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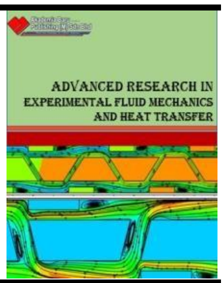

Characteristics of Void Fraction Using Image Processing of Two-Phase Flow of Air-Pure Water and Glycerin (40-70%) on A Transparent Mini Pipe with Slope of 45° to the Horizontal

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ABSTRACT

The two-phase flow is the simplest part of multiphase flow because it only involves two components or phases that flow in a channel either large, medium, small, mini or micro) at one particular time simultaneously, for example, liquid-gas, liquid-solid, gas-solid. he phenomenon of two-phase flow in mini channels is often found in supercomputer equipment, X-rays, heat exchangers in aerospace systems, cryogenic cooling systems in satellites, and others. Therefore, it is very necessary to study the problem there. One important problem is the void fraction characteristic caused by superficial velocity, fluid viscosity and slope. The purpose of this study was to determine the characteristics of the void fraction values on bubbly, plug, slug-annular, annular, churn, and also velocity, length and frequency patterns of bubbly and plug patterns in two-phase flow with a slope of 45 ° in horizontal capillary pipes. The study was conducted on a mini pipe with a diameter of 1.6 mm and a length of 130 mm which was installed at an angle of 45 ° to the horizontal position. The fluid used is a mixture of air-pure water and glycerin with concentrations of 40, 50, 60, and 70%. It was capturing the flow pattern video using a Nikon J4 camera with a speed of 1200 Fps, gas speed (JG) at intervals of 0.025 - 66.3 m / s and fluid velocity (JL) at intervals of 0.033 - 4.935 m / s. To determine the value of a void fraction, a digital image processing method is used with the MATLAB R2014a and Microsoft Excel application program. This paper's new finding is that the value of the void fraction for bubbly flow indicates conditions that are not so stable and have a low value. Meanwhile, the value of the void fraction for plug flow tends to be close to 1 in a certain period; this is induced by the air cavity, which almost fills the vessel, as shown by the results of the image processing and the void time series graphs. In the churn flow pattern, the void fraction has a value that fluctuates with a moderate value.

Keywords:
Frequency; glycerin; image processing, pure water; void fraction

1. Introduction

Two-phase flow is part of a multiphase flow where two phases flow in one channel, for example, liquid-gas, liquid-solid, or gas-solid. If based on the flow direction and channel geometry, the two-phase flow is divided into two types, namely current and counter current flow in either horizontal or vertical directions. Based on the dimensions of the channel, it is divided into several types namely large channel, microchannel, nanochannel, mini channel, normal channel [1]. The two-phase flow in

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mini and microchannels is very broad in its application and continues to be developed due to its wide use in science and advanced technology such as medical design, air-conditioning cooling systems, radiators, cryogenic cooling systems on satellites.

Matsubara and Naito [2] stated that the two-phase flow that occurs in mini and micro-sized channels of fluid has quite unique properties, where the formation of flow patterns is influenced by the viscosity of a liquid fluid, the superficial velocity value of gas fluids and the superficial velocity values of liquid fluids. Triplet *et al.,* [3] have conducted research on the flow of two-phase gas-water in microchannels with a diameter of 1.1 mm and 1.45 mm. The research was also carried out by Sur and Liu [4] who examined the two-phase flow of water gas in microchannels with hydraulic diameters ranging from 100-500 mm. Two-phase flow patterns have been visualized using high-speed photography techniques and generating Bubble, Slug, Churn, Slug-Annular and Annular flow patterns. Based on the above results it can be concluded that hydrodynamics in two-phase channels in microchannels are different than hydrodynamics in larger channels. Sudarja *et al.,* [5] studied a two-phase vacuum fraction using a 1.6 mm diameter pipe using air and pure water with working glycerin fluids. The void fraction values are obtained by processing video images using a 1200 fps Nikon J4 camera. This work was carried out in an adiabatic environment with a surface gas velocity of 0.83-65.4 m / s and a superficial liquid speed of 0.02 to 4.14 m / s. The result showed that the flow pattern plays an important role in the estimation of the void fraction. Whereas Sukamta *et al.,* [6] performed a report on the two-phase airflow void fraction and a mixture of glycerin with specific viscosities in capillary channels inclined 5° to the horizontal. The findings are processed using digital image processing. The results showed that the liquid 's viscosity is very important on bubbly and plug flow patterns. The increased value of the superficial velocity of the gas decreases the value of the void component, and vice versa. It is also generated that homogeneous flow values (β) affect the duration of the bubbly and plug flow patterns.

Wongwises [7] conducted research on the effects of 0°, 30 ° and 60 ° angle variations on two-phase flow. This research was carried out on annular pipes with an inner diameter of 8 mm, 10 mm and 11 mm and an outer diameter of 12.5 mm. The obtained flow patterns vary, namely plug flow, slug flow, slug-annular flow, annular flow, bubbly flow, churn flow, and dispersed bubbly flow. Based on this study, differences in angle variations affect flow change. Autee *et al.,* [8] performed a two-phase pressure drop test using angular variations of 30 °, 60 ° and 90 ° down in pipes with 4 mm, 6 mm and 8 mm diameters and 400 mm channel duration. As working fluids, the study uses a combination of air and water. The study was conducted to get the pressure drop value and to compare the results with existing Crisholm correlations on parameter C. The proposed correlation was found to predict a two-phase pressure drop to a satisfactory level.

Serizawa *et al.,* [9] also measure void fractions using video analysis. For all bubbly flow patterns and slug flow, the result is $\varepsilon = 0.833\ \beta$, showing a linear correlation between ε and β. Chung and Kawaji [10] assessed the void percentage, too. To differentiate the distance and average of the vacuum fractions from the video images of gas and liquid interfaces, different methods of image analysis are employed. The void fraction data at 530 and 250 µm was reduced to reach 300 video images each time the experiment. A void fraction is obtained by comparing the gas limit to the symmetrical volume and by estimating the gas volume fraction. This research provided a new model of slug flow to predict physical insights into the flow characteristics of microchannels. This model can predict gradients of the two-phase friction pressure by diameters of 100 and 50µm. Kawahara *et al.,* [11] performed a one-phase and two-phase flow analysis with a working stream, namely ionized nitrogen water with a fused silica channel of 100 µm in diameter. The parameters used are 0.1–60 m / s air surface velocity, and 0.002–4 m / s air surface velocity. The flow patterns found in this analysis were liquid alone flow patterns (oil slug), gas core flow with fine-thin liquid films, gas core flow with thick-fine liquid films, gas core flow with ring-shaped liquid films and gas core flow with the deformed interface. A very narrow channel allows the number of Reynolds to shrink and increase the surface tension, so that the bubbly and churn flow cannot be observed in this study.

Jagan and Satheesh [12] conducted a study of the flow patterns of the water-air mixture in two-phase flow in different directions. The research used 8 mm diameter pipe and 2 m long pipe with angles of 0 °, 30 °, 45 °, 60 ° and 90 °. Superficial gas and water velocities in the range from 0.06 to 1 m / s and 0.06 to 15 m / s. Flow patterns are obtained using high-speed recording and analyzed using an image processing technique. The results show that multilevel flow is seen in the horizontal position of the pipe and not in the oblique position of the pipe. At the same speed, the effect of turbulence dominates when the angle of the pipe increases when it is opposite to gravity and leads to the flow of churn.

Barreto *et al.,* [13] examined the two-phase flow with water and air fluids in circular pipes with a diameter of 1.2 mm. This study uses gas velocity varies JG = 0.1-34 m / s and JL superficial liquid velocity = 0.1-3.5 m / s. The correlation of small tubes with air-water shows the best pressure drop in the annular pattern with superficial gas velocities of more than 18.6 m / s. The void fraction in this study was used to increase the pressure drop prediction. Jia *et al.,* [14] performed calculations on the void fraction of two-phase flow at different pressures. The difference in pressure that occurs in the bubble and slug flow is substituted so that it gets a void fraction value. This research also discusses the effects of surface tension. It was found that friction loss cannot be ignored, especially when the vacuum gas fraction is less than 0.2. Gomyo and Asano [15] studied the characteristics of a vacuum fraction in a two-phase water gas flow in a small diameter pipe. This research was conducted to determine the void fraction in the pipe diameter of 4 mm, 2 mm, 1.1 mm and 0.5 mm. The void fraction is measured by the capacitance method and flow pattern using a high-speed camera. The study found that the number of annular flow waves increased because the diameter of the pipe narrowed to 1.1 mm. In the case of pipes with a diameter of 0.5 mm, the effect of surface tension increases and the frequency of the waves decreases.

Based on the description above, it can be concluded that there has been quite a lot of research related to the void fraction, but no one has focused on capillary pipes with high viscosity and significant slope. Therefore, this paper presents the results of a two-phase void fraction of air-water mixed with glycerin (40-70%) in a capillary tube with a slope of 45 ° to the horizontal position. For this reason, the purpose of this study is to determine the characteristics of the void fraction in several two-phase flow patterns under the conditions mentioned above. By knowing the characteristics of the void fraction, a pressure drop can be determined, which is useful in the design of early warning system equipment both in industry and in medical equipment.

2. Methodology

Research material in the form of air that has low humidity obtained from a compressor that has been equipped with a water trap, while for liquid fluid used is a mixture of water and glycerin 40%, 50%, 60% and 70%. This research was conducted at the superficial gas velocity (JG) = 0.025 -66.3 m / s and the superficial velocity of the fluid (JL) = 0.033 - 4.935 m / s. The study was carried out on a test equipment installation, as shown in Figure 1. The installation of this equipment consists of the main components of the water tank, water pump, air compressor, pressure vessel, mixer, test section. Besides that, supporting equipment is used, such as cameras, personal computers, acquisition systems, and video processing systems. It measured instruments used to include data acquisition, pressure transducer, airflow meter, water flow meter. The analysis uses digital image processing, MatLab, and the Microsoft Excel application to obtain the value of the void fraction.

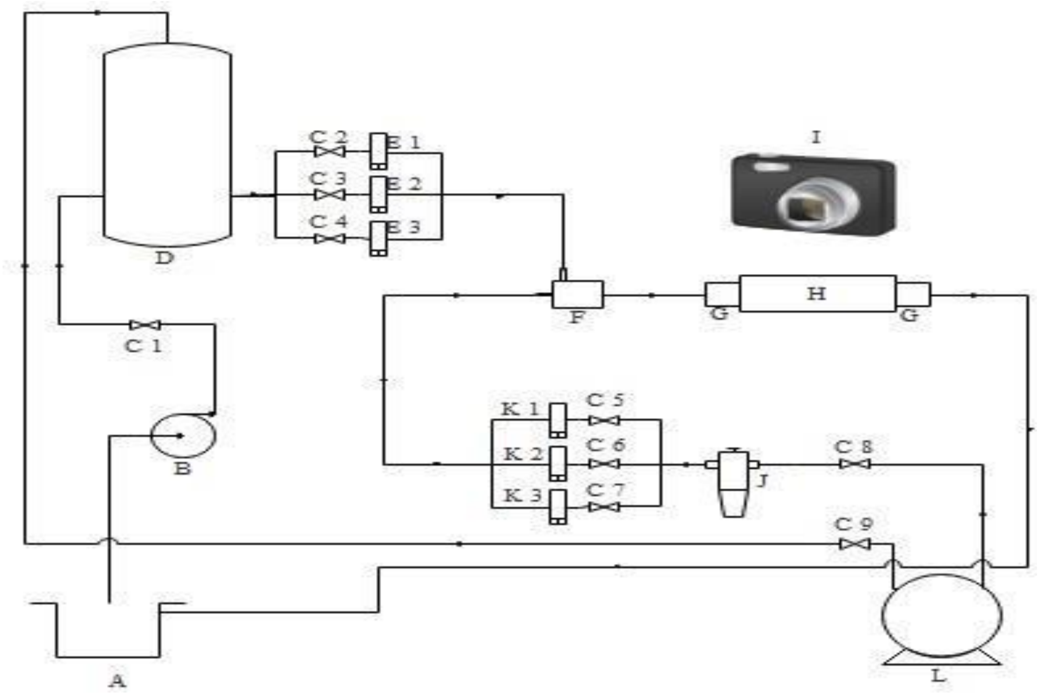


Fig. 1. Scheme of Research Installation

A = Water Tank	E = Flowmeter for fluid	I = Camera
B = Pump	F = Mixer	J = watertrap
C = Valve	G = Flange	K = Flowmeter for gas
D = pressure vessels	H = Test Section	L = Compressor

3. Results

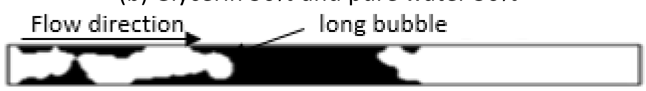
3.1 The Void Fraction of the Bubble Flow Pattern

The bubbly flow pattern is characterized by small air bubbles that usually resemble a ball. This pattern is formed when the position of the superficial gas velocity (JG) is low, and the position of the superficial fluid velocity (JL) is high. Result of image processing of the bubble flow pattern was shown in Figure 2, and void fraction time series was shown in Figure 3.

(a) Glycerin 40% and pure water 60%

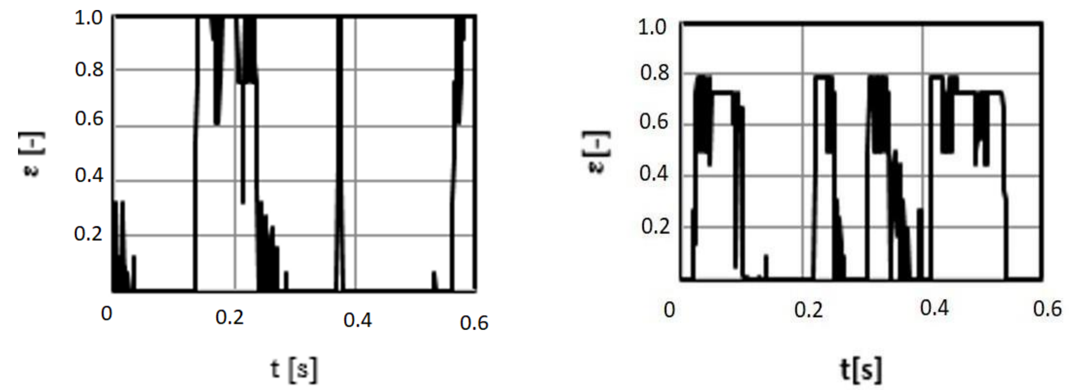
(b) Glycerin 50% and pure water 50%

(c) Glycerin 60% and pure water 40%

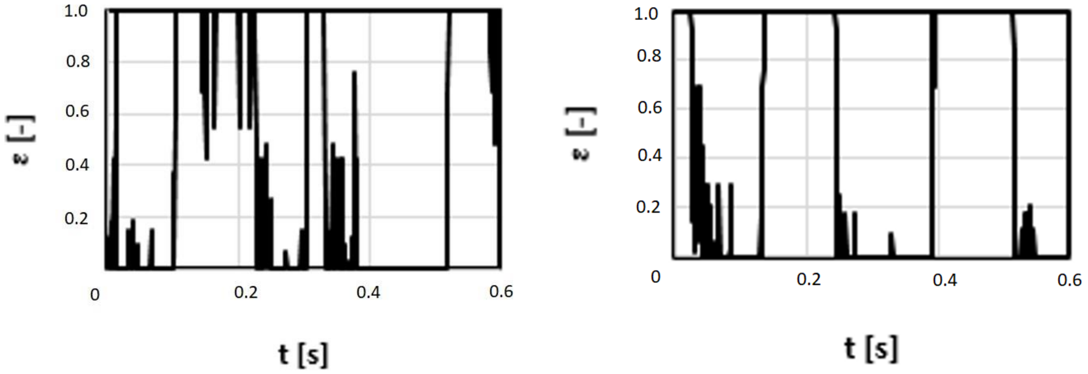


(d) Glycerin 70% and pure water 30%

Fig. 2. Image processing result of the bubble flow pattern on J_L = 2.297 m/s, and J_G = 0.423 m/s



(a) Glycerin 40% and pure water 60% (b) Glycerin 50% and pure water 50%



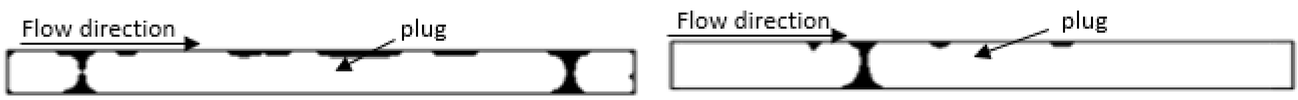
(c) Glycerin 60% and pure water 40% (d) Glycerin 70% and pure water 30%

Fig. 3. Void Fraction time series on J_L = 2.297 m/s, and J_G = 0.423 m/s

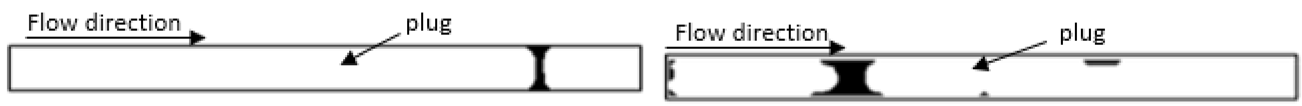
From Figures 2 and 3 it can be explained that the void fraction in the bubble flow pattern has a relatively small and unstable number due to the frequency of non-steady bubbles appearing. Besides that, it can also be explained that by increasing the concentration of glycerine, it will increase the size of the bubble almost like a plug flow pattern and reduce the frequency of appearance.

3.2. The Void Fraction of the Plug Flow Pattern

The flow pattern of the plug has a shape like an elongated bubbly whose flow pattern is like a bullet that covers the entire wall of the pipe with different length patterns. This flow pattern usually occurs when the superficial velocity of gases and liquids is low. The results of image processing and void fraction time series of the plug flow pattern can be seen in Figures 4 and 5.

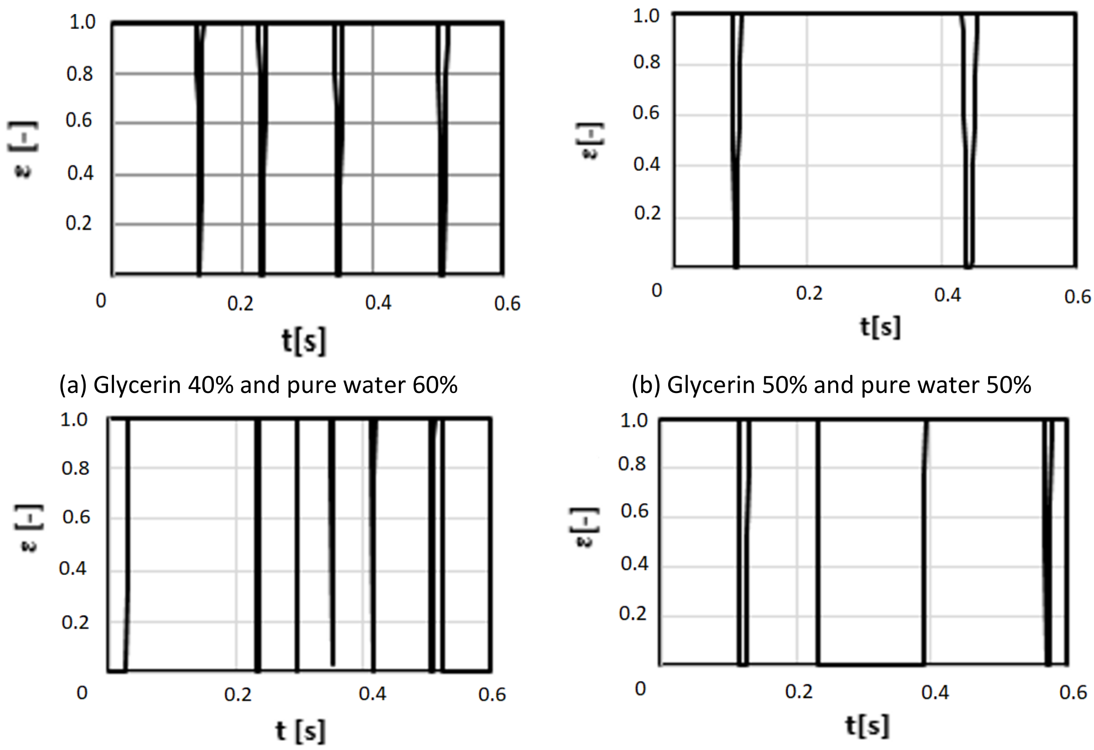


(a) Glycerin 40% and pure water 60% (b) Glycerin 50% and pure water 50%



(c) Glycerin 60% and pure water 40% (d) Glycerin 70% and pure water 30%

Fig. 4. Image processing result of the plug flow pattern on J_G = 0.066 m/s, and J_L = 0.7 m/s



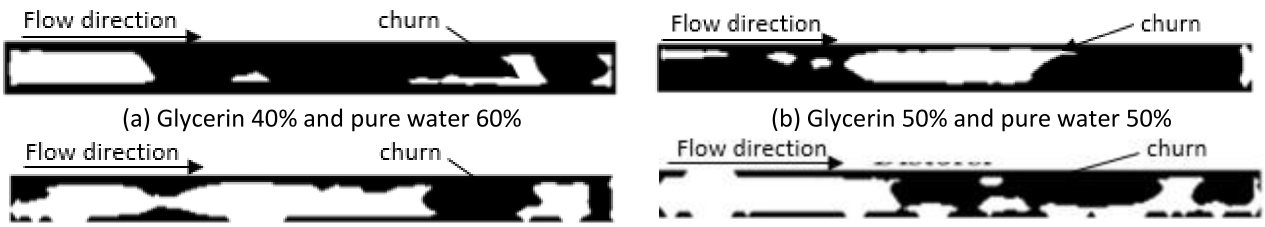
(a) Glycerin 40% and pure water 60%
(b) Glycerin 50% and pure water 50%
(c) Glycerin 60% and pure water 40%
(d) Glycerin 70% and pure water 30%

Fig. 5. Void Fraction time series on J_G = 0.066 m/s, and J_L = 0.7 m/s

From both Figures 4 and 5, it can be interpreted that the void fraction in the plug flow tends to have a value close to 1, this means that most of the fluid is in the form of gas. This phenomenon can be seen in the results of image processing that shows binary images in black and white, where black represents liquid and white represents gas. It appears in Figure 4 that gas dominates the mini pipeline, and this is reinforced by the results of the void fraction time series in Figure 5.

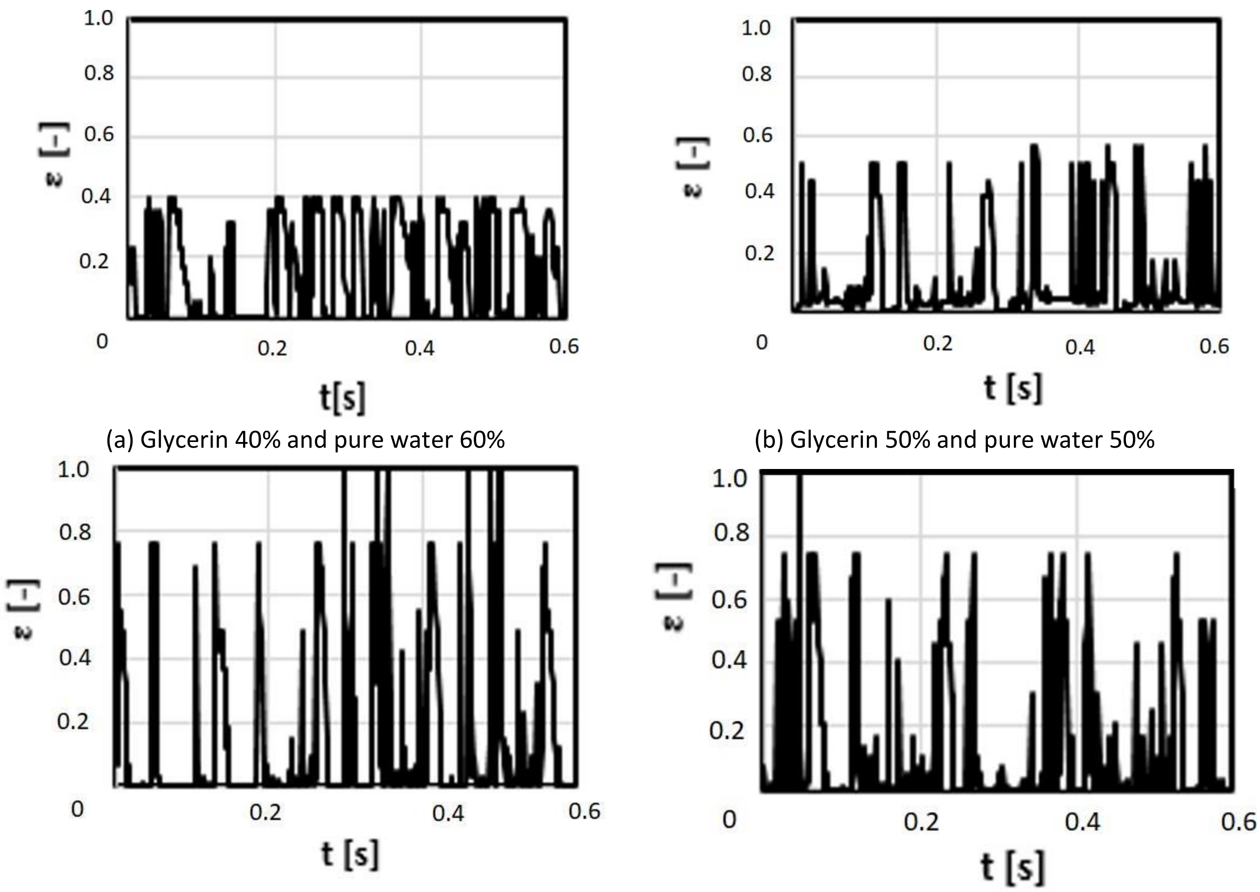
3.3. The Void Fraction of the Churn Flow Pattern

Results of image processing and void fraction time series of the churn flow pattern can be seen in Figures 6 and 7.



(a) Glycerin 40% and pure water 60%
(b) Glycerin 50% and pure water 50%
(c) Glycerin 60% and pure water 40%
(d) Glycerin 70% and pure water 30%

Fig. 6. Image processing result of the churn flow pattern on J_G = 66.3 m/s, and J_L = 4.935 m/s



(a) Glycerin 40% and pure water 60%
(b) Glycerin 50% and pure water 50%
(c) Glycerin 60% and pure water 40%
(d) Glycerin 70% and pure water 30%

Fig. 7. Void Fraction time series on J_G = 66.3 m/s, and J_L = 4.935 m/s

From Figures 6 and 7, it can be explained that The Churn flow patterns are formed when the superficial velocity of gases and superficial fluids are both high and have a very large difference, wherein this condition occurs the flow of gas and liquid flow that flows randomly and experiences instability so that there is a distortion. Previously, the authors also examined various flow patterns experimentally using an inner glass pipe diameter of 1.6 mm and a length of 130 mm, a slope of 5 degrees to the horizontal position. The visualization method uses a high speed camera, the working fluid used is air and water mixed with Glycerin with concentrations of 40%, 50%, 60%, and 70% for each mixture, and varies the speed of gas and water in the range of JG = 0.207 m / s-66.3 ms; JL = 0.149 m / s - 4.238 m / s. This research produces a mini bubble flow pattern, long plug, slug, slug-annular, and churn. The research also found new findings that the slug flow pattern influences the pressure difference which increases significantly [16].

For mini channels based on different flow models and drift flux models, an alternative connection of the two-phase friction pressure reduction and the void fraction is examined. The dominant parameters for the correlation of two-phase friction multipliers and void fractions are selected via the application of an artificial neural network. It was noticed that the non-dimensional Laplace constant was the principal parameter for correlating the parameters of Chisholm as well as the distribution parameters in the mini-channel [17]. Experimental investigations have been carried out on boiling flow in mini channels based on analysis of local void fractions. This research has been carried out at constant heat flux supplied to the mini channel with the mass velocity of the inlet liquid ranging between 30 and 248 kg s-1 m-2. The influence of hyper gravity (1.8g gravity level) and microgravity (gravity level ± 0.05g) on the determination of the experimental void fraction used image processing (image processing). Pressure drop for two-phase flow in microgravity was found to be significantly higher than for single-phase flow under the same conditions [18]. The previous research describes the process by which mini channels test two-phase flow structures. High-speed visualization techniques obtained the images and the stereological analysis used was based on linear methods. It has been found that the combination of stereological parameters can be used to monitor operating conditions during changes in flow structure. Therefore, knowledge of the character of changes occurring in flow structures may be used for constant process adjustments for various two-gas or gas-solid gas-liquid systems [19]. Experimental data were collected and analyzed for the void fraction and the reduction of the two-phase friction pressure from different sources. Experimental data show that the reduction of friction pressure is very sensitive to these two parameters as superficial gas velocity and void fraction increase to higher values. The correct characterization of the void fraction is important when the two-phase pressure drop is prone to variations in the void fraction [20]. Xing *et al.,* [21] stated that the correlation effect of the void fraction on the separation of pressure gradients in rectangular vertical channels from the two-phase flow of water. The velocities of superficial gas and liquid range between 0.58 and 32 m/s and between 0.16 and 3.8 m/s. The findings showed that while the association of the void fraction had a great impact on the gradient of the gravity pressure of slug flow, churn flow and annular flow, it had almost no effect on the flow of bubbles.

4. Conclusions

The novelty value obtained from the discussion of this paper is that the value of the void fraction for bubbly flow shows conditions that are not so stable and with a low value and is often followed by the appearance of a plug. Meanwhile, the value of the void fraction for plug flow tends to be close to 1 in a certain period; this is caused by the air cavity almost filling part of the pipe as shown from the results of image processing and void time-series graphs. However, at some time the void fraction showed a value of 0 caused only by passing through water, there was no emergence of air. The void fraction in the churn flow pattern has a value that is fluctuating with moderate value. This result shows that the composition of the liquid and gas tends to be balanced. This conclusion has been compared with previous studies and has a good fit of results.

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