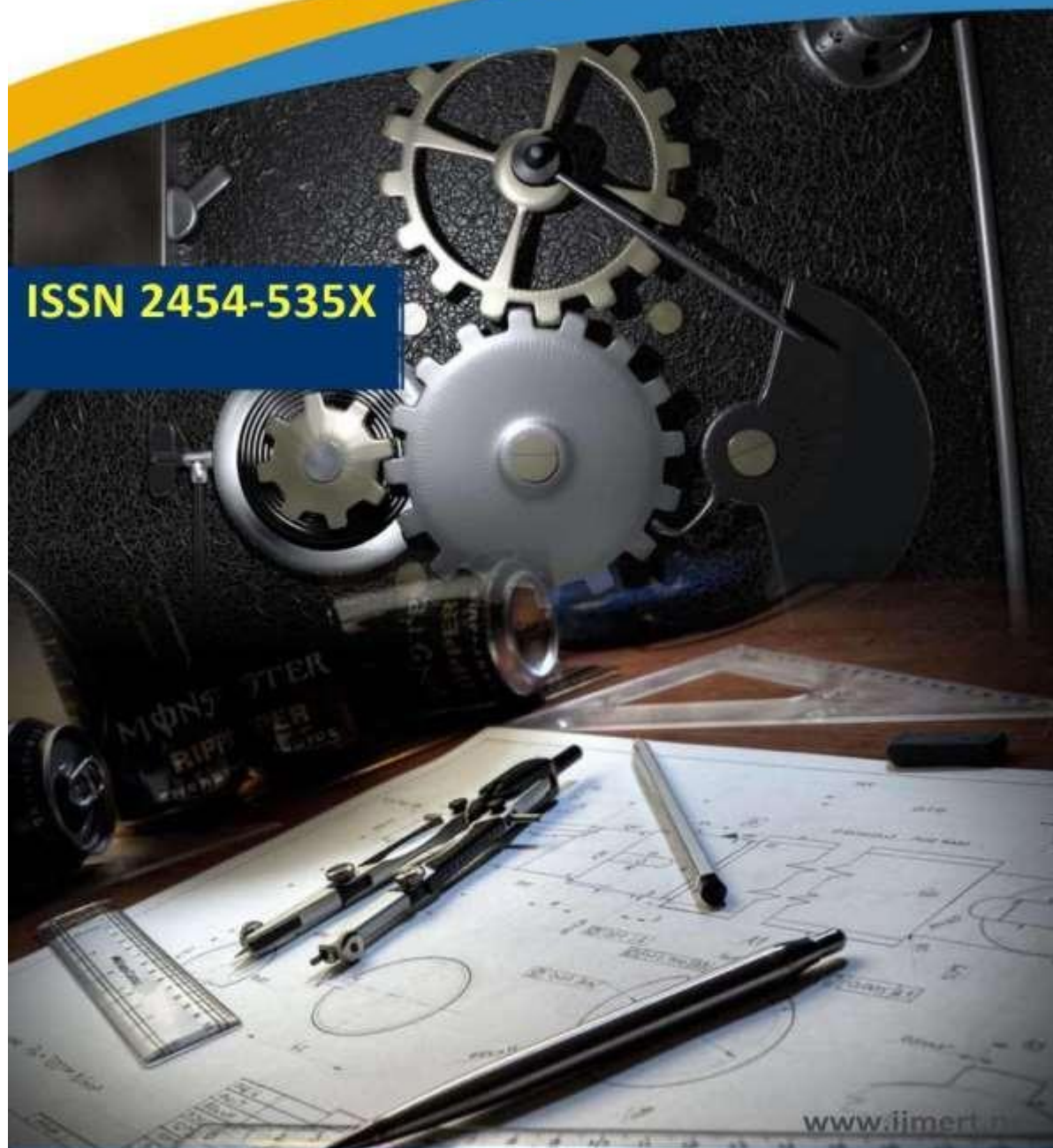




International Journal of
Mechanical Engineering Research and Technology

ISSN 2454-535X



www.ijmert.net

Email ID: info.ijmert@gmail.com or editor@ijmert.net

Seaweed Fiber Solution's Ability to Reduce Drag in Round and Spiral Pipe

Rahul¹, Girish^{2*} & Vadluri Rakesh³

Department of Mechanical Engineering, Universitas Indonesia, Kampus UI Depok, Jakarta 16424, Indonesia

*E-mail: girish @eng.ui.ac.id

ABSTRACT:

Researchers are interested in energy efficiency. One of the intriguing studies focuses on adding a drag-reducing chemical to the fluids to reduce drag in pipes. A spiral pipe was used to conduct experimental study on the impacts of bio-fibers that reduce drag. This study looked into how much drag may be reduced in a spiral pipe by adding a seaweed fiber solution to the water. As a comparison, a seaweed fiber solution with concentrations of 20, 50, and 100 ppm was made and circulated by pump through spiral pipes with a P/Do of 7.6 and circular pipes with an ID of 38 mm. From low to high Reynolds numbers up to 35,000, experiments were run. Utilizing the experimental data that was collected when the drag-reducing chemical was present, the percentage of drag reduction was estimated. The findings revealed that

KEYWORDS: drag reduction; reducing agent; seaweed Fiber

INTRODUCTION

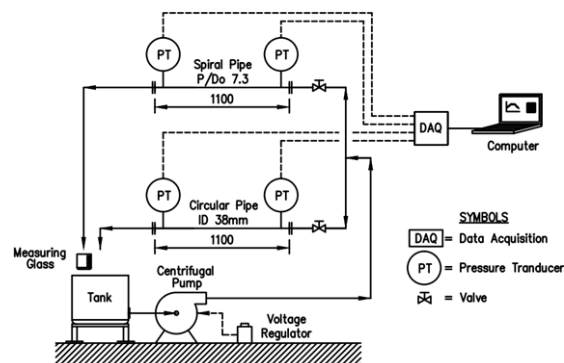
Pipelines are a reliable way to move fluids, especially when distributing them to far-off locations. The issue is that fluid flow might be impeded by friction on the pipe walls. The issue can be resolved by increasing the fluid's pressure with a large capacity pump. However, because of the high energy usage, this is not advised.

The reduction of fluid drag was recommended

using both active and passive methods. Variations in pipe geometry can be made passively, such as by employing coated pipe, injecting microbubbles to lessen skin friction for marine applications [1,], or using grooves on spiral pipes [2, 3]. While the active technique involves very sparingly introducing friction-reducing chemicals into the fluid

METHODOLOGY

The experimental set up used in this research is shown in Figure 1. The experimental set up consisted of main tank, centrifugal pump (PS-128 BIT: Shimizu), voltage regulator, spiral pipe P/Do 7.3, round pipe ID 38 mm, ball



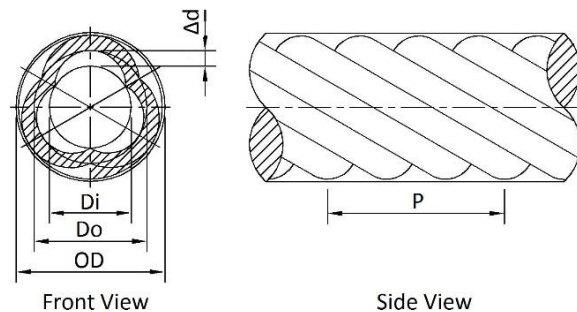
valve, pressure transducer (PX209-100GI: Omega), DAQ, computer, and measuring glass. Both test pipes are about 1200 mm length with acrylic material.

Figure 1. Experimental set-up

Table 1 is the data of spiral pipe used in this research where P is pitch, Do is outer diameter, Di is inner diameter, Δd is pipe wall thickness, and P/Di is ratio of pitch to inner diameter.

Table 1. Dimension of experimental pipes

Pipe	Di (mm)	Do (mm)	Δd	Ds (mm)	P (pitch)	P/Do
Round Pipe	38	40	2	-	-	-
Spiral Pipe	19	26	3.5	23.9	190	7.3

**Figure 2.** Schematic diagram of spiral pipe

The seaweed fiber solution prepared in concentration 20, 50, and 100 ppm. The temperature of the solution was constantly maintained at 27°C. The seaweed fiber solution mixed in the main tank and then circulated into experimental pipe by using centrifugal pump at various flow rates. The spiral and round pipe were being tested alternately. The experimental was performed in a closed-loop system, where the output flow from the experimental pipe returns back to the main tank.

Entrance length was about 2500 mm to ensure the fully development flow. The pressure transducers were placed

close to the inlet and the outlet of test pipe to

RHEOLOGICAL MODEL

Experimental data is plotted in the moody chart. The laminar region refers to Hagen-Poiseuille line and the turbulent region refers to Blasius line. Drag reduction is defined by decreasing of the coefficient of friction on the flow. The friction factor caused by shear stress that occurs between each layer of the velocity.

The relationship between shear stress (τ) in fluid is proportional to the velocity gradient or shear rate ($\dot{\gamma}$) and can be described by Newtonian model (Equation 1) as stated bellow:

$$\tau$$

$$= \mu$$

$$\frac{du}{dy} = \left(\frac{1}{\mu} \right)$$

Where the constant of proportionality μ is known as the viscosity. The Newtonian viscosity only depends on temperature and pressure. It is not affected by the shear rate. Viscosity is described as the ratio between the shear stress and the shear rate.

Other than that, some fluids show a non-linear relationship between shear stress and shear rate. It shall follow Power Law model or non-Newtonian fluid. Non-Newtonian fluid is divided into Bingham, Pseudoplastics, and Dilatant. It does not depend on temperature and pressure, but affected by shear rate.

The relationship between shear stress and shear rate can be described by measuring the pressure drop and the flow rate by using Equation 2 stated below:

$$\frac{D\Delta P}{4L} = \mu \frac{8u}{D} \quad (2)$$

Where D is inner diameter, ΔP is pressure drop, L is length of the experimental pipe, u is average velocity.

Whereas, coefficient of friction (f) can be expressed by Darcy equation (Equation 3) as stated below:

$$ff = \frac{2Dg\Delta h}{Lu^2} \quad (3)$$

Where f is friction factor, g is gravity, and Δh is different height of head between two measuring point.

Drag reduction can be obtained by using Equation 4 as stated below:

$$DR = \frac{f_{water} - f_{fiber}}{f_{water}} \times 100\% \quad (4)$$

RESULT AND ANALYSIS

The type of seaweed fiber solution can be conducted by comparing the results of water testing on round pipe. Variations in seaweed fiber solution are divided into three concentrations including 20, 50, and 100 ppm. The test results are displayed on the shear stress and shear rate diagram.

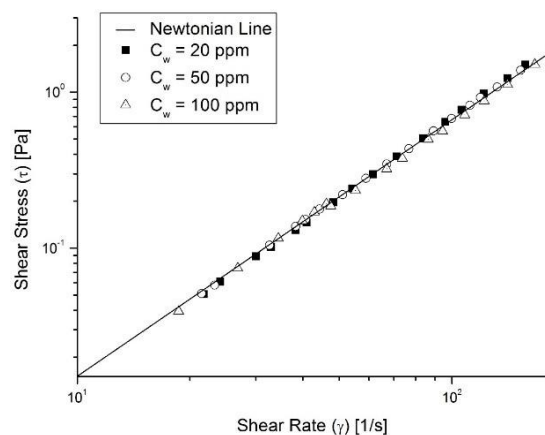
The relationship of shear stress and shear rate on water and seaweed fiber solution with

concentrations of 20, 50,

and 100 ppm flowed on round pipe ID 38 mm can be seen on figure 3.

Figure 3 shown the flow curve of the test results of water and seaweed fiber solution. It can be seen that the relationship between shear stress and shear rate shows a linear relationship for the fluid solution of seaweed fibers, either for concentrations of 20, 50, and 100 ppm.

Figure 3. The relationship of shear rate and shear stress of water and seaweed fiber solution on round pipe.



In Figure 3 it can be seen that the graph is formed to resemble a straight line and close to the water data. The straight line is a line of relationship between shear stress and shear rate for Newtonian fluids, where the water data shows conformity to the straight line. Thus, it can be seen that the seaweed fiber solution is Newtonian fluid type.

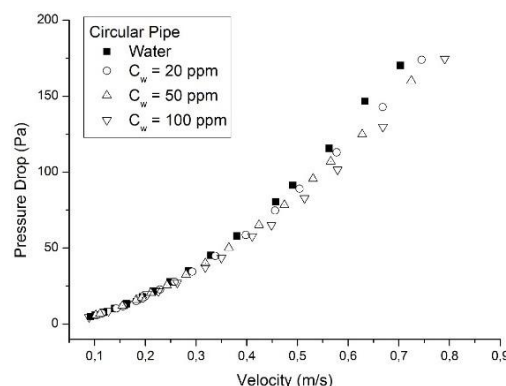


Figure 4. Pressure drop of seaweed fiber solution compared to water on round pipe

The pressure drop is influenced by several factors such as the length of the channel that is flowed by the fluid.

Besides that, another factor is the velocity. The

pressure drop in fluid is as small as possible to reduce losses in fluid. The pressure on the inlet of

the pipe will be higher than the pressure on the outlet of the pipe. The value of pressure drop is an important parameter in fluid flow because it relates to the energy required in the fluid distribution process.

The relationship between the velocity and the pressure drop of seaweed fiber solution with concentration 20, 50, and 100 ppm and water on round pipes can be seen in figure 4. It shows that at low velocity ranging from about 0.1 m/s to 0.3 m/s, the pressure drop of seaweed fiber solution is still relatively similar as water. However, at velocity above 0.3 m/s to 0.8 m/s, the pressure drop of seaweed fiber solution is lower

than water on the round pipe.

The higher the concentration of seaweed fiber solution, the lower the pressure drop when compared to water on the round pipe. This can occur because seaweed fiber solution has a lower viscosity than water, especially at higher concentration around 100 ppm. Thus, the shear stress that occurs is also lower than water at the same velocity. Another factor that influences other than concentration is velocity. The higher the velocity, the lower the pressure drop of seaweed fiber solution when compared to water on the round pipe.

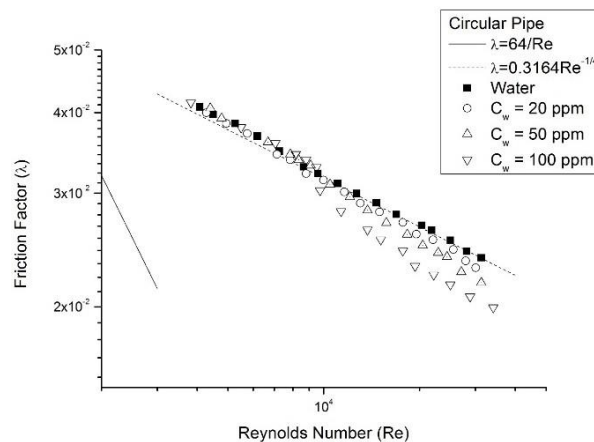
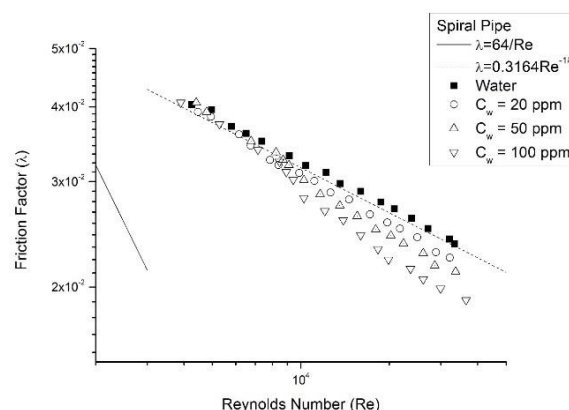


Figure 5. Friction coefficient of seaweed fiber solutions compared to water on round pipe

Figure 5 shows the relationship between Reynolds number and friction factor on the round pipe ID 38 mm. The test fluids are seaweed fiber solution with concentration 20, 50, and 100 ppm and water as comparison.

In Figure 5, it can be seen that the straight line shows the Hagen Poiseuille equation for laminar flow. Whereas the dashed line is the Blasius equation for turbulent flow. The test data in this study did not get laminar data because the flow velocity was high enough to immediately get turbulent flow.

From the experiment data, it can be seen that the water data is in the turbulent Blasius equation. The relationship of Reynolds number to friction coefficient on round pipe shows that friction coefficient of seaweed fiber solution is



smaller than water starting from Reynolds number around 10,000 to higher Reynolds number which is about 33,000 in this study. The higher the Reynolds number, the lower the friction coefficient. The low friction coefficient results in lower energy use, which can save energy.

Figure 6. Friction coefficient of seaweed fiber solutions compared to water on spiral pipe

The relationship between the Reynolds number compared to the friction factor in the Spiral Pipe P/Do 7.3 can be seen in Figure 6. The fluid test is the same which is seaweed fiber solution and water. The straight line shows the Hagen Poiseuille equation for laminar flow. Whereas the dashed line is the Blasius equation for turbulent flow. The test data in this study did not get laminar data because the flow velocity was high enough to immediately get turbulent flow.

At Reynolds numbers ranging from 4000 to 9,000, data from the test results of seaweed fiber solutions in the spiral pipe follow the water data in the turbulent Blasius equation. However, at Reynolds number above 9,000, the friction coefficient of seaweed fiber is smaller than water and is below the turbulent Blasius line. The reduction in the friction coefficient of seaweed fiber solution is decreasing as the Reynolds number increases to 35,000 in this study. The lowest friction coefficient is at high Reynolds number around 35,000. The low friction coefficient results in lower energy use, which can save energy.

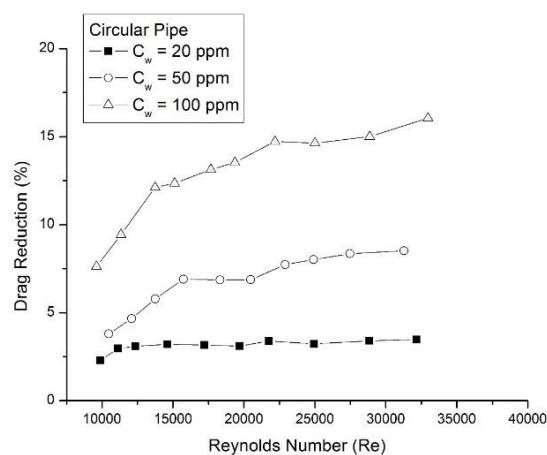


Figure 7. Drag reduction ratio of seaweed fiber solution on round pipe

The drag reduction ratio of seaweed fiber solution is obtained from the ratio of friction coefficient of water. Figure 7 is the relationship between Reynolds number compared to the drag reduction of seaweed fiber solution on round pipe ID 38 mm.

Based on figure 7, the drag reduction ratio of seaweed fiber solution on round pipe ID 38 mm began to occur at Reynolds number around 10,000 to the highest Reynolds number in this study which was around 33,000. Drag reduction occurs for all concentration. The drag reduction ratio increases with increasing Reynolds number.

It can be seen that there are two factors that influence the drag reduction ratio, namely Reynolds number and seaweed fiber solution concentration. The higher the concentration of seaweed fiber solution, the greater the drag reduction ratio. Thus, it can be concluded that the highest drag reduction ratio in round pipe occurs in seaweed fiber solution with concentration 100 ppm with drag reduction ratio is about 16% and occurs at Reynolds number around 33,000.

The relationship of Reynolds number compared to the drag reduction ratio of seaweed fiber solution in spiral pipe P/Do 7.3 can be seen in Figure 8. The friction coefficient of water compared to seaweed fiber solution. The result shown that the drag reduction in seaweed fiber solution began to occur at Reynolds number around 9,000. The drag reduction continued to increase until the higher Reynolds number reached around 35,000 in this study.

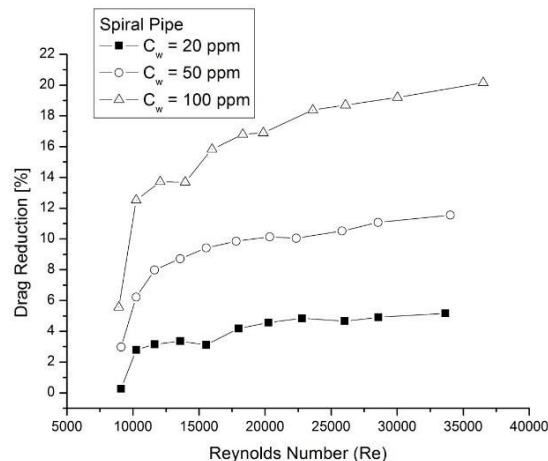


Figure 8. Drag reduction ratio of seaweed fiber solution on spiral pipe

In Figure 8, it can also be seen that another factor that influences the drag reduction is the concentration of seaweed fiber solution. The higher the concentration of seaweed fiber solution, the greater the drag reduction ratio. The highest drag reduction occurs at seaweed fiber with concentration 100 ppm with ratio about 20% and occurred at Reynolds number around 35,000. This is consistent with the highest drag reduction ratio data on round pipe which also occur at 100 ppm concentration at around Reynolds number 33,000.

It can be seen that what distinguishes the drag reduction ratio in the spiral and round pipe is the initial Reynolds number when the drag reduction is occurred. If in round pipe the drag reduction starts at Reynolds number around 10,000, while the drag reduction in spiral pipe occurs at lower Reynolds number which is about 9,000. From this study, it can be concluded that spiral pipes are more effective in drag reduction than round pipe because the drag reduction occurs at lower Reynolds numbers.

This is occurred due to the presence of fluid flow in the spiral pipe experiencing the swirl flow [21]. The swirl flow cause the flow not only moves horizontally towards the pipe axis, but also flows along the pipe groove at certain distance. Then, the right distance allows the drag reduction occurred in the flow in the flow.

Drag reduction is divided into two types, namely type A and type B [22]. Characteristic of drag reduction type A is the additive solution produces a friction factor segment that expands outward from the "general" point on the Prandtl-Karman line, the curve increasing with increasing concentration. The drag reduction also increases with the increase of $Re.f^{1/2}$. This is occurred due to the characteristics of random macromolecules.

In the drag reduction type B, the additive solution produces a segment that is relatively parallel to the Prandtl-Karman (P-K) line where the drag reduction does not depend on $Re.f^{1/2}$, but increases with increasing concentration. This behavior is shown by various types of additives including extended polyelectrolytes, fiber, soap and clay. This reduction in barriers occurs without clear onset effect where macromolecules that cause the effect are already extended and do not need to be stretched by strong flow.

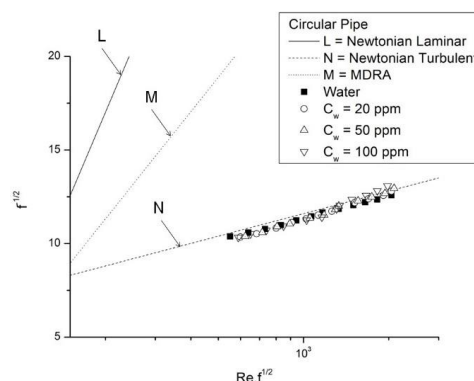


Figure 9. Drag reduction ratio of seaweed fiber solution on spiral pipe

Figure 9 is the graph of the experimental results for seaweed fiber solution on round pipe using the equation of the coordinate semi-logarithmic friction factor of Prandtl-Karman $f^{-1/2}$ with $Re.f^{1/2}$. Three straight lines characterized by L, N and M. L are Newtonian laminar flows, N is Newtonian turbulent flow, and M is the maximum possible drag reduction asymptote (MDRA) [23].

From Figure 10 it can be seen that the results of testing the seaweed fiber solution in turbulent flow is parallel to line N, where the higher concentrations are on a higher graph. This indicates that the seaweed fiber solution is considered as drag reduction type B.

In general, the mechanism of drag reduction type B is associated with suppression of vortices [24]. In the fiber solution, it is estimated that the floc produced in the flow field affects the resistance of the liquid and fiber to suppress vortices when distributed evenly towards the destination, thus this is resulting in a drag reduction [25-28].

CONCLUSION

The results of this research shown that the seaweed fiber solution on round pipe ID 38 mm has an effect on the drag reduction about 16% at Reynolds number around 33,000. Whereas the drag reduction in the spiral pipe P/Do 7.3 is about 20% at Reynolds number 35,000. The drag reduction is affected by the concentration of fiber solution. The higher the concentration of seaweed fiber solution, the greater the drag reduction ratio that occurs. In this study, the concentration of fiber with the highest drag reduction ratio was seaweed fiber solution with concentration 100 ppm in both round and spiral pipes.

ACKNOWLEDGEMENT

This work was funded by Universitas Indonesia with PIT 9 scheme (NKB-0083/UN2.R3.1/HKP.05.00/2019).

REFERENCES

- [1] Yanuar, et al. "Micro-bubble drag reduction on a high speed vessel model". *Journal of Marine Science and Application*, vol. 11, no. 3, pp. 301-304, 2012.
- [2] Yanuar, et al. "Hydraulics conveyances of mud slurry by a spiral pipe". *Journal of Mechanical Science and Technology*, vol. 23, no. 7, pp. 1835-1839, 2009.
- [3] K. Watanabe, M. Hirakawa, H. Kato. "Experimental study on turbulent flow in curved spiral tube. *Trans. JSME B.*, vol. 57, no. 538, pp. 73, 1995.
- [4] D. Mowla, A. Naderi. "Experimental study of drag reduction by a polymeric additive in slug two-phase flow of crude oil and air in horizontal pipes. *Chemical Engineering Science*, vol. 61, no. 5, pp. 1549-1554, 2006.
- [5] B.A. Toms. "Some observations on the flow of linear polymer solutions through straight tubes at large Reynolds numbers". *Proceedings of the 1st International Congress on Rheology*, vol. 2, pp. 135-141, 1949.
- [6] M. Drzazga, et al. "Influence of Nonionic Surfactant Addition on Drag Reduction of Water Based Nanofluid in a Small Diameter Pipe". *Chinese Journal of Chemical Engineering*, vol. 21, no. 1, pp. 104- 108, 2013.
- [7] C. Huang, D. Liu, J. Wei. "Experimental study on drag reduction performance of surfactant flow in longitudinal grooved channels". *Chemical Engineering Science*, vol. 152, pp. 267-279, 2016.
- [8] I.T. Dosunmu, S.N. Shah. "Turbulent flow behavior of surfactant solutions in straight pipes". *Journal of Petroleum Science and Engineering*, vol. 124, pp. 323-330, 2014.
- [9] Yanuar, Gunawan, M. Baqi. "Characteristics of drag reduction by guar gum in spiral pipes. *Jurnal Teknologi (Sciences and Engineering)*, vol. 58, pp. 95-99, 2012.
- [10] Yanuar, et al. "Drag reduction and velocity profiles distribution of crude oil



- flow in spiral pipes”.
International Review of Mechanical Engineering, vol. 9, no. 1, pp. 1-10, 2015.
- [11] T. Al-Wahaibi, et al. “Experimental investigation on the performance of drag reducing polymers through two pipe diameters in horizontal oil–water flows”. *Experimental Thermal and Fluid Science*, vol. 50, pp. 139-146, 2013.
- [12] A.M. Khattak, M. Younas, G.A. Khan, M. Ur Rehman, S. Nadeem, M. Safeer. “P-Separation Axioms in Supra Soft Topological Space”. *Matrix Science Mathematic*, vol. 2, no. 2, pp. 07-10, 2018.
- [13] S. Sathishkumar, M. Kannan. “Design and Fatigue Analysis of Multi Cylinder Engine and Its Structural Components”. *Acta Mechanica Malaysia*, vol. 2, no. 2, pp. 10-14, 2018.
- [14] U.K. Hassan, S. Kasim, R. Hassan, H. Mahdin, A.A. Ramli, M.F. Md Fudzee, M.A. Salamat. “Most Stationery Inventory Management System”. *Acta Electronica Malaysia*, vol. 2, no. 2, pp. 10-13, 2018.
- [15] S. Tao. “Evaluation of Technology Innovation in Hubei Province”. *Engineering Heritage Journal*, vol. 2, no. 2, pp. 09-10, 2018.
- [16] L.C. Edomwonyi-Otu, M. Chinaud, P. Angeli. “Effect of drag reducing polymer on horizontal liquid– liquid flows. *Experimental Thermal and Fluid Science*, vol. 64, pp. 164-174, 2015.
- [17] A. Abubakar, et al. “Roles of drag reducing polymers in single- and multi-phase flows”. *Chemical Engineering Research and Design*, vol. 92, no. 11, pp. 2153-2181, 2014.
- [18] Yanuar, et al. “The Effect of Calcium Carbonate (CaCO₃) Nanoparticles on the Flow through a Pentagon Spiral Pipe”. Vol. 8, pp. 1258, 2017.
- [19] S.N. Kazi, G.G. Duffy, X.D. Chen. “The Effect of Varying Fiber Characteristics on the Simultaneous Measurement of Heat and Momentum Transfer to Flowing Fiber Solutions”. *Journal of Heat Transfer*, vol. 137, no. 1, 2015.
- [20] A.J. Bobkowicz, W.H. Gauvin. “The turbulent flow characteristics of model fibre solutions”. *The Canadian Journal of Chemical Engineering*, vol. 43, no. 2, pp. 87-91, 1965.
- [21] T.N. Satoshi Ogata, K. Takuya. “Drag Reduction of Bacterial Cellulose Solutions. *Advances in Mechanical Engineering*, Article ID 528373, pp. 6, 2011.
- [22] G.G. Duffy, S.N. Kazi, X.D. Chen. “Heat transfer and pressure drop characteristics of solutions of synthetic and wood pulp fibres in annular flow”. *Applied Thermal Engineering*, vol. 31, no. 14–15, pp. 2971-2980, 2011.
- [23] Gunawan, et al. “Drag reduction of bamboo and abaca fiber solutions in circular pipe”. In 5th International Meeting on Advances of Thermofluids, IMAT 2012.: Bintan Island, pp. 34-39, 2013.
- [24] W. Wulandari, et al. “Effect of coconut fiber solutions on drag reduction in circular pipe”. *IOP Conference Series: Earth and Environmental Science*, vol. 105, no. 1, pp. 012050, 2018.
- [25] Y. Yanuar, et al. “Helical twisted effect of spiral pipe in generating swirl flow for coal slurries conveyance, vol. 79, 2017.
- [26] P.S. Virk. “Drag reduction fundamentals”. *AIChE Journal*, vol. 21, no. 4, pp. 625-656, 1975.
- [27] P.S. Virk, H.S. Mickley, K.A. Smith. “Ultimate Asymptote and Mean Flow Structure in Toms' Phenomenon”. *Journal of Applied Mechanics, Transactions ASME*, vol. 37, no. 2, pp. 488-493, 1970.
- [28] T.N.S. Ogata, T. Kubo. “Drag reduction of bacterial cellulose solutions”. *Advances in Mechanical Engineering*, pp. 6, 2011.