Evaluation of Polyethersulfone- based filtration performance with the presence of antifoam

Siti Zalina binti Ali, Syazana binti Mohamad Pauzi,

Faculty of Chemical Engineering, Universiti Teknologi Mara

***Abstract*— The performance of polyethersulfone membrane filtration was analyzed with the presence of silicon based antifoam. The purpose of this experiment to determine the loading capacity of filtration process and the effect of antifoam agent on Polyethersulfone (PES)- based filter membrane. In this experiment, Cobetter Polyethersulfone membrane and Hyclon silicon antifoam solution have been used. PES are usually used for culture media sterilization, life science and microbiology fluid applications, clinical, and general filtration. The filtration was conducted using dead end filtration mode. Different concentration of silicon based antifoam agent will be added to the process filtration within the range from low to high concentration. The filtration processes were conducted with the concentration of the silicon solution at 0% v/v, 0.1% v/v, 0.5% v/v and 1.0 % v/v with two different speed which were 25ml/min and 50 ml/min. Performance of the filter membrane were evaluated. Flux rate behavior of the membrane with addition of different concentration of silicon based antifoam agent throughout the filtration process time were recorded. Flux decline in membrane filtration is a result of the increase in the membrane resistance due the membrane pore blockage and the formation of a cake layer on the membrane surface. The analysis also conducted on resistance and capacity of the membrane filter from the pressure exerted throughout the filtration process**

Keywords*— *Antifoam, Biopharmaceuticals; Dead- end filtration; Downstream process; Polyethersulfone membrane

I. INTRODUCTION

Filters are majorly used in many stages during the production of small molecules drugs or also known as active pharmaceutical ingredients (API). Pharmaceutical filtration often used in upstream and downstream, cell separation, final product processing, raw material filtration, water purification, an air purification [1]. The rising of global market for pharmaceutical filtration lately is resulting from the rise in expenditure in research and development by biopharmaceutical companies to offer a strong biologics pipeline.

In cross-flow filtration the suspension flows tangentially to the filter medium surface, preventing the formation of a filter cake. Only a small flow of liquid passes through the filter medium. Some solids will suspended in the boundary layer on the filter surface, and reduces the flow of filtrate. After certain times, a dynamic equilibrium is established between convective transport of solids to the filter surface and removal of solids by hydrodynamic forces acting on the particles due to turbulence and diffusion [2].

Polyethersulfone (PES) is an extensively used in microfiltration membrane material that has been widely applied in water treatment, biomedical applications and other industrial fields [3]. PES membrane is hydrophilic in nature. PES membrane provides removal of fine particles, bacteria, viruses, and fungi making it a versatile membrane for applications such as sample preparation, sterile filtration and infusion therapy. PES membrane has characteristic of easily wet resulting in fast filtration with superior flow rates and high throughputs. PES membrane is also extremely low protein binding minimizing the likelihood of target analyte binding [1]

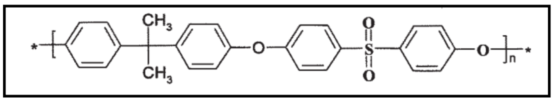

Fig. 1: Chemical structure of polyethersulfone [4]

However, fouling of polymeric membranes is a problem in membrane separation processes [5]. Membrane fouling is referring to the blockage of membrane pores during filtration process. It is cause by the adsorption of particulates and compounds onto the membrane surface or within the membrane pores [6]. Pore blockage reduces the permeate production rate and increases the complexity of the membrane filtration operation. This is the most challenging issue for further membrane development and applications.

Antifoams are sometimes added to the process of filtration. It is known that there are several antifoams that can give impacts on the cells or product. The antifoams affect the growth rate the media and organisms to changing surface properties such as lipid content, resulting in changes of their permeability [7]. However, in some cases, certain concentration of antifoams can give unfavorable depending upon how the protein (media) being expressed. Antifoams are generally hydrophobic materials and tend to concentrate on interface. Antifoam adsorb at the membrane surface, thereby reducing the flux rate and often also retention of micromolecules [8] [9].

This article provides the information about the evaluation behavior of polyethersulfone filter membrane using dead end filtration mode in two different flow rates. Different concentration of silicon based antifoam agent will be added to the process filtration within the range from low to high concentration. By the addition of antifoam agent, the performance of the filter membrane will be evaluated by several parameters such as flux rate of the filtration process with addition of different concentration of silicon based antifoam agent throughout the filtration process time. Besides, there are also the analysis of resistance and capacity of the membrane filter from the pressure exerted throughout the filtration process.

II. METHODOLOGY

A. Materials

Microfiltration membrane used was polyethersulfone membrane with the average pore diameter of 0.45µm and with diameter of 47mm. The nutrient media is LB Broth. Silicone based emulsion was used as the antifoam agent. Distilled water is used to prepare the media and flushing the system before and after the experiment.

B. Apparatus and Methods

Media was prepared by the addition of 600 ml distilled water to 15g of LB broth in beaker. The media solution was stirred homogenously. Different concentration of silicon based antifoam was added into the media broth. The concentration of the silicon based were 0% v/v, 0.1% v/v, 0.5% v/v and 1.0 % v/v with two different speed which were 25ml/min and 50 ml/min.

By using the Bioprene- thermos plastic tubing with 2.4 mm wall tubing, the beaker connected to the pump head of Watscon-Marlow Sci- Q 300 Series Peristaltic pump. The pump operated at the speed of 7 rpm (25 ml/min) and 13 rpm (50 ml/min). Then, the pump was connected to the pressure gauge and the filter head.

The lab started with placing 600 ml of the LB broth media at position as shown in figure 2. A 500-measuring cylinder was used to collect the filtered media at filter head. A disc polyethersulfone membrane with the average pore diameter of 0.45µm and with diameter of 47mm was placed in the filter head. In each experiment, new disc membrane is used.

To run the filtration process, the plug was switched on the peristaltic pump. The calibration for the feed flow rate was done. The feed flow rate was setting at 7 rpm for 25ml/min and 13 rpm for 50 ml/min. The suction direction was setting from left to the right.

After the plug was switched on, the LB broth media was sucked by the Bioprene peristaltic pump tubing from left to the right direction. The pressure readings of the pressure gauge were recorded. The time recorded started as the first drop of the filtered media collected in the measuring cylinder. The time taken for every 25 ml of filtered media collected were recorded.

III. RESULTS AND DISCUSSION

A. Flux rate behavior

The Flux decline in membrane filtration is a result of the increase in the membrane resistance by the membrane pore blockage by the media broth and the formation of a thin layer of cake on the membrane surface.

The pore blocking increases the membrane resistance while the cake formation cause resistance to the permeate flow. Pore blocking and cake formation can be considered as two essential mechanisms for membrane fouling.

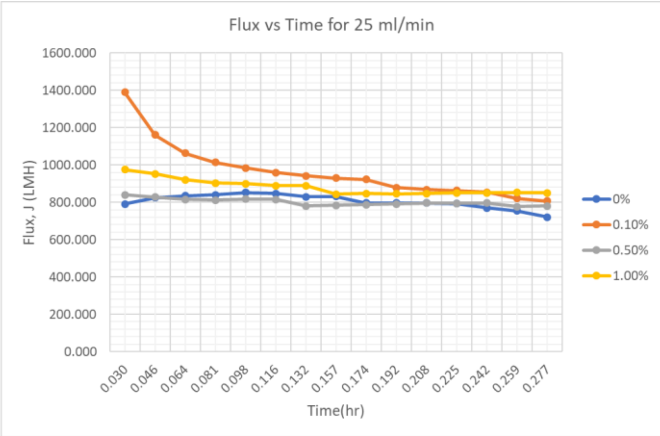

Fig.2: The graph of flux vs time for the filtration process at feed flowrate of 25 ml/ min.

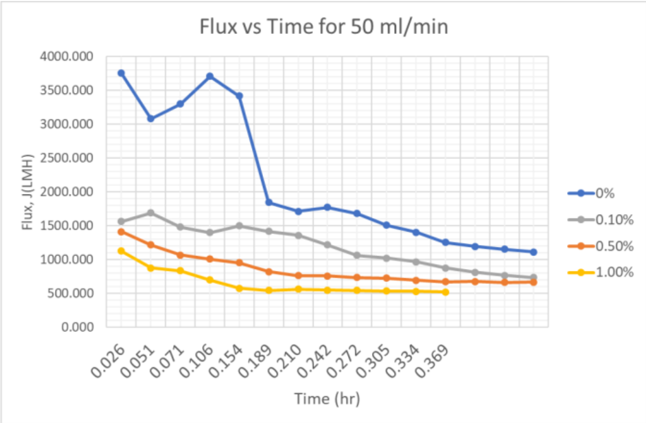

Fig.3: The graph of flux vs time for the filtration process at feed flowrate of 50 ml/ min

The main effect of antifoam is the reduction of membrane permeate flux during cross- flow filtration due to membrane fouling [8]. From the graph shown in figure 2, the flux permeated by the membrane with feed flowrate of 25ml/ min at 0%, 0.1% 0.5% and 1.0 % are all decrease throughout the filtration process. The flux rate value obtained from the experiment is a bit fluctuated due to some errors occurs during the experiment. One of the errors occurred during the experiment was the presence of high pressure in the system and cause the inconsistency in the flow of the broth media. The inconsistency of the flow of broth media affects the time taken time taken for every 25 ml of broth media collected in the measuring cylinder. Thus, the condition causing the graph obtained to fluctuated.

The high-pressure present was believed due to some errors during the connection setting of the tubing to the head filter. The head filter was a bit loosed and causing some air to enter the system pipe line and interrupted the pressure exerted by the pump. Based on graph in figure 3, the flux rate permeated by the polyethersulfone membrane with feed flowrate of 50 ml/ min at 0%, 0.1%, 0.5% and 1.0% of silicon antifoam agent were all decreased and fluctuated throughout the filtration process. There are a high fluctuated on the 0% concentration of antifoam due to the same problem mentioned before where there was presence of air that interrupted the pressure in the pipeline system during the filtration process.

The graph shows that almost all antifoam concentration follows the same decline and a bit fluctuated pattern as the flux pattern at feed flowrate at 25 ml/ min. This is due to the same problem occurred during conducting the filtration process at 25 ml/ min. From the graph shown in figure 2 and 3, the permeate flux pattern is following the theory as the longer the time, the permeate flux will declined.

The degree of fouling can be analyzed based on the type and concentration of antifoam agent, the type of membrane used, the organism and other components presents in the media broth [8].

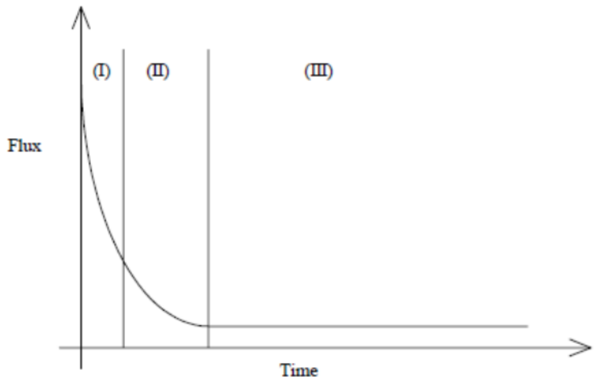

Fig.3: A Schematic presentation of the three stages in flux decline **[6]**

Figure 3 shows a typical flux-time curve of microfiltration (MF), as shown in Figure 3, starts with (I) a rapid initial drop of the permeate flux, (II) followed by a long period of constant flux decrease, and (III) ended with a steady-state flux [6].

The rapid initial drop of the permeate flux are resulting from quick blocking of membrane pores. During stage I where at the beginning of filtration, there are maximal permeate flux because at this time membrane pores are still clean and opened. However, during stage II, flux starts to decline as membrane pores are being blocked by retained particles. At this moment, pores are more likely to be blocked by the retained particles depends on the shape and the relative size of the retained particles and the pores. The blockage is happened when the particles and the pores are similar in both shape and size [6].

The further flux decline during stage III is due to pore blockage by the formation and growth of a cake layer on the membrane surface. At this moment, the cake layer is formed on the membrane surface as the amount of retained particles increases. The cake layer creates an additional resistance to the permeate flow and the resistance of the cake layer increases with the growth of cake layer thickness. Hence, the permeate flux continues decreasing with time [6].

B. Resistance and loading capacity analysis

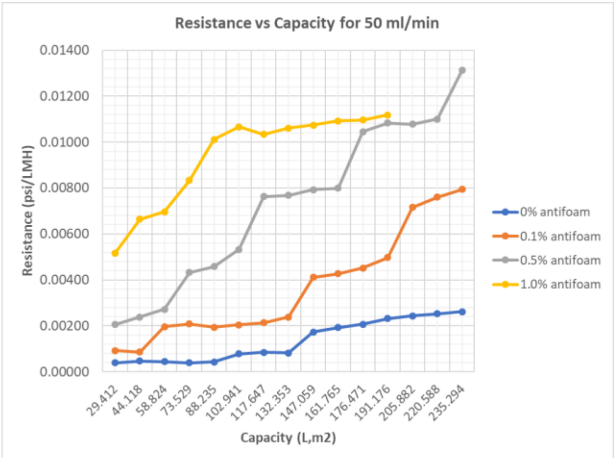

Fig.4: The graph of resistance vs capacity for the filtration process at feed flowrate of 25ml/min.

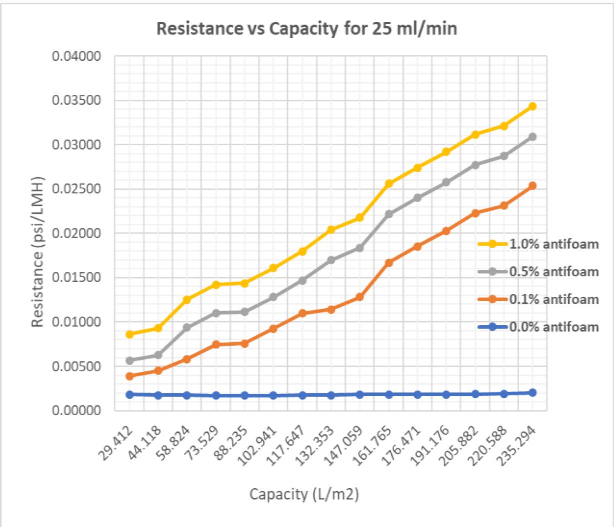

Fig.5: The graph of resistance vs capacity for the filtration process at feed flowrate of 50ml/min.

Based on figure 4 and 5, it was shown the resistance increase as the loading capacity increase. The addition of antifoam can affect the surface properties of the membrane [10].

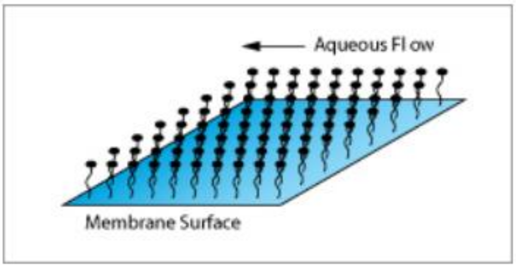

Fig.6: Hydrophilic Surface Formation on Membrane Surface

The addition of silicon based antifoam able the hydrophobic of the membranes cause non-polar or hydrophobic compound to be absorbed onto the surface of the membranes. However, pretreating the membranes with an antifoam agents can reduce the hydrophobicity of the membrane surface. based on figure 6, The surfactant or the wetting agent forms a layer on the surface of the membranes, creating hydrophilic surface.

IV. CONCLUSION

The permeate flux behavior of the polyethersulfone membrane was analyzed with the presence of silicone antifoam agent. It was found that the permeate flux decreased throughout the filtration process resulting from the formation of membrane fouling.

Membrane fouling is a critical problem that reduces the permeate flux and requires regular cleanings. Fouling is resulting from the deposition of suspended solids in the feed on the external membrane surface, on the membrane pores, or within the membrane pores. There are several factors that has a significant effect on membrane fouling including the membrane properties, such as: pore size and distribution, hydro- phobicity and membrane material.

As the fouling form, the permeate flux theoretically will decrease due to the reduction of the pore sizes and the slower of filtration flow rate as time goes by.

Membranee fouling is a phenomenon involving the interaction between the membrane and the solution. Therefore, another important factor governing fouling is the solution properties, such as: concentration and nature of components and the particle size distribution.

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REFERENCES

1. Crespo, J.G. and K.W. Böddeker, *Membrane Processes in Separation and Purification*. 2013: Springer Netherlands.
2. SIEGFRIED RIPPERGER, W.G.o., CHRISTIAN ALT, *Filtration, 1. Fundamentals.* Encyclopedia of industrial chemistry, 2005. **14**.
3. Susanto, H. and M. Ulbricht, *Characteristics, performance and stability of polyethersulfone ultrafiltration membranes prepared by phase separation method using different macromolecular additives.* Journal of Membrane Science, 2009. **327**(1): p. 125-135.
4. Nady, N., *PES Surface Modification Using Green Chemistry: New Generation of Antifouling Membranes.* Membranes, 2016. **6**(2): p. 23.
5. Trussell, R.S., et al., *The effect of organic loading on process performance and membrane fouling in a submerged membrane bioreactor treating municipal wastewater.* Water Research, 2006. **40**(14): p. 2675-2683.
6. Abdelrasoul, A., H. Doan, and A. Lohi, *Fouling in Membrane Filtration and Remediation Methods*, in *Mass Transfer - Advances in Sustainable Energy and Environment Oriented Numerical Modeling*, H. Nakajima, Editor. 2013, InTech: Rijeka. p. Ch. 08.
7. Routledge, S.J., *Beyond de-foaming: the effects of antifoams on bioprocess productivity.* Computational and Structural Biotechnology Journal, 2012. **3**: p. e201210014.
8. Kroner, K.H., et al., *Effects of Antifoams on Cross-flow Filtration of Microbial Suspensions*, in *Membranes and Membrane Processes*, E. Drioli and M. Nakagaki, Editors. 1986, Springer US: Boston, MA. p. 223-232.
9. Xinghua Sun, D.M.K., Raja Ghosh, *), Characterization and theoretical analysis of protein fouling of cellulose acetate membrane during constant flux dead- end microfiltration.* Journal of Membrane Science 320 2008: p. 372–380.
10. Laskin, A.I., *Advances in Applied Microbiology*. 1988: Elsevier Science.