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MEMBRANE FILTRATION SIMULATION STUDY WITH VARIATION IN THE NUMBER OF FILTERS ON PEAT WATER MEDIA

Rachmat Subagyo
Doctor of Mechanical Engineering, Researcher*
E-mail: rachmatsubagyo@ulm.ac.id
Hajar Isworo
Masters of Mechanical Engineering, Researcher*
E-mail: hajarisworo@gmail.com
*Department of Mechanical Engineering
University of Lambung Mangkurat Banjarmasin
Jl. Brigjen. H. Hasan Basri, Kotak Pos 219, Banjarmasin-South Kalimantan, Indonesia, 70123

The rapid population growth has an impact on the increasing need for drinking water. In swamp areas, the need for drinking water cannot be met immediately because it still contains organic compounds that make the water unfit for consumption. Peat water contains dissolved organic compounds that cause the water to turn brown and have an acidic character, so it needs special processing before it is ready for consumption. For peat water to be used by the community for drinking water, it is necessary to find an easy and cheap way to treat peat water. The use of a filtration device is one of the solutions that must be done in peat water treatment. The purpose of this study was to determine the effect of flow patterns, speed, and pressure on the filtration process with variations in the type of membrane and filtration arrangement. This research method was carried out by simulation using ANSYS 14.5 series. The simulation process begins with designing a filtration device with the following types: two-filter, three-filter, and four-filter. Then the simulation was performed by entering the value of the peat water properties into the regulatory equation.

The results of this study indicate that the collaboration of two membranes with different holes in type-2 and 3 filters produces a good filtration rate. However, in type-4 filters, the use of a similar membrane is highly recommended. This filtration rate is influenced by the presence of a cross-flow reversal (CFR) region that appears, when using different filtration membranes at low pressure it doesn't matter. However, in other cases of systems operating at high pressure, CFR that appears tends to decrease the filtration rate, this is because CFR inhibits the flow rate in the filtration process

Keywords: swamp areas, peat water, type of membrane, filtration arrangement, ANSYS 14.5

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1. Introduction

The rapid population growth has an impact on the increasing need for drinking water. In swamp areas, the need for drinking water cannot be met immediately because it still contains organic compounds that make the water unfit for consumption. In the South Kalimantan area, we still encounter a lot of peat water, which is inundated peatlands or lowlands. Peat water contains dissolved organic compounds that cause the water to turn brown and have an acidic character, so it needs special processing before it is ready for consumption. For peat water to be used by the community for drinking water, it is necessary to find an easy and cheap way to treat peat water. The use of a filtration device is one of the solutions that must be done in peat water treatment.

Filtration with a membrane system is very suitable for application in peat water purification. In this purification process, several layers of membranes are needed to remove dissolved organic substances, so that the purified water is suitable for consumption. To determine the processes that occur in each layer of the membrane, it is necessary to examine the flow pattern, velocity, and pressure at each layer level. The best membrane arrangement needs to be examined by means of simulations in each layer by making variations in the arrangement of membranes in each type.

Therefore, a special study is examining membranes suitable for filtration of peat water, which contains a lot of dissolved organic compounds that cause water to turn brown and have an acidic nature so that it needs special processing before it is ready for consumption.

2. Literature review and problem statement

A fairly complicated and very challenging filtration simulation research has been carried out by [1]. In this research, the calculation of the airflow field and the trajectory of the air particles in a 3-D geometry that resembles the internal structure of a fibrous filter media was made. The pressure drop and efficiency of the microfilter (nanofibers) were simulated and compared with existing experimental studies. The results of this study were successful in finding the cross-section of the filtration fibers for the flow-slip type preferably (nanofibers) and no-slip microfibers. The leaner the fiber geometry, the lower the resistance, this shows that micron-sized fibers are better than nano-sized fibers. This research was continued by [2], conducting a simulation to determine the phenomenon of inflow concentration, flow rate, pressure, and membrane permeability in the filtration process. The simulation results can explain the variables that affect the filtration process, but they are not specifically able to explain the effect of flow patterns on the number of filters with different membrane hole sizes. Different membrane hole sizes have a great influence on the filtration flow rate, this is influenced by the size of the fiber itself [1]. The size of the membrane fibers at the micro-scale affects the flow that occurs, especially the speed during filtration. To determine the effect of micro-size membranes on the filtration rate, it is necessary to further study the numerical analysis of the membrane filtration process with variations in the filtration arrangement.

Filtration is a method of physical separation or better known as filtering that is done to separate solids and liquids. The types of filtration we are familiar with are: crystallization, distillation, sublimation, extraction, adsorption, chromatography, sieving, and evaporation. Research on various filtration methods has been carried out, including ceramic membrane microfiltration method [3, 4], coagulation filtration method [5], filtration method using self-cleaning materials [6], filtration method with adsorption mechanism [7], filtration method with xylem plant [8], biological sand filtration method (BSF) [9], filtration method with organic filtration membrane [10], Multi Soil Layering (MSL) filtration method [11], coagulation and flocculation type filtration methods [12], hybrid coagulation-ultrafiltration system filtration method [13] and hybrid coagulation-ultrafiltration method [14]. Each of these types of filtration has its advantages and results in different filtration results.

The disadvantages of Ceramic water purifiers (CWP) mainly arise from the preparation process where it is very difficult to achieve reproducible final product quality. This is due to the brittle nature of the ceramic membrane making it more expensive than polymer membranes. In addition, the price of this membrane increases significantly with the increasing requirements for product properties, such as porosity, pore size, reproducibility, and reliability. Apart from the weaknesses that have been stated according to the research [4], there is frequent damage to ceramic filter elements during implementation, limited availability of spare parts, and susceptibility to contamination. The absence of further studies regarding backwash ability, increasing the efficiency of backwash chemically to remove membrane foulants [3]. For these reasons, it is very important to look for superior filtration membranes to be developed further apart from being cheap, easy to produce, and easily increasing their capacity as needed.

Membrane filtration systems have become a hot topic in recent years. Membrane separation has many advantages that other separation methods do not. This advantage is that separation from membranes does not require additional chemical substances and also has a very minimum energy requirement. The membrane can act as a very specific filter. Only molecules of a certain size can pass through the membrane while the rest will be stuck on the membrane surface. Apart from the advantages already mentioned, this membrane technology is simple, practical, and easy to do.

Membrane separation is a technique for separating a mixture of 2 or more components without using heat. The components are separated by size and shape, with the aid of pressure and a semi-permeable membrane. The separation results are in the form of retentate (part of the mixture that does not pass through the membrane) and permeate (part of the mixture that passes through the membrane). Research with membrane technology continues to evolve in line with expanding filtration needs. The researchers tried to combine membrane filtration with other methods such as that done by [15], this research method was carried out by mixing Powdered Activated Carbon (PAC) in the liquid. The results showed that PAC did not cause fouling on the filtration but instead facilitated the absorption of organic and inorganic materials in the filtered liquid.

The main problem faced in the application of membrane technology is membrane fouling [16]. So far, the hybrid process with coagulation-ultrafiltration in drinking water treatment has been carried out by several studies, namely using one-stage coagulation. This study aimed to investigate the effect of two-stage coagulation as a pretreatment on the performance of the coagulation-ultrafiltration hybrid process to remove Natural Organic Matter (NOM) in peat water. NOM is a problem that needs to be considered in the problem of filtration, especially in terms of membrane decay, which results in a gradual decrease in infiltration ability. The research conducted in [17] found the organic causes of membrane fouling, including its molecular weight and hydrophilicity/hydrophobicity and then presented a brief introduction to methods that can prevent membrane fouling such as feedwater pretreatment (e.g. coagulation, adsorption, and pre-oxidation) and membrane hydrophilic modification (e. g. plasma modification, irradiation graft modification, surface coating modification, mixture modification, etc.).

Membrane research can be carried out experimentally and simulated, each type of research has its advantages and disadvantages. The weaknesses of experimental research are: it is difficult to generalize in everyday life, generally requires a relatively long time and costs a lot of money, hurts knowledge, psychology, and morals. Whereas simulation research is a way of proving a model that when carried out using analytic failure, simulation is seen as more realistic in representing real system behavior because there are fewer assumptions, changes in configuration and structure in simulations are simpler if needed to answer various possible changes in system behavior and most cases, simulation is cheaper.

One of the software that has been applied in the simulation is Computational Fluid Dynamics (CFD). CFD is an excellent tool for understanding the flow and trajectory characteristics of droplets through a filter, which is very difficult to do experimentally. In this study, CFD was developed using commercial FLUENT ANSYS. Various methodologies and tests were developed to obtain the data needed to be included in the model and to validate the data predicted by the computational model. The simulation results are close to the experimental results [18].

3. The aim and objectives of the study

The aim of this research is to find the best filtration design in types two, three, and four, with variations in pressure and speed.

To achieve the aim, the following objectives are set:

– to create two, three, and four type filter designs with two different types of filtration membranes then perform simulations with variations in speed and pressure to obtain the best filtration design;

– to analyze the effect of pressure and speed on the filtration process.

4. Material, methods, and models of research

This research was conducted by simulation using ANSYS 2019 series, student version. The simulation process begins with designing a filtration device with the following types: Two-filter, Three-filter, and Four-filter as shown in Fig. 1. Each type has four formations with the following details: Type-2 is (2A; 2B; AB and BA), Type-3 is (3A; 3B; BAB and 2B-A) and Type-4 is (4A; 4B; BA-2B and 3B-A) as shown in Table 1. This is intended to determine the effect of the number of filters on the flow rate pattern and the effect of the number of filters on the flow resistance pattern. The results of measurements of peat water properties at three locations in the Banjarbaru area are shown in Table 1, while the dimensions of the filtration membrane are shown in Fig. 1. Filters were used, each with a hole size of 0.1 mm and 0.2 mm.

The simulation process begins with entering the properties of peat water in Table 1, the measurement results into the equation set as follows:

$$Q=\frac{\mathrm{d}v}{\mathrm{d}t}, \quad (1)$$

$$Q=\frac{\Delta PA}{\mu\left(\frac{\alpha_{ave}c_v}{A}+R_m\right)},$$

with the value, $\left(\frac{\alpha_{ave}c_v}{A}+R_m\right)=1$, where:

Q – flow rate (m^3/s);
T – time of filtration (s);
ΔP – pressure drop (Pa);
A – effective area of filtration (m^2);
μ – viscosity of filtrate (Pa·s);
α_{ave} – average specific resistance;
c – kg of dry cake per volume of filtrate;
V – volume of filtrate (m^3);
R_m – medium resistance.

The peat water variables measured: density (ρ), temperature (T), air pressure (P), and viscosity (μ) are shown in Table 1.

Assumptions: constant area, ignore gravity.

Table 1

Results of measurement of peat water properties

Properties	Unit	Measurement results			Average results
		1	2	3	
Density (ρ)	(gr/m^3)	1.00175	0.99425	0.9950	0.9970
Temperature (T)	(°C)	28	29	30	29
Air pressure (P)	(hPa)	1006.4	1006.2	1006.7	1006.4
Viscosity (μ)	Pa.s	1.109×10^{-3}	1.101×10^{-3}	1.143×10^{-3}	1.118×10^{-3}

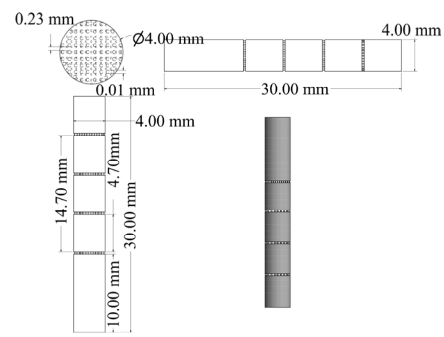

Fig. 1. Design of a type-four filter peat water filtration device

Fig. 1 shows the type-four filter filtration design, in the 3B-A filter variation, the position of the water entering from above passes through vertically arranged filters then the water comes out as a result of filtration. Inlet distance=10 mm, the distance between filters=4.70 mm, and outlet distance=4.70 mm. The dimensions of the filter used are shown in Fig. 2, with filter diameter-A (100 microns): 4 mm, hole diameter 0.10 mm, and the distance between holes 0.31 mm. While the filter diameter-B (200 microns): 4 mm, hole diameter: 0.20 mm, and the distance between holes is 0.53 mm.

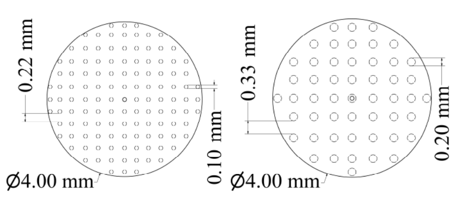

Fig. 2. Filter size dimension: *a* — 100 micron (Type-A) and filter sizes; *b* — 200-micron filter (Type-B)

The choice of two types of filters with different sizes is to distinguish their advantages and disadvantages if they are arranged uniformly or non-uniformly. With this formation, it is hoped that it can determine the best arrangement that can be used as a practical guide for infiltration design.

5. Results of the membrane filtration simulation study with variation in the number of filters on peat water media

Table 2 shows the simulation results on the filter type 2, 3, and 4, the values of varying velocity and pressure. In the formation of two filters, the velocity values between two (8.553 to 12.46 m/s), three filters (9.1313 to 11.33 m/s) and four filters (9.271 to 12.56 m/s) are obtained. The lowest velocity value of 8.553 m/s occurs in the type-2 filter (2B), while the highest velocity of 12.56 m/s occurs in the type-4 (4A) filter. The pressure on the type-2 filter ranges from (6.066×10^4 to 13.18×10^4 Pa), type-3 filter: (9.29×10^4 to 15.30×10^4 Pa) and type-4 filter: (10.57×10^4 to 19.66×10^4 Pa). The lowest pressure value of 6.066×10^4 Pa occurs in the type-2 (2B) filter, while the highest pressure of 19.66×10^4 Pa occurs in the type-4 (4A) filter.

Table 2

Velocity and pressure simulation results for various filters

Filter type	Velocity (m/s)	Pressure (Pa)	Filter formation
2	12.29	13.48×10^4	(A-A) or 2A
	8.553	6.066×10^4	(B-B) or 2B
	11.32	11.16×10^4	(A-B)
	12.46	11.74×10^4	(B-A)
3	11.27	15.30×10^4	(A-A-A) or 3A
	9.313	9.29×10^4	(B-B-B) or 3B
	10.64	12.41×10^4	(B-A-B)
	11.33	11.96×10^4	(B-B-A) or 2B-A
4	12.56	19.66×10^4	(A-A-A-A) or 4A
	9.271	10.57×10^4	(B-B-B-B) or 4B
	9.594	13.52×10^4	(B-A-B-B) or B-A-2B
	11.10	12.85×10^4	(B-B-B-A) or 3B-A

Table 2 shows the simulation results on filter types 2, 3, and 4 with 4 different formations each. For type two, the best filtration rate results are obtained in the B-A formation, with a speed value of 12.46 m/s. Type 3 results in the best filtration speed in the 2B-A formation, with a speed value of 11.33 m/s. Type 4 results in the best filtration rates in the 4A formation. These results allow concluding that when the number of membranes is 23, the collaboration between two different membranes results in good filtration rates. But in type four filters, the use of a similar filter is recommended.

6. Discussion of the research results of the membrane filtration simulation study with variation in the number of filters on peat water media

These results allow concluding that when the number of membranes is 23, the collaboration between two different membranes results in good filtration rates. But in type four filters, the use of a similar filter is recommended.

Based on the calcification of the research conducted by [2], there are three cases during filtration that are studied, namely: high pressure and low intake speed, high pressure and high intake speed, low pressure and high intake speed. In this experiment, the third case at low pressure and high speed was tried. Three things happen, namely: the velocity value is directly proportional to the pressure value that occurs, but there is one uniqueness that occurs in Type 2 and 3 filters, in the use of twin membranes: 2A, 3A, and 4A, each at a speed of 12.29 m/s, 11.27 m/s and 12.56 m/s shown in Table 2, the highest pressure value is obtained. This is supported by the research [1], but the highest flow rates are achieved by the BA and BBA formations. In type-4 filters, this is no longer the case, the greater number of membrane holes leads to a higher flow rate [1] but causes a non-uniform flow that disturbs dust deposition on the membrane surface. In the type four filter, the above phenomenon is no longer valid, this is because the number of holes in the membrane does not affect increasing the speed and pressure.

The limitation of this study is that it only simulates one case of filtration, namely the low pressure and higher intake speed compared to previous research. It is not possible to know globally to conclude all cases that occurred in filtration. The advantage of this research is that it can provide an overview of the filtration process at higher speeds.

The drawback of this study is that it only uses one model, namely at high pressure and speed, to produce a more in-depth analysis, research will be carried out on all filtration models so that it can solve all cases in membrane filtration.

The development of this determination is to carry out experiments to test the results of this simulation so that more valid results will be obtained. Fig. 3 shows a graph of the relationship between the filter formation and the pressure that occurs in the filtration process. This graph shows the lowest pressure occurrence in each filter type represented by type-2 with a 2B formation; type-3 with a 3B formation and type-4 with a 4B formation. This shows that using the same hole filter provides an advantage at a lower pressure level compared to using a different type of filter with a different hole. In the use of different filter holes, the pressure value tends to be higher. The pressure value increases when there is a large resistance as it passes through the filter. Placement of the filter with a large hole at the beginning of the filtration will increase the pressure as in the type-2 filter with the B-A formation, with a pressure value of $P_{B\text{-}A}=11.74\times10^4$ Pa. This happens because the filtration process at the first level will be smoother with a larger membrane hole. Then proceed to the second level of filtration with a smaller membrane hole so that the pressure is better when compared to the A-B formation.

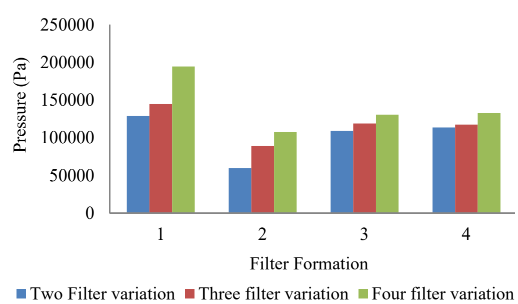

Fig. 3. Relationship between filter formation and pressure

Fig. 4 shows a graph of the relationship between filter formation and the rate of filtration that occurs. The results of this graph show that the lowest velocity in each filter type is represented by: type-2 with a 2B formation (8.553 m/s); type-3 with the 3B formation (9.133 m/s) and type-4 with the 4B formation (9.271 m/s).

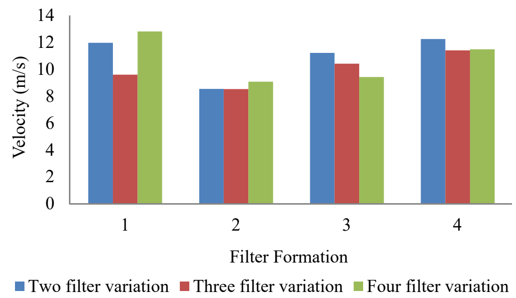

Fig. 4. Relationship between filter formation and velocity of filtration

This shows that using a filter with the same membrane hole provides a lower velocity rate compared to using a filter with a different membrane hole. The velocity value increases as the fluid passes through the filter with a small hole due to the large resistance.

There are three unique features that can be used as guidelines in arranging the filtration formation when combining several filters that have membrane holes of different sizes. The first is that the arrangement of the filtration membrane in sequence from large to small hole sizes is very advantageous, this is evidenced by the better velocity and pressure values as shown in Table 1, occurring in the A-B and B-A formations. In a type-3 filter, if the membrane is positioned with a small hole in the middle, the velocity decreases, and the pressure increases. If the pinhole membrane is placed in the last arrangement then the opposite applies. This can be observed in the phenomenon shown in Table 1, which occurs in the B-A-B and 2B-A formations. In a type-4 filter, if the small hole membrane is placed in the middle, the velocity decreases but the pressure increases. This applies the other way around when the membrane of the pinhole is arranged at the end. This can be observed in the phenomena shown in Table 1, in the B-A-2B and 3B-A formations.

The results of the velocity simulation on a type-2 filter, with the formations A-A, B-B, A-B, and B-A are shown in Fig. 5. The highest velocity in the B-A formation with a velocity value of 12.46 m/s, the lowest velocity in the B-B formation with a velocity value of 8.553 m/s.

The results of velocity simulation on a type-3 filter, with the formations 3A, 3B, B-A-B, and 2B-A are shown in Fig. 6. The highest velocity in the 2B-A formation with a velocity value of 11.33 m/s, the lowest velocity in the 3B formation with a velocity value of 9.1313 m/s.

The results of velocity simulation on a type-4 filter, with the formations 4A, 4B, B-A-2B, and 3B-A are shown in Fig. 7. The highest velocity in the 4A formation with a speed value of 19.66 m/s, the lowest velocity in the 4B formation with a speed value of 9.271 m/s.

Fig. 8 is the simulation result of the pressure that occurs in the filtration process with the formation of 2A; 2B; A-B and B-A. The pressure in each filter formation is: P_{2A}=(13.48×10^4 Pa), P_{2B}=(6.056×10^4 Pa), $P_{A\text{-}B}$= =(11.16×10^4 Pa) and $P_{B\text{-}A}$=(11.74×10^4 Pa). Two things are important in the preparation and selection of the type of filtration in this condition, namely: if you use a small hole filtration membrane at the beginning and then end with a large filtration hole, low pressure is obtained as shown in Fig. 8, *c* (circle mark), whereas if the opposite is true the pressure tends to be higher, Fig. 8, *d* (circle mark).

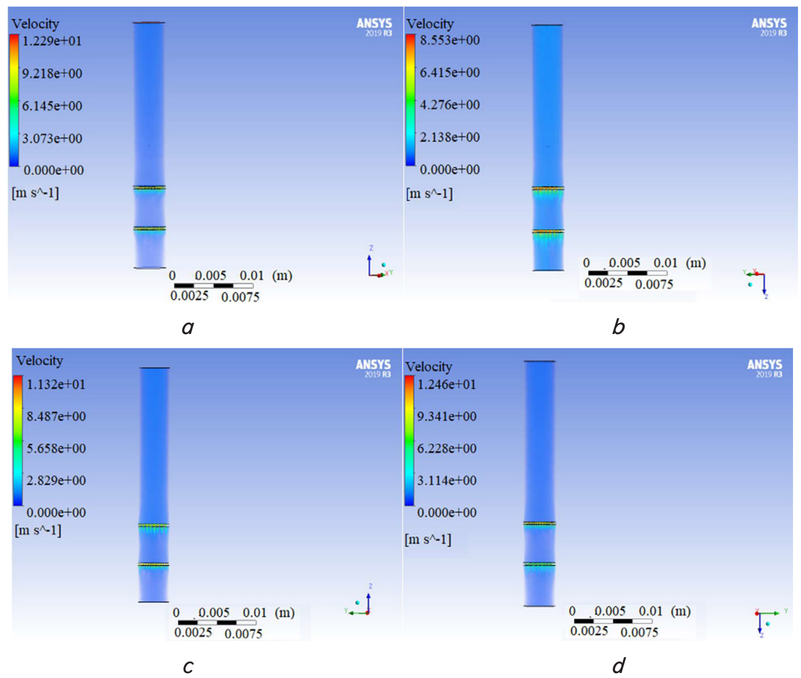

Fig. 5. Velocity simulation on: *a* — Filter type 2 formation: A-A; *b* — Filter type 2 formation: B-B; *c* — Filter Type 2 formation: A-B; *d* — Filter type 2 formation: B-A

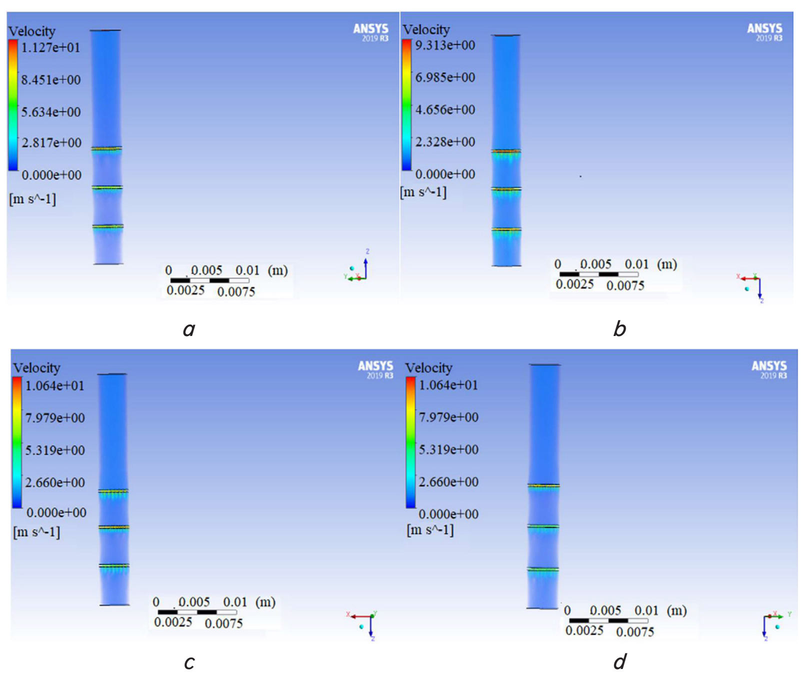

Fig. 6. Simulation of velocity on: *a* — Filter type 3 formation: 3A; *b* — Filter type 3 formation: 3B; *c* — Filter Type 3 formation: B-A-B; *d* — Filter type 3formation: B-B-A

When using a filtration membrane with the same hole size, the pressure tends to be high in the small membrane hole, Fig. 8, *a* (circle mark) and if the membrane hole is large, the pressure tends to be low Fig. 8, *b* (circle mark).

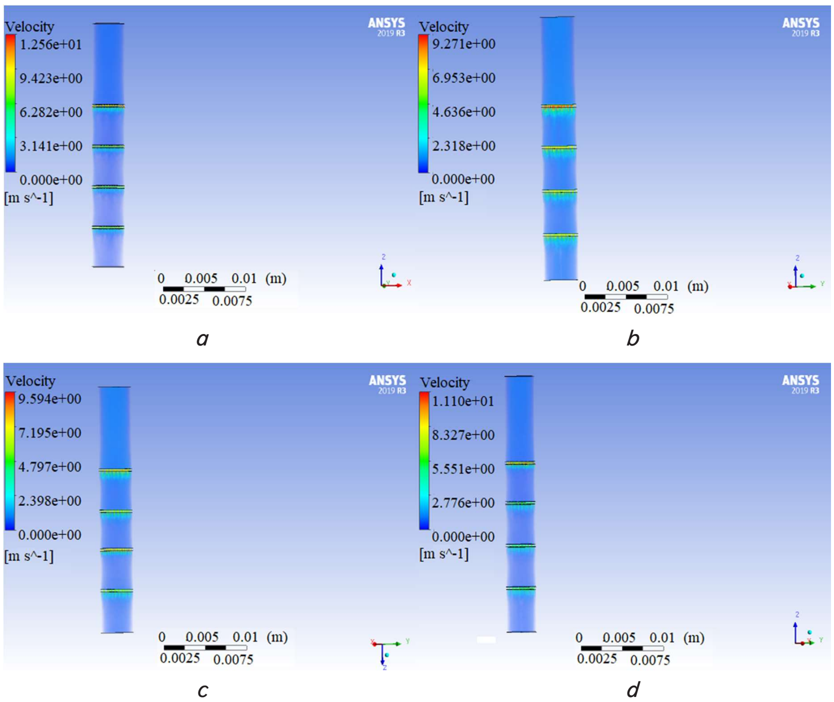

Fig. 7. Velocity simulation on: *a* – Filter type 4 formation: A-A-A-A; *b* – Filter type 4 formation: B-B-B-B; *c* – Filter Type 4 formation: B-A-B-B; *d* – Filter type 4 formation: B-B-B-A

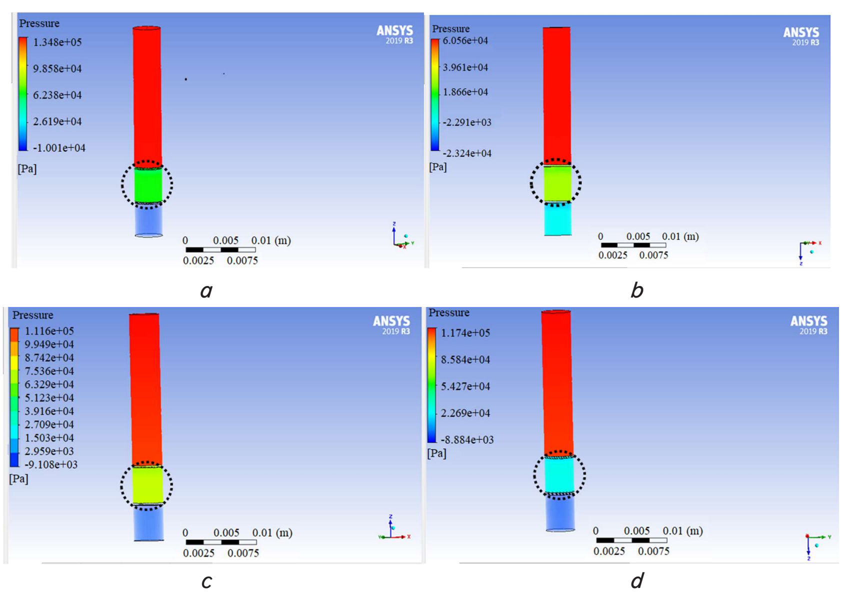

Fig. 8. Pressure simulation on type-2 filter: *a* – Formation: A-A; *b* – Formation: B-B; *c* – Formation: A-B; *d* – Formation: B-A

when compared to the B-B-A filter. This is because the backpressure of the fluid flow hitting membrane A is very effective at increasing pressure that occurs in the space between membranes one and two as shown by the circle mark in Fig. 9, *c*. This applies in reverse to the B-B-A formation shown in Fig. 9, *d* (circle mark).

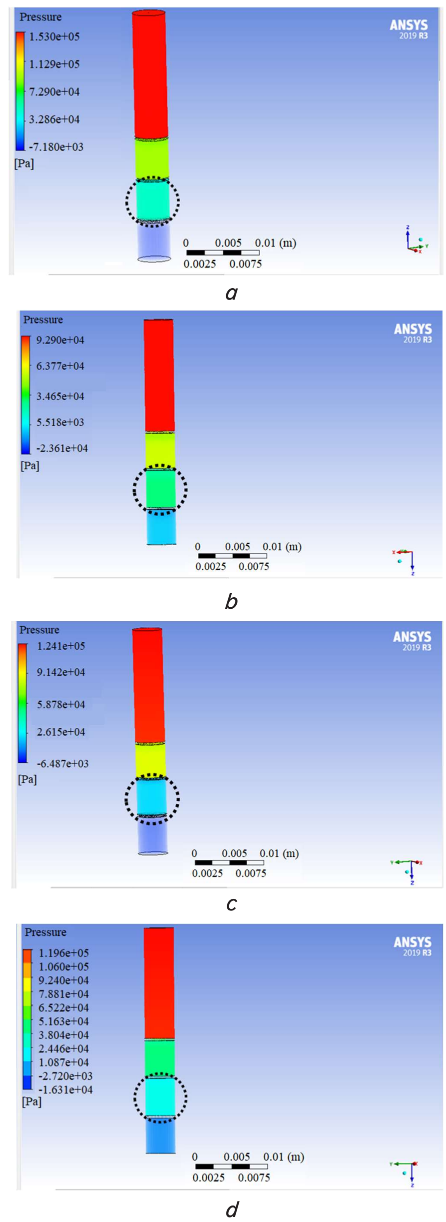

Fig. 9. Simulated pressure on: *a* – Filter type 3 formation: 3A; *b* – Filter type 3 formation: 3B; *c* – Filter Type 3 formation: B-A-B; *d* – Filter type 3 formation: B-B-A

Fig. 9 is the result of simulation on a type-3 filter with the formation: 3A; 3B, B-A-B, and 2B-A. The pressure in each filter formation is: P_{3A}=(15.30×10^4 Pa), P_{3B}=(9.29×10^4 Pa), $P_{B\text{-}A\text{-}B}$=(12.41×10^4 Pa) and $P_{2B\text{-}A}$=(11.96×10^4 Pa). The 3-type filter shows that the 3A formation tends to be higher as shown in Fig. 9 (circle mark) when compared to other formations, this is due to the smaller size of the filtration holes. The B-A-B filter formation tends to have higher pressure

Fig. 10 is the simulation result of the pressure that occurs in the filtration process at type-4: 4A; 4B; B-A-2B and 3B-A. The pressure in each filter formation is: P_{4A}=(19.66×10^4 Pa), P_{4B}=(10.57×10^4 Pa), $P_{B\text{-}A\text{-}2B}$=(13.52×10^4 Pa) and $P_{3B\text{-}A}$==(12.85×10^4 Pa). This result shows that the four-layer filter arrangement-A tends to have higher pressure in Fig. 10 (circle mark) when compared to the arrangement of four B-filters in Fig. 10 (circle mark). This is due to the smaller filter holes, which increase the backpressure. For the collaboration formation of filter A with B, the pressure is higher when filter-A is between filter B as shown in Fig. 10 (circle mark). When filter-A is at the end of the formation, the pressure tends to decrease as shown in Fig. 10 (circle mark).

Fig. 11 is the result of velocity simulation on the type-2 formation (B-B), type-3 formation (3B), and type 4 formation (B-A-2B) filters. The velocity in the center (light blue) is higher than the velocity at the edge (dark blue). This simulation resulted in the value of filter type-2 (8.553 m/s)<filter type-3 (9.313 m/s)<filter type-4 (9.594 m/s).

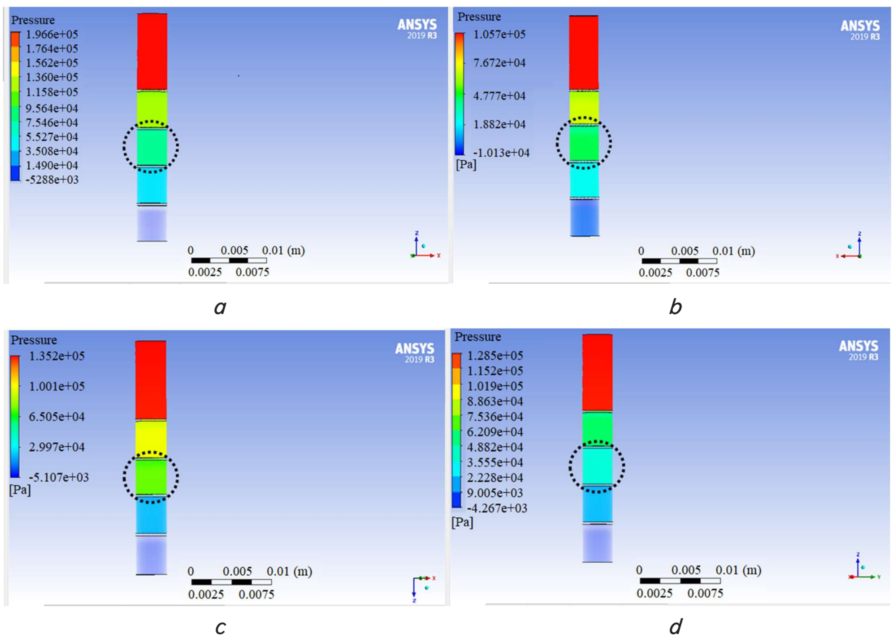

Fig. 10. Simulated pressure on: *a* — Filter type 4 formation: 4A; *b* — Filter type 4 formation: 4B; *c* — Filter Type 4 formation: B-A-2B; *d* — Filter type 4 formation: 3B-A

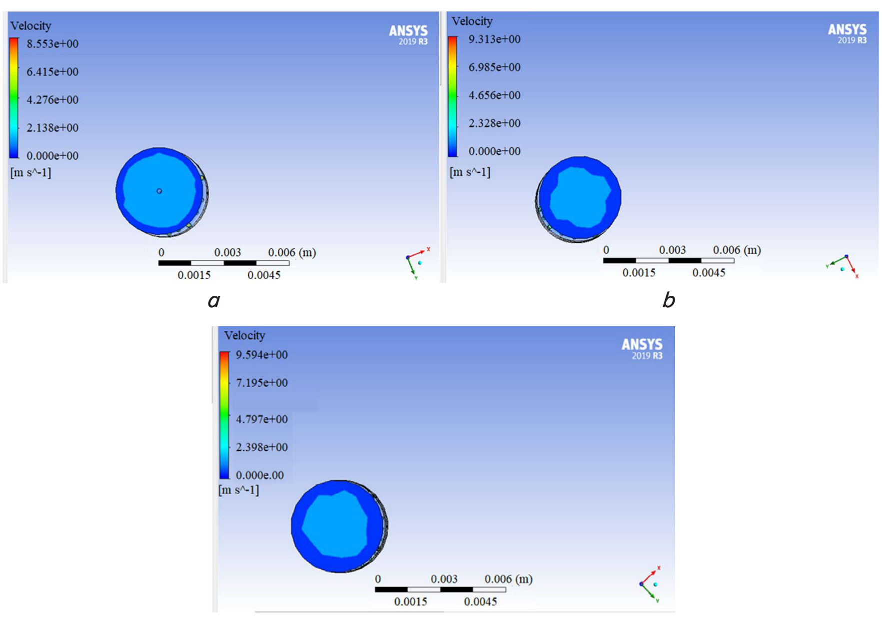

Fig. 11. Velocity simulation on: *a* — Filter type-2 formation: B-B; *b* — Filter type-3 formation: 3B; *c* — Filter type4 formation: B — A —2B

There is a change from one velocity profile to the next: the light blue area is narrowing, this indicates an increase in the concentrated velocity energy in the center. Where the center of gravity of the fluid is centered in the middle then gives the impetus to pass through the filtration gaps down to the bottom. The particles that have a large size remain in the filter, while the smaller sizes pass through the filtration to the next filter. The center of the membrane is the area that receives the strongest thrust from the filtration fluid, so this area is likely to be damaged quickly. When the velocity increases, the filtration process becomes faster.

The high-pressure operation contributes to the rapidly expanding boundary layer across the channel. This condition does not allow the system to reach axial steady-state conditions [2]. The development of this boundary layer is also influenced by the entry speed. When the entry velocity is low, the solute tends to be along the medium channel, at high speed tends to be stuck and decreases due to the viscosity effect. In another case of a system operating at high pressure, the Cross-Flow Reversal (CFR) area appears as shown in Fig. 11 (dark blue). In the area near the wall, the pressure tends to slow down due to CFR and friction with the wall.

Fig. 11 displays the simulation results of increasing the speed under each condition: image (Fig. 11, *a*): V_{2B}=8.553 m/s, image (Fig. 11, *b*): V_{3B}=9.133 m/s and image (Fig. 11, *c*): $V_{B\text{-}A\text{-}2B}$=9.594 m/s. It appears that when the speed increases the area of the light blue color gets smaller and the area of the dark blue is getting wider. This is due to the presence of organic compounds contained in the peat water that is collected in the middle so that it inhibits the rate of the filtration process that occurs. The edge tends to be less obstructed so that the peat water breaks through the membrane at the edge first.

7. Conclusions

1. The amount of membrane 2–3 collaboration between two different membranes results in a good filtration rate. But in type four filters, the use of a similar filter is recommended.

2. In another case of a system operating at high pressure, the Cross-Flow Reversal (CFR) region appears. In the area near the wall, the pressure tends to slow down due to CFR and friction with the wall.

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