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IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 19, Issue 3 Ser. III (May. – June. 2022), PP 09-15
www.iosrjournals.org

Formation of POLYETHERSULFONE (PES) Membrane with Titanium Dioxide (TiO2) Reinforcement for Water Treatment Applications

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Abstract:
The challenge in technology is to innovate in technology and materials in carrying out water filtration processes that are more cost-effective but have a better level of efficiency and effectiveness than ever before. The test materials used were membranes with polymers made of polyetherculphons with 27.5wt%, 30wt%, and 32.5 wt% and titanium dioxide reinforcing agents with concentrations of 2wt% marine additives N.N Dimethylformamide. The membrane formation method was the phase inversion . The method used was the phase inversion, in which the polymer, reinforcement, and solvent were mixed homogeneously for approximately 2-3 hours, and the membrane was directly printed on a glass plate. Three tests were conducted for membrane formation: tensile test, microscopic test using scanning electron microscope, and flux value test using clean water permeability (CWP). Membranes show that the higher the polymer concentration value will increase the tensile stress value on the membrane. In microscopic testing, the higher the membrane concentration, the greater the pore density formed on the membrane surface. CWP test, highest flux values membrane shown PES membrane concentration 27.5wt% compared concentrations 30wt% and 32.5wt%. This study concluded that membrane expansion by increasing the concentration of polyetherculphons at concentrations of 27.5wt%, 30wt% and 32.5wt%, and 2wt% titanium could increase the tensile stress and pore density on the membrane surface. The resulting flux values were smaller at a concentration of 32.wt% compared to the concentrations of 30wt% and 27.5wt%.

Key Word: *membrane; Polyethersulfone; titanium dioxide; N,N Dimethylformamide, Tensile Strength; SEM; Clean Water Permeability.*

Date of Submission: 15-05-2022 Date of Acceptance: 30-05-2022

I. Introduction

Water is the most valuable natural resource in the world. The growing world population daily is accompanied by a growing demand for clean water.[1] Currently, the technology in water purification processes such as reverse osmosis is the most classy process as it can perform energy efficiency. One of the most widely used materials is composite membranes such as brackish water desalination applications, seawater, freshwater softening, organic matter removal, pure wastewater purification, and advanced wastewater purification[2]. In membrane development, fouling control is a competitive and challenging step in membrane development, as studies have shown that increasing membrane hydrophilicity reduces the hydrophobicity between foul in the feed and the membrane surface.

Although Polyethersulfone (PES) has good thermal and mechanical stability, PES has limitations in its hydrophobic properties that cause high water permeability and fouling[3]. In many studies, Polyethersulfone has proven its efficiency in nanofiltration, gas separation, and other wastewater purification. [3]. Membrane development using polyethylene polymers with titanium dioxide as reinforcement has been widely used. Performed by adding a reinforcing matrix, i.e., titanium dioxide. Titanium dioxide has semiconductor properties with a mylar band gap, charge carrier mobility, low toxicity, and low cost in membrane formation[4]. The development of membrane formation with polyethersulfone polymers with titanium dioxide as reinforcement requires a solvent to dissolve homogeneous bonds between the two materials. N, N Dimethylformamide solvents combine extraction, distillation, and reverse osmosis.[5]

At a concentration of 27.5% by weight, 30% by weight, and 32, 5% by weight. The development of this membrane formation aims to determine the value of the maximum tensile strength of the membrane, the surface of the membrane produced in microscopic tests using a scanning electron microscope, and the value of the flux produced by the membrane. With several series of tests and concentration limits used, it is hoped that the results obtained are the development of membranes with better mechanical and microscopic properties.

II. Material And Methods

In carrying out membrane development, membrane manufacturing and printing, and clean water permeability testing, were carried out at the Department of Magister Mechanical Engineering, Faculty of Engineering, Universitas Sriwijaya, South Sumatra, Indonesia. The materials were Polyethersulfone polymer with a concentration of 27.5wt%, 30wt%, 32.5 wt%, titanium with a 2wt%, and solvents, namely N, N Dimethylformamide.

The method intended was mixing materials can produce a membrane with a homogeneous mixture of materials. The membrane formation method used is polyetherculphone, titanium dioxide and DMF solvent, mixing is done by stirring without a time limit. In this study, stirring lasted about 2-4 hours, after the membrane is formed and has been mixed homogeneously. Then the membrane was printed using the phase inversion method and then immersed in water. The resulting membrane was in the form of flat sheets. This is the illustrion of printed membrane.

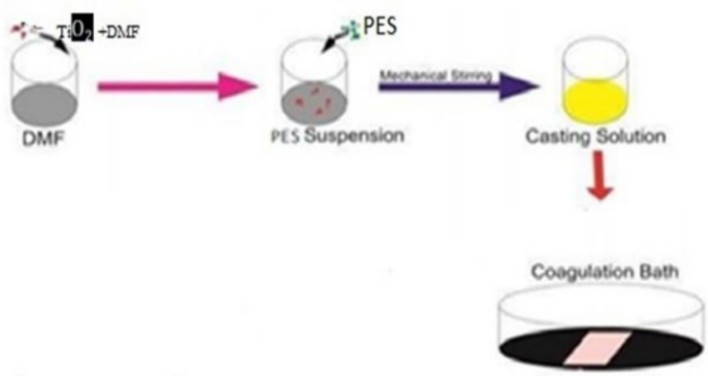

Figure 1 membrane manufacturing process.

After the forming process was carried out, the membrane that has been formed in the flat sheets is carried out by forming a membrane sample according to the test carried out. There were three tests conducted in this study. These are tensile testing, microscopic testing, and clean water permeability test.

Tension test:

This tensile test is carried out to determine the membrane's mechanical properties. Before testing on membranes, test samples were first measured according to the ASTM D38 standard with IVB type. The testing tool used is the WP 310 Gunt Hamburg Material Testing Machine tensile testing machine. The sample used in this tensile test consisted of 9 samples. There are three samples for each concentration of polyethylene polymer that has been mixed with titanium dioxide and DMF. Each concentration used was 27.5wt% with three samples, 30wt% concentration with three samples, and 32.5wt% concentration with three samples.

Figure 2. Tensile Testing Equipment Model WP 310 Gunt Hamburg Material Testing Machine

Test Scanning Electron Microscope

SEM is an electron microscope designed to observe and analyze the material's surface directly. Instruments for analyzing the surface of materials. SEM test was conducted at the University of Lampung. The sample taken was 1 sample for each concentration. The device used is a Zeiss EVO 10 I Scanning Electron Microscope (SEM). The results can be seen in Figure 4-2. 4-3 and 4-4 with 5000x magnification

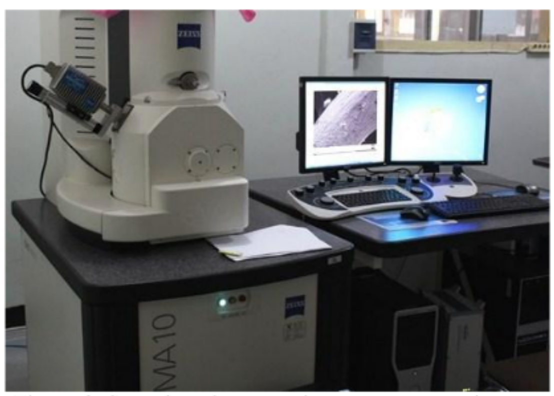

Figure 3. Scanning electron microscope test equipment

Clean Water Permeability Test:

This test aims to measure the flux parameters for the formation of membrane fouling. This test was conducted at Mechanical Engineering, Faculty of Engineering, Sriwijaya University, Palembang. The device used is a clean water permeability device that uses a 1 bar pressure pump. The membrane sample used in this test was 56.2 cm in diameter or with a circle radius of 28.1 m., where the water collected will flow through the pipes. Water that passes through the tap for 0.5 hours will record how much water is released. This test used 1 sample for each concentration of polyethersulfone polymer and titanium dioxide.

Figure 4. Clean Water Permeability

III. Result

Tension Test

Table 1 Membrane PES 27.5wt%, TiO_2 2wt%, and DMF

Specimen	Material Composition (% by weight)			Area (mm2)	Max Load (kN)	Tensile Stress (kN/mm2)
	PES (gr)	DMF	TiO2 (gr)			
A1	13.75	35.975	0.275	1.2	0.01	0.0083
A2	13.75	35.975	0.275	1.2	0.011	0.0092
A3	13.75	35.975	0.275	1.2	0.012	0.0100
Average Maximum Tensile Stress					0.011	0.009166667

Table 2 Membran PES 30wt%, TiO_2 2wt%, dan DMF

Specimen	Material Composition (% by weight)			Area (mm2)	Max Load (kN)	Tensile Stress (kN/mm2)
	PES (gr)	DMF	TiO2 (gr)			
A1	15	34.7	0.3	1.2	0.012	0.0100
A2	15	34.7	0.3	1.2	0.014	0.0117
A3	15	34.7	0.3	1.2	0.015	0.0125
Average Maximum Tensile Stress					0.013667	0.011388889

Table 3 Membran PES 32,5 wt%, TiO_2 2wt%, dan DMF

Specimen	Material Composition (% by weight)			Area (mm2)	Max Load (kN)	Tensile Stress (kN/mm2)
	PES (gr)	DMF	TiO2 (gr)			
A1	16.2	33.425	0.325	1.2	0.02	0.0167
A2	16.2	33.425	0.325	1.2	0.016	0.0133
A3	16.2	33.425	0.325	1.2	0.015	0.0125
Average Maximum Tensile Stress					0.017	0.014166667

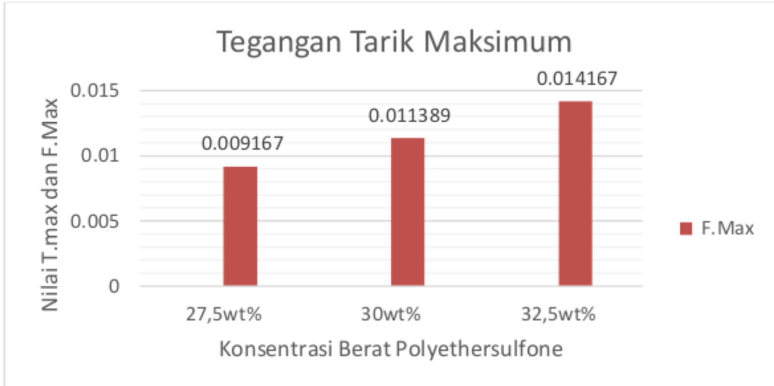

Figure 5-Graph of Stress Stress Increase of PES, TiO2, and NN-Dimethylformide

Microscopic Test

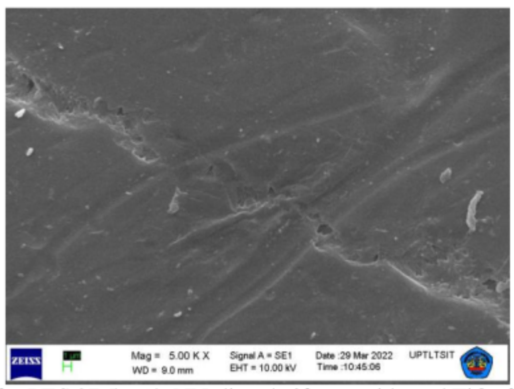

Figure 6. SEM results for PES 27,5wt%, NN-dimethylformamide and TiO_2 for Magnification 5000x

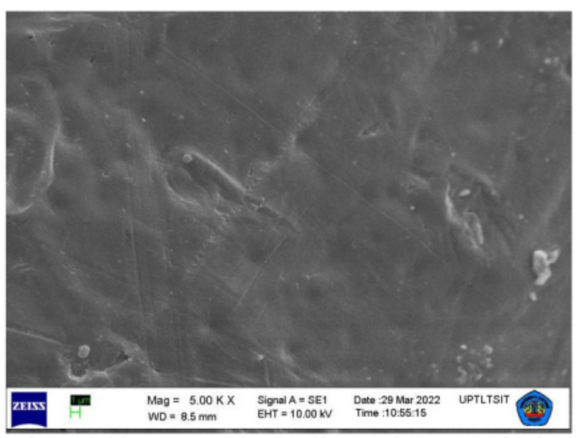

Figure 7 SEM results for PES 30wt% , NN-dimethylformamide, and TiO2 for Magnification 5000x

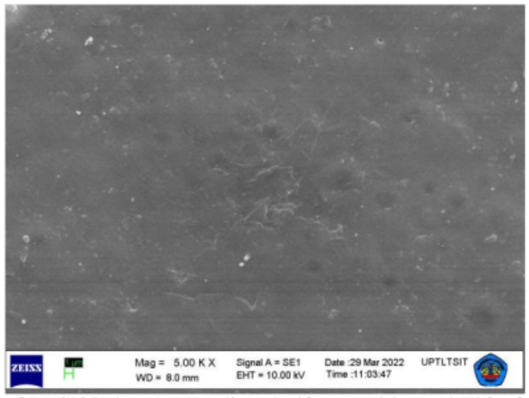

Figure 8. SEM results of PES 32,5wt%, NN-dimethylformamide, and TiO_2 for Magnification 5000x

Clean Water Permeability Test

Membranes were tested at a pressure of 1 bar per hour and ambient temperature. The test was conducted at the Department of Mechanical Engineering, Sriwijaya University. Each sample was tested using a clean water permeability device, with the aim of finding out the flux value of each polymer concentration produced for 0.5 h. To analyze the results as in table 4-4. With the provision of a dead-end system with an effective membrane area of 18.08 cm^2 was used to analyze the performance of the prepared membrane.
the following test results:

Table 4 Tire Test Results using CWP

No	Membrane	Volume Permeat (L)	Membrane area (m^2)	Time (h)	Pressure (Bar)	Flux L/m^2.h.bar
1	PES 27,5wt%	0.004	0.0025	0.5	1	3.2266
2	PES 30wt%	0.0032	0.0025	0.5	1	2.5813
3	PES 32,5%	0.0029	0.0025	0.5	1	2.3393

IV. Discussion

Based on the table 1, table 2, table 3 and figure 5, the results obtained are at a PES concentration of 27.5 %, and the average tensile stress value is 0.00916 kN/mm2. In membranes with a PES concentration of 30wt%, the average maximum tensile stress was 0.011288 kN/mm2, while the average maximum tensile stress at a concentration of 32.5wt% was 0.014116 kN/mm2. Based on the data, it is concluded that the average value of the highest maximum tensile stress is at a concentration of 27wt%, which is 0.00916 kN/mm2. 0.00916 kN/mm2, while the lowest maximum load value and maximum stress value were at 27.5% concentration at 0.010 kN and 0.0083 kN/mm2.

Microscopic test results (Figure 6-8) PES membranes, NN-dimethylformamide, and TiO2 has as a pore shape with a homogeneous size. Based on concentrations of 27.5wt%, 30wt%, and 32.5wt%, it was shown that membranes with concentrations of 27.5 wt% had less homogeneous pore surface sizes than membranes at concentrations of 32.5wt%. The higher the concentration of Polyethersulfone contained in the membrane, the greater the pore density formed on the membrane. Increased porosity causes increased membrane hydrocitivity [6].

At clean water permeability test shown that the greater the concentration of PES polymer added, the more pore density will occur, which causes the flux value or water flow rate to decrease. According supported by research conducted by Eryildiz and colleagues that membranes with high hydrophilicity have higher membrane stability. When hydrophobic membranes are tested for water filtration, the mass water transfer will be significantly reduced, and consequently, the flux permeability of the membrane will be reduced[7]

V. Conclusion

Based on the results of tests conducted on Polyetersulfon Membrane Formation (PES) with the addition of the addictive substance Titanium dioxide (TiO_2), it is concluded that development of membrane formation with polyethersulfone polymers with 27.5 wt%, 30wt%, and 32.5 wt% and titanium with concentrations of 2wt% can be carried out. In the tensile test, Polyethersulfone and titanium dioxide membranes showed a higher maximum tensile stress value with a value of 0.00167 kN/mm2 at a concentration of 32.5wt%, and the lowest maximum tensile stress value occurred at a concentration of 27.5wt% with a value of 0.010 kN/mm2. In testing the maximum water flow rate value on the membrane, which is at a concentration of 27.5 wt% of 3.2266 L/ m2.h.bar, while the lowest water flow rate value is at a concentration of 32.5wt% which is 2.3393 L/ m2.h.bar

Acknowledgments

Thanks to research funding support from the DIPA BLU budget Universitas Sriwijaya, Achieved the 2022 Competitive Research Scheme.

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Nadiyah Rohmatullah, et. al. "Formation of POLYETHERSULFONE (PES) Membrane with Titanium Dioxide (TiO2) Reinforcement for Water Treatment Applications". *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),* 19(3), 2022, pp. 09-15.

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