as claimed in claim 6, wherein the time varying physical parameters of membrane are estimated by using plant data such as feed flow rate, feed pressure, feed concentration, reject flow rate, reject pressure, product flow rate, product concentration etc.

8. A system for scaling control in a membrane system operation in accordance with the method as claimed in any one of the preceding claims, the said system has a control system having a model, and comprising:

one or more sensors to obtain plant data; and wherein

an antiscalant selector unit is provided for selecting one or more antiscalant corresponding to one or more components of the scale;

an antiscalant estimation unit is provided for estimating the composition of one or more selected antiscalant; and

an antiscalant dosage control unit is provided for administering and / or controlling the dosage of the said estimated composition of one or more antiscalant.

9. The system as claimed in claim 8, wherein the control system corresponds to a Distributed Control System, Programmable Logic Controller or any other microprocessor based embedded system.

10. The system as claimed in claim 8 or 9, wherein the said model caters to one or more of antiscalant selector unit, antiscalant estimation unit and antiscalant dosage control unit.

11. The system as claimed in claim 8, wherein the plant data include one or more of feed flow rate, feed pressure, feed concentration, reject flow rate, reject pressure, product flow rate, product concentration etc.

12. The system as claimed in claim 8, wherein the said antiscalant dosage control unit includes flow indicator controller, membrane performance indicator controller, membrane and a tool for monitoring the membrane.