Application of Buoyancy Weighing-bar Method to Measure the Droplet Size Distribution of Kerosene in Water

R. Tambun[1*], P. Sibagariang[1], B. Alphantaria[1], A. A. Silaen[1], A. M. Rambe[1] and F. Batubara[1]
[1]Chemical Engineering Department, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia

Keywords: Buoyancy Weighing Bar, Droplet Size Distribution, Kerosene, Water, Separation Time.

Abstract: Buoyancy Weighing-Bar Method has been proven to be capable of measuring the particle size distribution of the settling particles and floating particles. Besides a simple operations and low-cost equipment, the Buoyancy Weighing-Bar Method could produce high accuracy results in measurement of particle size distribution. In this study, the Buoyancy Weighing-Bar Method is developed to measure droplet size distribution in the liquid-liquid systems. The samples used in this study are the mixture of kerosene of 1% in water of 99%, the mixture of kerosene of 2% in water of 98%, the mixture of kerosene of 3% in water of 97%, the mixture of kerosene of 4% in water of 96%and the mixture of kerosene of 5% in water of 95%. This study also decides the separation time of kerosene – water mixtures. The weighing-bar's diameter is 15 mm, and the vessel's diameter is 65 mm. The result by the Buoyancy Weighing-Bar Method are checked by using the gas chromatography to verify the purity of sample, and the droplet size distribution of kerosene in water is calculated by Stokes formula and compared to that measured by Coulter LS100. Based on the results obtained, the Buoyancy Weighing-Bar Method can decide the separation time of kerosene and water mixtures, and the droplet size distribution that calculated by Stoke formula is proportional to the Coulter L100.

1 INTRODUCTION

Application of buoyancy weighing-bar method had been done for measurement particle size distribution either floating particles or settling particles (Obata, et al., 2009; Motoi, et al., 2010). In this Buoyancy Weighing-Bar Method, the density change of solution due to droplet migration is determined by weighing buoyancy against a weighing bar hung in the suspension. Theoretically, the Buoyancy Weighing-Bar Method also could be applicable to measure droplet size distribution either in Stoke region or Allen region (Obata, *et al*., 2009; Motoi, *et al*., 2010; Tambun, *et al*., 2011; Tambun, et al., 2012a; Tambun, *et al*., 2012b; Tambun, *et a*l., 2018). In this study, the Buoyancy Weighing-Bar Method will determine the measure droplet size distribution for liquid-liquid systems with the different density. The measure droplet size distribution had been investigated by using light scattering method (Mao, et al., 1998), microscope (Boxall,et al., 2010), nuclear magnetic resonance (Fridjonsson, et al., 2014), and laser diffraction with a Coulter LS-230 (Jurado, et al., 2007). In a short time, all methods can give highly precise results but require extremely expensive equipment. Hence, the Buoyancy Weighing-Bar Method will be a low cost method in droplet size distribution determination.

The principle of Buoyancy Weighing-Bar Method that measurement the density change in a suspension due to liquid migration is determined by weighing buoyancy against a weighing bar hung in the suspension. The tools of Buoyancy Weighing-Bar Method consists of an analytical balance with a hook for under-floor weighing and a weighing bar, which is used to determine the density change of suspension (Obata, *et al*., 2009; Motoi, *et al*., 2010). Besides, the Buoyancy Weighing-Bar Method has been proven to be able to estimate the fine particles by using the Rosin-Rammler equation (Tambun, *et al*., 2016).

In this study, Buoyancy Weighing-Bar Method will be applied in liquid-liquid systems of different densities, where in this experiment the sample used is kerosene and water (O/W) mixture. The Buoyancy Weighing-Bar Method used to investigate the measure droplet size distribution of kerosene in water (O/W) and the separation time of kerosene – water mixture. The principle of this study is similar to distributions system of the settling particles and floating particles, where the initial buoyant mass of

Tambun, R., Sibagariang, P., Alphantaria, B., Sialaen, A., Rambe, A. and Batubara, F.
Application of Buoyancy Weighing-bar Method to Measure the Droplet Size Distribution of Kerosene in Water.
DOI: 10.5220/0010087402910296
In *Proceedings of the International Conference of Science, Technology, Engineering, Environmental and Ramification Researches (ICOSTEERR 2018) - Research in Industry 4.0*, pages 291-296
ISBN: 978-989-758-449-7

the weighing bar according to the mixtures of liquid between the bottom and top of the weighing bar in a suspension (Tambun, *et al.*, 2018a; Tambun, *et al.*, 2018b).

2 METHODS

The illustration of the experimental apparatus is shown at Figure 1. The weighing bar is made of aluminum rod with the diameter of 15 mm, the length of 210 mm, and the density of 2700 kg/m^3. The sample materials are water (ρ= 0.99708 g/cm^3) and kerosene (ρ= 0.810 g/cm^3). The material samples is put into glass cylinder with volume 1000 ml (diameter: 65 mm) with the mixture of kerosene of 1% in water of 99%, the mixture of kerosene of 2% in water of 98%, the mixture of kerosene of 3% in water of 97%, the mixture of kerosene of 4% in water of 96%and the mixture of kerosene of 5% in water of 95%. All experiments are operated at room temperature (approximately 298 K). The measuring time is 1 h and the measure droplet size distribution is calculated by Stokes formula and the result is compared to that measured by Coulter LS100.

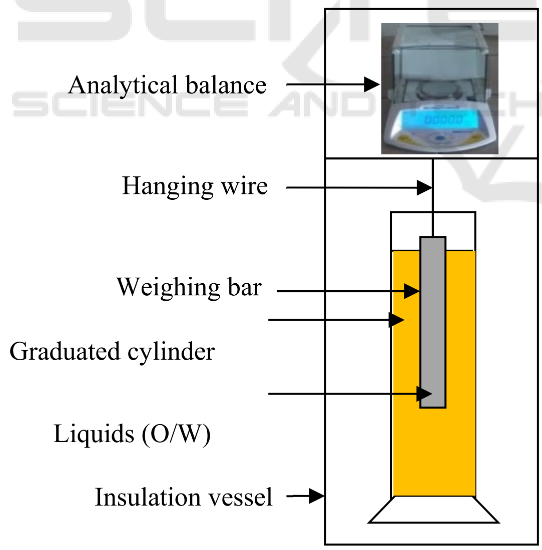

Figure 1: Schematic diagram of experiment to measure droplet size distribution of O/W by using Buoyancy Weighing-Bar Method.

The Stokes formula can be seen in equation 1 below:

$$x = \sqrt{\frac{18\,\mu_L v(x)}{g(\rho_P - \rho_L)}} \tag{1}$$

where g is the gravitational acceleration and μ_L is the viscosity of the solution. The stokes equation applies only to laminar flow types with Reynold Numbers, Rep < 0,2 (Allen T, 1990). After the separations time of samples are obtained from this research, the purity of samples are then analyzed by using gas chromatography.

3 RESULTS AND DISCUSSION

3.1 Effect of Time on Apparent Mass of the Weighing-Bar When Comparison of O/W Water is 1 % : 99%

Figure 2 shows the correlation between apparent mass of the weighing-bar and time when comparison 1% : 99% of O/W is used. In the figure 2, the apparent mass of the weighing-bar decreased until all the kerosene floated above the weighing-bar, and then the apparent mass of the weighing-bar become constant.

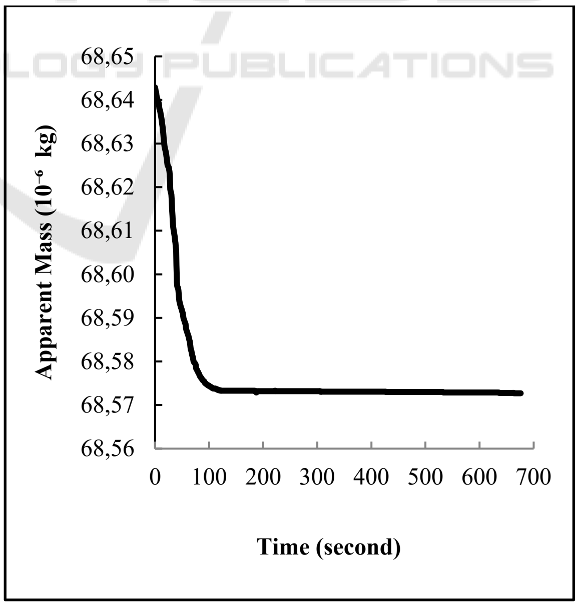

Figure 2: The correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 1 % : 99%.

The mass of weighing bar is decreased rapidly from beginning (at 0 second) until at 100 seconds and then the mass of weighing-bar tends to be constant. In this experiment, the weighing bar detect that all of the larger droplets have floated after 100 seconds. This is because the largest droplets will float first, then the medium droplets and the smaller droplet, so the weighing-bar mass decrease gradually and then constant after all the droplets is floating above the weighing bar. The results obtained by the Buoyancy Weighing-Bar Method are compared with those measured by gas chromatography. At 100 seconds of experiment, the purity of water is 94.9496% and at 680 seconds the purity of water is 97.1326%. At this experiment, at 680 seconds the mass of weighing-bar had not changed again and the water and kerosene are already separate but not complete. Hence, the separation time of O/W had been detected by using the Buoyancy Weighing-Bar Method.

3.2 Effect of Time on Apparent Mass of the Weighing-Bar When Comparison of O/W is 2 % : 98%

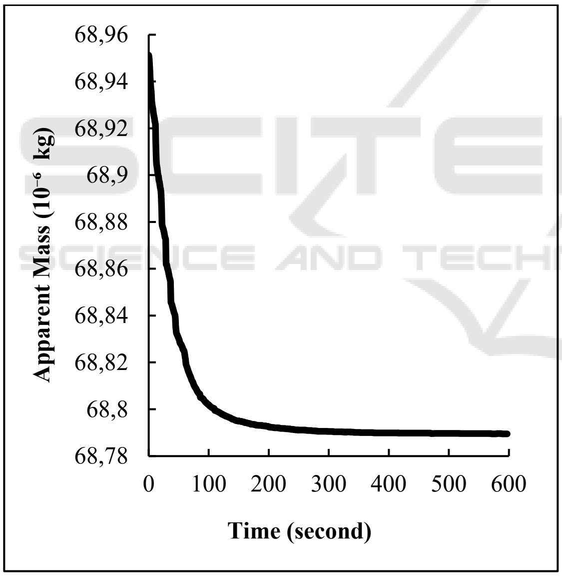

Figure 3: The correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 2 % : 98%.

Figure 3 shows the correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 2 % : 98%. Similar with the figure 3, the mass of weighing bar is decreased rapidly from beginning until at 146 seconds and then the mass of weighing-bar tends to be constant. In this experiment, the weighing bar detect that all of the larger droplets have floated after 146 seconds. This is because the largest droplets will float first, then the medium droplets and the smaller droplet, so the weighing-bar mass decrease gradually and then constant after all the droplets is floating above the weighing bar. At this experiment, at 597 seconds the mass of weighing-bar has been constant and the water and kerosene are already separate but not complete.

3.3 Effect of Time on Apparent Mass of the Weighing-Bar When Comparison of O/W is 3 % : 97%

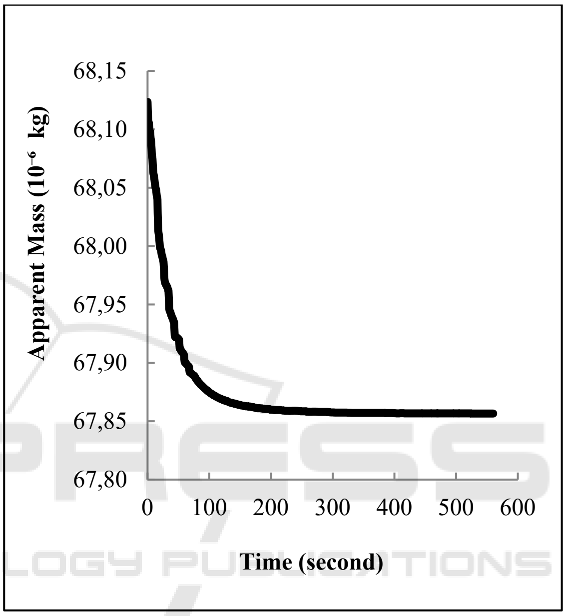

Figure 4: The correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 3 % : 97%.

Figure 4 shows the correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 3 % : 97%. At this comparison, the mass of weighing bar is decreased rapidly from beginning until at 157 seconds and then the mass of weighing-bar tends to be constant. In this experiment, the weighing bar detect that all of the larger droplets have floated after 157 seconds. This is because the largest droplets will float first, then the medium droplets and the smaller droplet, so the weighing-bar mass decrease gradually and then constant after all the droplets is floating above the weighing bar. At this experiment, at 560 seconds the mass of weighing-bar has been constant and the water and kerosene are already separate but not complete.

3.4 Effect of Time on Apparent Mass of the Weighing-Bar When Comparison of O/W is 4 % : 96%

Figure 5 shows the correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 4 % : 96%. At this comparison, the mass of weighing bar is decreased rapidly from beginning until at 164 seconds and then the mass of weighing-bar tends to be constant. In this experiment, the weighing bar detect that all of the larger droplets have floated after 146 seconds. This is because the largest droplets will float first, then the medium droplets and the smaller droplet, so the weighing-bar mass decrease gradually and then constant after all the droplets is floating above the weighing bar. At this experiment, at 870 seconds the mass of weighing-bar has been constant and the water and kerosene are already separate but not complete.

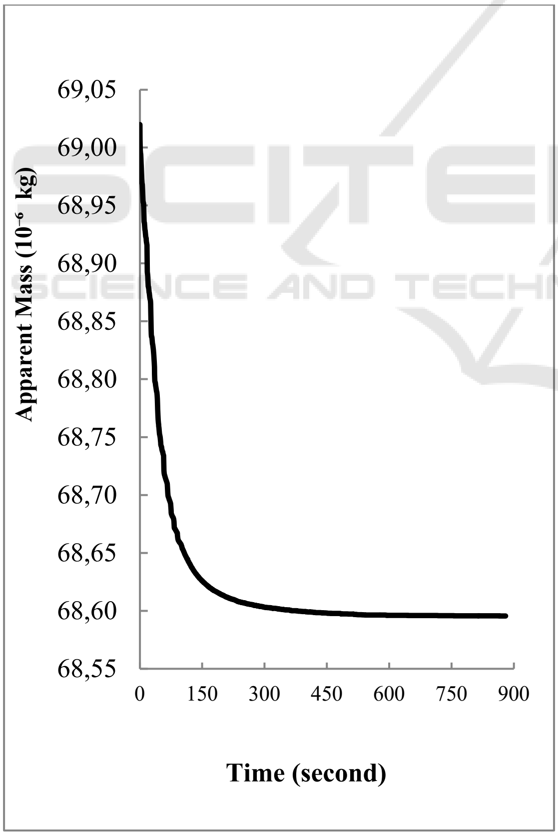

Figure 5: The correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 4 % : 96%.

3.5 Effect of Time on Apparent Mass of the Weighing-Bar When Comparison of O/W is 5 % : 95%

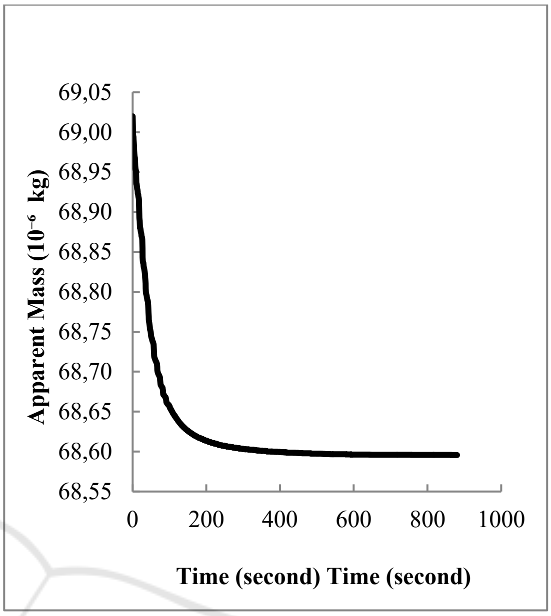

Figure 6: The correlation between apparent mass of the weighing-bar with the time separation when comparison of O/W is 5 % : 95%.

Figure 6 shows the influence of time separation on apparent mass of the weighing-bar when comparison of O/W is 5 % : 95%. At the figure 6, we could see that mass of weighing bar is decreased rapidly from 0 second until at 245 seconds and then the mass of weighing-bar tends to be constant. In this experiment, the weighing bar detect that all of the larger droplets have floated after 245 seconds. This is because the largest droplets will float first, then the medium droplets and the smaller droplet, so the weighing-bar mass decrease gradually and then constant after all the droplets is floating above the weighing bar. At this experiment, at 880 seconds, the mass of weighing-bar has not changed again and the water and kerosene are already separate but not complete.

3.6 Determination Measure Droplet Size Distribution by using Buoyancy Weighing-Bar Method

Figure 7 shows the measure droplet size distribution measured by using Buoyancy Weighing-Bar Method when the concentration 99% water : 1% kerosene. The measure droplet size distribution is calculated by

Stokes formula, and the results obtained are compared with Coulter LS 100. The result obtained by measuring the BWM is comparable to that measured by Coulter LS100. In figure 5 can be seen that the results obtained by Buoyancy Weighing-Bar Method and Coulter are close. According to these results, Buoyancy Weighing-Bar Method could identify the measure droplet size distribution of O/W when comparison of O/W is 1% : 99%.

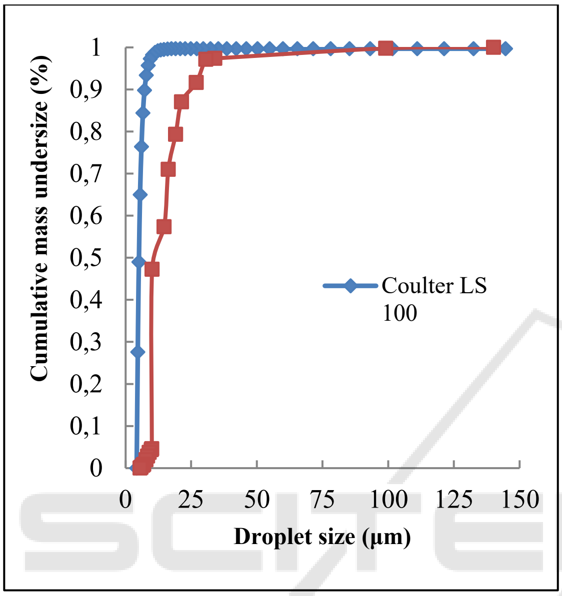

Figure 7: The measurement comparison of droplet size distribution of O/W between BWM and Coulter LS 100 when comparison of O/W is 1 % : 99%.

4 CONCLUSION

The Buoyancy Weighing-Bar Method has been applied to experimentally investigate the droplet size distribution of O/W and to detect the separation time of O/W mixtures. The conclusions of this study are:

1. The Buoyancy Weighing-Bar Method could identify the droplet size distribution of O/W when comparison of O/W is 1% : 99% by using Stoke equation, and the precision of result is near to that measured by a Coulter LS100.
2. The Buoyancy Weighing-Bar Method could decide the separation time of O/W mixtures when comparison of O/W are 1% : 99%, 2% : 98%, 3% : 97%, 4% : 96% and 5% : 95%.
3. The separation time for each comparison of O/W is different.

ACKNOWLEDGEMENT

This research is supported by Directorate of Research and Community Service (DRPM) of the Ministry of Research, Technology, and Higher Education of Republic Indonesia for Research Grant, under Fundamental Research scheme, 2018.

REFERENCES

Allen, T, Particle Size Measurement, Fourth Edition, London : Chapman and Hall, 1990.

Boxall, J. A., Koh, C. A., Sloan, E. D., Sum, A. K., and Wu, D. T. (2010). Measurement and calibration of droplet size distribution in water in oil emulsion by particle video microscope and focused beam reflectance method. *Ind. Eng. Chem. Res*. 49(3) pp 1412-1418.

Fridjonsson, E. O., Graham, B. F., Akhfash, M., May, E. F., and Johns, M. L. (2014). Optimized droplet sizing of water in crude oil emulsion using nuclear magnetic resonance. *Energy & Fuels*. 28(3) pp 1756-1764.

Jurado, E., Bravo, V., Camacho, F., Vicaria, J. M., and Arteaga, A. F. (2007). Estimation of the distribution of droplet size, interfacial area and volume in emulsions. *Colloids and Surfaces A: Physicochem. Eng. Aspects*. 295 pp 91-98.

Mao, Y., Yong, L., Tao, H., Shimin, W., and Yiqian, X. (1998). In situ measurement of droplet size distribution by light scattering method. *Wuhan University Journal of Natural Sciences*. 3(4) pp 418-422.

Motoi, T., Ohira, Y., and Obata, E. (2010). Measurement of the floating particle size distribution by buoyancy weighing–bar method. *Powder Technology*. 201 pp 283–288.

Obata, E., Ohira, Y., and Ohta, M. (2009). New measurement of particle size distribution by buoyancy weighing–bar method. *Powder Technology*. 196 pp 163–168.

Tambun, R., Furukawa, K., Hirayama, M., Shimadzu, M., Yamanaka, S., and Ohira, Y. (2016). Measurement and estimation of the particle size distribution by the buoyancy weighing-bar method and the Rosin-Rammler equation. *Journal of Chemical Engineering of Japan*. 49 (2) pp 229-233.

Tambun, R., Motoi, T., Shimadzu, M., Ohira, Y., and Obata, E. (2011). Size distribution measurement of floating particles in the allen region by a buoyancy weighing–bar method. *Advanced Powder Technology*. 22 pp 548–552.

Tambun, R., Nakano, K., Shimadzu, M., Ohira, Y., and Obata, E. (2012). Sizes influences of weighing bar and vessel in the buoyancy weighing-bar method on floating particle size distribution measurements. *Advanced Powder Technology*. 23 pp 855-860.

Tambun, R., Shimadzu, M., Ohira, Y., and Obata, E. (2012). Definition of the new mean particle size based on the settling velocity in liquid. *Journal of Chemical Engineering of Japan*. 45 (4) pp 279-284.

Tambun, R., Sibagariang, P., Alphantaria, B., and Rambe, A. M. (2018). Droplet size distribution measurement of water in kerosene by the buoyancy weighing-bar method. *MATEC Web of Conferences*. 154.

Tambun, R., Sibagariang, Y., J Manurung, J.2018. Influence of the Weighing Bar Size to Determine Optimal Time of Biodiesel-Glycerol Separation by Using the Buoyancy Weighing-Bar Method. *TALENTA-CEST 2017. IOP Conf. Series: Materials Science and Engineering.* 309**.**

Tambun, R., Sihombing, R. O., Simanjuntak, A., F Hanum, F. 2018. Influence of the weighing bar position in vessel on measurement of cement's particle size distribution by using the buoyancy weighing-bar method. *TALENTA-CEST 2017 IOP Conf. Series: Materials Science and Engineering*. 309.