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Analysis of Average Flow Velocity and the Transformation of Flow Symmetry of Selected Fluid Samples in a Cylindrical Bifurcated Channel

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A B S T R A C T

Research interest in the field of bifurcation and its role in flow distribution and recovery has grown greatly in the past two decades. In this study, data obtained from an experimental investigate of the flow of water, diesel oil, crude oil and peanut oil representing the following categories of fluid samples, polar solvent, as they are allowed to flow through a geometrical glass cylindrical tube with the following angles 10^o, 20^o, 30^o, 40^o, 50^o, and 30^o. and the designated volumes of 100ml, 200ml, 300ml, 400ml and 500ml of the fluid samples were recovered, results obtained how water representing polar solvent as a consequences of its properties can easily attain maximum average velocity, results also show how we can predict the average velocity of a fluid sample with known Specific Gravity (S.G), finally our result further shows how the flow symmetry in the branched channels changed from the conventional flow symmetry in a straight pipe.

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INTRODUCTION

The natural means of distribution and recovery of fluid substances to or from all necessary ends has been through the formation of bifurcation and confluence. Bifurcation is the sudden splitting of a main flow channel into two or more daughter channels. It is broadly classified into symmetrical and asymmetrical bifurcation models. The symmetrical model is a geometric situation where the main channel is splits into two daughter channels of equal inner diameter, length and branched angle. while the asymmetrical model is the geometric situation where the main channel splits into two unequal inner diameter, length and branched angle. The asymmetrical bifurcation is the bifurcation model that exist commonly and naturally in nature, and it is usually found in river bifurcation, bifurcation in plants, arterial bifurcation, bifurcation of the star in the astrophysical environment.

Research on application of bifurcation has been growing since the last decade as adopted the mirror concept model of bifurcation which is the concept of confluence, in their study of droplets merging in a microfluidic flow condition using an experimental approach they were able to demonstrate how droplet coalescence within microfluidic channel can be controlled. Their study of flow splitting was extended by who studied the behavior of droplets in a bifurcated channel using the three-dimensional numerical experiment together with the phase theory of fields, where they were able provide some explanations for the mechanism of droplets breakup between the boundaries of droplets splitting and non-splitting regime. Research in the field was taken further into hemodynamics in physiology as considered bifurcation in a microvascular situation in there bide to comprehensively understand and be able to predict the basic flow parameters in the arterial system.

They were able to identify some measures of flow resistance due to vessel bifurcation, and were also able to show some significant drop in flow velocity in relation to models with constant pressure and non-vessel bifurcation. Studies was further extended by using two-dimensional phase theory of fields investigated the flow dynamics of droplets in a bifurcated capillary channel, where they identified some conditions of droplets splitting or being absorbed completely into one of the branched channels were able to establish a relationship between droplets of vegetable oil and London force as they experimentally examine intermolecular interaction. Examined the impact of angle of bifurcation on the uniformity of fluid flow distribution through a bifurcated channel using the two-dimensional numerical model.

Recent studies on bifurcation have also been conducted by Egbo et al has conducted some analysis on the flow of some selected fluid samples in a bifurcated channels and has been able to establish some fascinating relationship regarding flow velocity gradient with respect to the physical properties of the fluid samples, the existence of a range of velocity in the branched channel and the stability of the flow as the angles of bifurcation increases. In the study we extensively examine the average flow of both processed and unprocessed hydrocarbons, polar solvent and viscous fluid to be able to wholistically look at their velocity profile to enable us establish a relationship between their physical properties and their relative average flow velocity, there flow symmetry at different stage of the flow motion and how they can be utilized in a multiphase flow and flow separation.

THEORETICAL REVIEW

Egbo et al has conducted some analysis on the flow of some selected fluid samples in a bifurcated channels and has been able to establish some fascinating relationship regarding flow velocity gradient with respect to the physical properties of the fluid samples, the existence of a range of velocity in the branched channel and the stability of the flow as the angles of bifurcation increases. In the study we extensively examine the average flow of both processed and unprocessed hydrocarbons, polar solvent and viscous fluid to be able to wholistically look at their velocity profile to enable us establish a relationship between their physical properties and their relative average flow velocity, there flow symmetry at different stage of the flow motion and how they can be utilized in a multiphase flow and flow separation.

METHODOLOGY

The selected fluid samples are meant to be represent polar solvent, processed hydrocarbon, unprocessed hydrocarbons and viscous fluid, that is fluid samples with distinct physical properties

Table 1. Physical Properties of the Selected Fluid Samples

Fluid Sample	Specific Gravity (kg/cu.m)	Density ρ (kg/m^3)	Viscousity μ (cP)
Water	1.00	997.00	1.00
Diesel oil	0.89	894.33	0.89
Crude oil	0.88	920.00	3.20
Peanut oil	0.92	919.70	3.26

The materials and method adopted in this experiment is comprehensively highlighted in.

RESULTS

The results obtained using the realistic values of the properties of the fluid substances presented in the table 1 and the data obtained from the experiment is presented in the figures 1, 2, 3 and 4. Figure 1 compared the average flow velocity of peanut oil through angle 10^o, 20^o, 30^o, 40^o, 50^o and 60^o of bifurcation, while the figure 2 compares the average flow velocity with the horizontal and vertical components of the flow velocity. Figure 3 presents result of the average flow velocity of diesel oil through the selected angles of bifurcation, while results presented in figure 4 is the comparison between the average velocity and the vertical and horizontal component. The figure 5 compares the results of the samples considered in with results obtained in the experimental for various angles of bifurcation.

The figure 1 presented the results of the average flow velocity across the designated volume recovery, the figure which contains six trends, each representing the average flow velocity through each of the angles of the geometrical bifurcated system, as the angles 5°, 10°, 15°, 20°, 25°, and 30° are represented by red, green, yellow, purple, blue and brown trends respectively. A gradual decrease in the value of the average flow velocity on the vertical axis is due to a proportionate decrease in the flow pressure as the height of the fluid in the reservoir decrease according to the relation. The result in the figure further shows that at maximum and minimum flow pressure from the bottom of the reservoir, the brown trend representing the average flow velocity through a bifurcation angle of 30° has the least average flow velocity gradient amongst all, followed by the green trend representing a bifurcation angle of 10°.

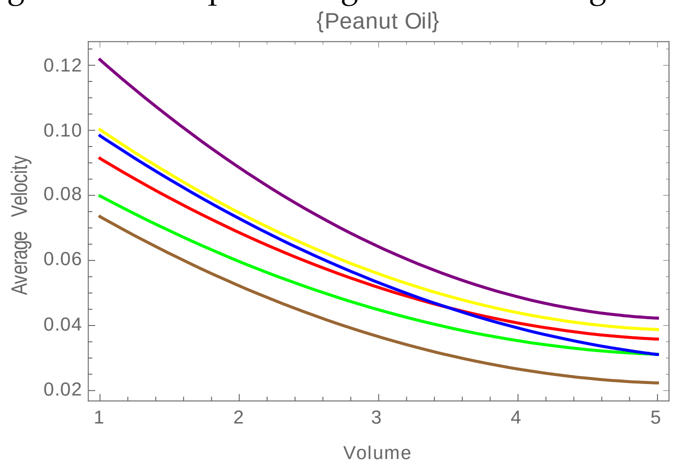

Figure 1. Profile of Average Flow Velocity Across Designated Volume

At maximum flow velocity, the average velocity flow gradient increases further from the red, blue, yellow and purple trends representing the 5°, 25°, 15° and 20° respectively. While at minimum flow, directly above the green trend is the blue trend, followed by the red, yellow and purple trends representing the 25°, 5°, 15°, and 20° angles of bifurcation.

Figure 2 shows a block of profile of average flow velocity with the vertical and horizontal component of the velocity through the designated bifurcated. For bifurcation angle of 5° and 30°, the purple trendline representing the velocity component parallel to the main flow channel, while for bifurcation angles of 10°, 15°, 20°, and 25° represented by the blue trendline is at a higher velocity gradient for this profile of results, as the green trendline is seen to at a position where it indicates a relatively lower average velocity gradient in the symmetrical bifurcated channel.

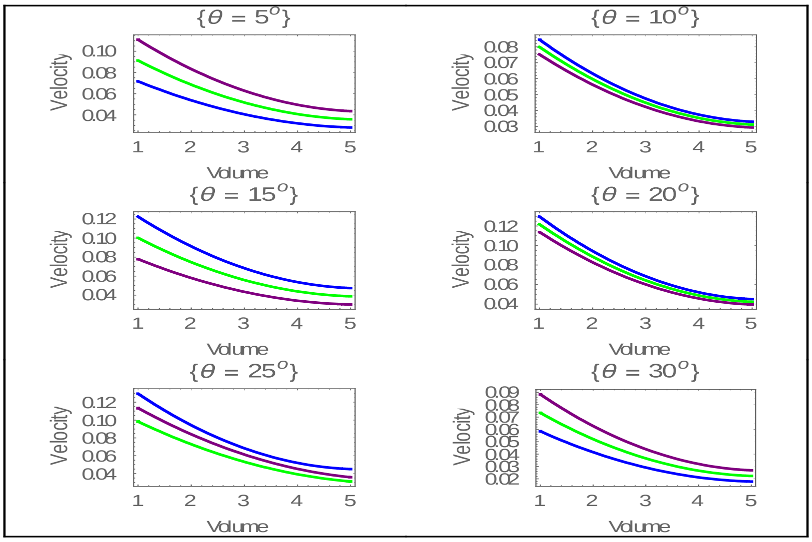

Figure 2. Profile of Average Flow Velocity Across Designated Volume

Figure 3 presents the profiles of the average flow velocity of diesel oil, the results shows that at a maximum flow pressure observed at recovery volumes of 100ml and 200ml, where the average velocity gradient increases from the green trendline, through the red, brown, yellow and purple trendlines representing the average flow velocity recorded in the bifurcation angles of 10o, 5o, 30o, 15o, 20o, and 25o. as the value of the average flow velocity drops to a minimum at 400ml and 500ml recovery volume, the values of the average flow velocity increases gradually from the green trendline representing the angle 10°, to the red trendline representing the angle 5°, brown representing the angle 30°, yellow representing 15° and blue representing the bifurcation angle of 25°.

In figure 4, the average velocity is compared with the vertical and horizontal velocity of the bifurcated symmetrical channel. The velocity profile obtained from the bifurcation angle of 5o, 25o and 30o shows that the purple trendline representing the vertical velocity components is seen to be at a higher velocity gradient, while the blue trendline representing the horizontal component is at a relatively lower average flow velocity gradient.

The profile of results presented in figure 5, compares the results obtained in the study with the results obtained by [Egbo et al], examination of the profiles for each of the selected angles revealed a pattern and arrangement of the trendlines that shows how the average gradient decreases from green, to blue, to purple and then to yellow, which respectively represents water, diesel, crude oil, and peanut oil, indicating and increasing order of viscosity and decrease order of average velocity gradient.

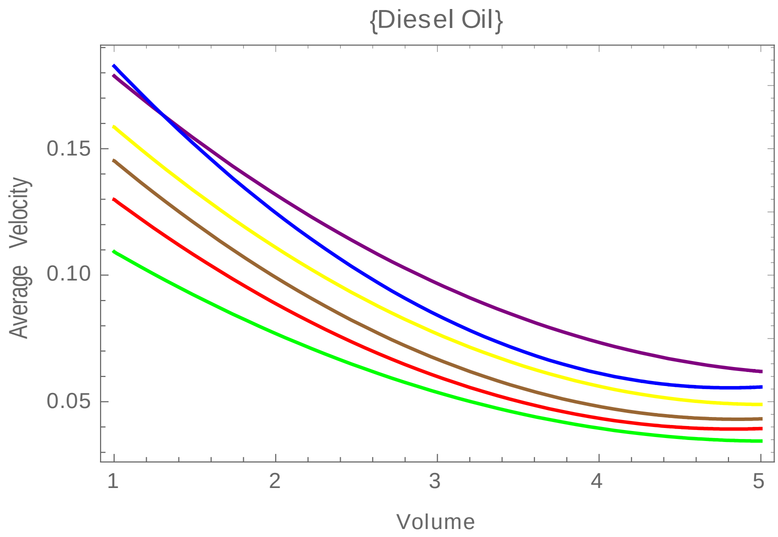

Figure 3. Profile of Average Flow Velocity Across Designated Volume

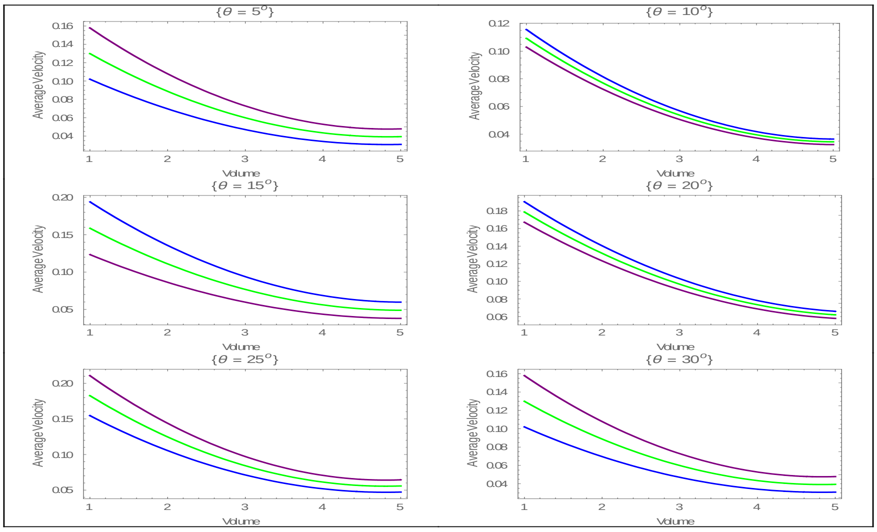

Figure 4. Profile of Average Flow Velocity Across Designated Volume

The results presented in this figure contains results of water and crude oil samples obtained from combined with the result of diesel and peanut oil. As part of the observation from the profile of result presented in figure, is the steep distance of each trendlines from the green trendline representing the average flow velocity of water.

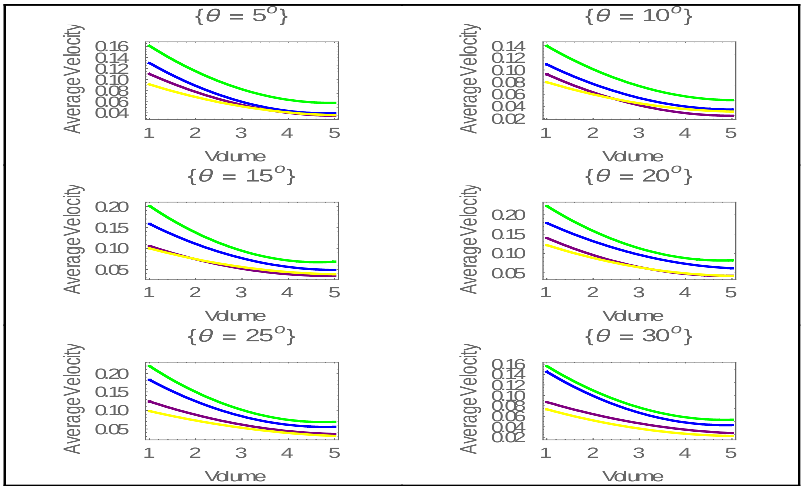

Figure 5. Profile of Average Flow Velocity Across Designated Volume

Diesel oil represented by the blue trendline, which is less dense when compared to crude oil and peanut oil is seen to be closest to the green trendline of water. The followed by the purple trendline representing the average flow velocity gradient of crude oil, and the peanut oil represented by the yellow trendline which is the densest is correspondingly seen to be farthest away from the green trendline of water.

CONCLUSIONS AND RECOMMENDATIONS

The average flow velocity of fluid in a straight pipe has been shown to exist at the center of a straight pipe, also critical examination of the streamline has shown that the maximum velocity exists only at the center of a pipe, hence in the flow situation considered in this experiment study, and amongst other fluid samples considered, water has been revealed to easily attained maximum average flow velocity gradient. And as part of the situation where it has been proven to be a better reference fluid substance for use in computation of the Specific Gravity (SG) of other fluid substances.

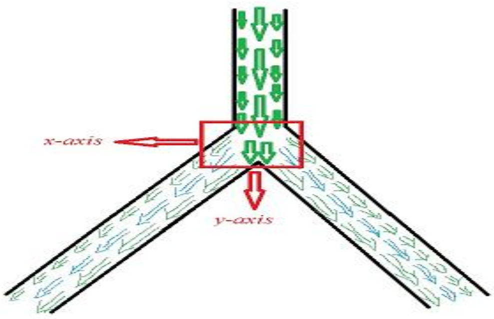

Figure 6. Fluid Substance for Use in Computation of the Specific Gravity (SG)

We further conclude that at the point of bifurcation the flow symmetry of fluid substances changes, as the average flow velocity is then seen at the center of the bifurcated daughter channel, while the maximum velocity is seen on either the inner or outer all of the branched daughter channel of a symmetrical bifurcated network.

We recommend that a multiphase flow in a straight pipe be conduction with fluid samples of different physical properties to be able to understand their various velocity under the same inlet flow velocity, these can further be extended by including branched outlet where possibly the fluids layer closest to the wall can be easily collected for distribution.

FURTHER STUDY

We further conclude that at the point of bifurcation the flow symmetry of fluid substances changes, as the average flow velocity is then seen at the center of the bifurcated daughter channel, while the maximum velocity is seen on either the inner or outer all of the branched daughter channel of a symmetrical bifurcated network.

REFERENCES

Xize Niu and Joshua B. Edel (2008), GEOMETRICALLY MEDIATED DROPLET MERGING IN MICROCHANNELS, Twelfth International Conference on Miniaturized Systems for Chemistry and Life Sciences, 1423 - 1425.

Carlson, A. & Do-Quang, Minh & Amberg, Gustav. (2010), Droplet dynamics in a bifurcating channel. International Journal of Multiphase Flow. 36. 397-405.

Yang, Jiho & Pak, Y. Eugene & Lee, Tae-Rin (2016), Predicting bifurcation angle effect on blood flow in the microvasculature, Microvascular Research. 108. 10.1016/j.mvr.2016.07.001.

Wang, Yuli & Do-Quang, Minh & Amberg, Gustav (2016), Viscoelastic droplet dynamics in a Y-shaped capillary channel. Physics of Fluids. 28. 033103. 10.1063/1.4943110.

Muhammad Akhlis Rizza, Widya Wijayanti, Nurkholis Hamidi, I. N. G. Wardana (2018), Role of Intermolecular Forces on the Contact Angle of Vegetable Oil Droplets during the Cooling Process, Hindawi The Scientific World Journal, Volume 2018, pp 8.

Jun Cao, Manfred Kraut, Roland Dittmeyer, Li Zhang, Hong Xu (2018), Numerical analysis on the effect of bifurcation angle and inlet velocity on the distribution uniformity performance of consecutive bifurcating fluid flow distributors, International Communications in Heat and Mass Transfer, Vol. 93, Pp 60-65.

Scott J. Hymel, Hongzhi Lan, Hideki Fujioka , and Damir B. Khismatullin (2019), Cell trapping in Y-junction microchannels: A numerical study of the bifurcation angle effect in inertial microfluidics, Physics of Fluids 31.

Ma, Daofan & Liang, Di & Zhu, Chunying & Fu, Taotao & Ma, Youguang & Yuan, Xigang & Li, Huai. (2020), The breakup dynamics and mechanism of viscous droplets in Y-shaped microchannels, Chemical Engineering Science. 231. 116300. 10.1016/j.ces.2020.116300.

Deka, Dhrijit & Pati, Sukumar & Randive, Pitambar. (2021), Implications of capillarity-wettability interaction on geometrically mediated droplet splitting mechanism, Colloids and Surfaces A: Physicochemical and Engineering Aspects. 633.

Egbo C. A., Abbey T. M., Ngiangia A. T., Dappa J. A., Ugorji U. K. (2022), Analysis of the Flow of Viscous Fluid in Cylindrical Bifurcating Channel, International Journal of Innovative Science and Research Technology, 12, 6, 234-238.

Egbo C. A., Abbey T. M., Opuene O. D., Faket K. N, Taiwo O. S., Olumide O. S., Onwe P. B., Azi O. A. (2020), Profile of Average Flow Velocity of Polar Solvent and Unprocessed Hydrocarbon in a single stage symmetrical bifurcated channel, East Asian Journal of Multidisciplinary Research (EAJMR), Vol.1, No.3 2022: 331-342