ANALYSIS OF THE FLOW STRUCTURE OF SELECTED FLUID SAMPLE IN A CYLINDRICAL BIFURCATED GLASS TUBE

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Abstract— The effect of geometric bifurcated system on the flow of fluid samples may greatly be influenced also by the physical properties such as viscosity, density, capillary action etc. of the fluid. An experimental method was used in this paper to study the flow structure of water, diesel, crude oil, and peanut oil representing polar solvent refined hydrocarbon, unrefined hydrocarbon and vegetable oil respectively, flowing through a bifurcated channel. The bifurcated angles measured from the centerline of the main channel corresponding to 5^o, 10^o, 15^o, 20^o, 25^o and 30^o, the fluid samples were allowed to flow through the bifurcated channels and the time taken to recover 100ml, 200ml, 300ml 400ml and 500ml in a beaker of 1000ml is recorded, the bifurcated angle is resolved into vertical and horizontal components and the total length with respect to both components obtained, as the flow velocity is computed for both lengths and the results presented. The profile of resulted shows that for polar solvents represented by water, the velocity gradient increases as the vertical distance increases and horizontal distance decrease correspondingly due to increasing bifurcation angle, as similar trend of result is also observed for refined hydrocarbon, unrefined hydrocarbon and for vegetable oil. For all the fluid samples representing the selected categories of fluid, the result further shows the existence of velocity difference at opposite walls of the bifurcated daughter channels, the wall at higher velocity is usually the site where the skin friction is gradually created that consequently changes the flow structure from laminar to turbulent. and finally, the experimental result confirmed that effects of bifurcation on the flow stability of fluid is more significant in viscous fluid.
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Index Terms— Velocity gradient, Flow stability, Bifurcation angle, Refined Hydrocarbon, Unrefined Hydrocarbon, Vegetable oil, Polar solvent.

1 INTRODUCTION

The importance of hydrodynamic flows in bifurcating channel cannot be overemphasized. This is principally because of its wide application in several works of life. Bifurcating system abound in nature, ranging from green plants, human arterial systems, rivers to domestic and industrial piping network. For example, the drainage network systems in civil engineering, electrical circuit designs in electronics, domestic and urban water distribution, in recoveries and distribution of hydrocarbon products as well as other multi-distribution system in the processing industries. the relevance of bifurcation has led to the development of several studies that has adopted both experimental and theoretical approach and methods ranging from analytical, numerical etc. been conducted in the literature for over ten (10) decades. For instance [1] uses numerical method to analyze the flow performance of consecutive bifurcating distributors in two dimensions. In this study the inlet velocity, bifurcation angles ranging from 15^o to 90 were considered, as they were able to obtain a relationship between the inlet velocity, flow distribution uniformity and the bifurcation angle. The study is also extended to the impact of bifurcated microchannel on the breakup of viscous droplets where [2] visually investigate the dynamics of the breakup of viscous droplet, and they were able to explain phenomena associated with the squeezing, transition and pinch-off stages of viscous droplets through the bifurcated microchannel. [3] further simulated the viscoelastic droplets through a two dimensional bifurcated capillary microchannel, there results revealed hoe the droplet size and capillary number will behave when it approaches the point of bifurcated. [4] using numerical experimental technic, investigated the behavior of droplets as it gets to the tip at the junction of a symmetrically bifurcated system, they established a relationship between the Rayleigh-Plateau instability with the splitting and non-splitting regime of the viscous droplets. A mathematical model and a three-dimensional flow simulation were used to quantitatively predict the effect of bifurcation on microvasculature of hemodynamics, were also able to show how degree of influence vessel bifurcation hold on the viscosity of blood [5]. And in addition to the Y-shaped geometric system, the curved T-junction and flat T-junction were also adopted by [6] to examine physical behaviors such as droplets deformation, droplets neck thickness as well as the time droplets spent at the junction point of bifurcation, and wettability and the capillary actions on selected geometric system. [7] considered the use of T-shaped and Y-shaped geometrical systems for the sorting and isolation of cells of specific types, and bifurcation angle within the range of 30^o to 180^o were considered in this study that they used the computational algorithm to study the separation of deformed cells in the Y-shaped microchannel for the selected bifurcation angles, and the effects of the various sizes of cell, cytoplasmic viscoelasticity, cortical tension, flow rate for this geometrical system and angles were identified. [8] studied flow through bifurcated arteries of the human arterial system. They were able to show that in the coronary, carotid, aorto-iliac and in some other large arteries, the site of branching is associated with the development of atherosclerotic plague and hemodynamic factor such as shear stress and particle residence time with some implications. [9] in the analysis of various application of bifurcation, they addressed the flow symmetry through a large bifurcated network segment in the presence of a loop. The profile of results obtained from their study shows that out-flow flux at a low Reynolds number can be represented by the distribution of electric current existing an analog resistor network, they were able to deduce that flows at the out-let depends on the velocity at the in-let and tends to become more homogeneous as the Reynolds number increases. [10] investigated the fundamental flow in a converging bifurcated channel using the Particle Image Velocimetry (PIV) and the Laser Induced Floresence (LIF) in the experimental study. A transparent model of three machine tubes mated together in a Y-shaped to enable the determination of the amount of secondary flow through a bifurcated channel during respiration, and to enhance the understanding of how doses are distributed into the bloodstream. The study also explain airflow through the complicated series of bifurcation from the bronchi to the final alveoli of the human respiratory system. Flow of fluid samples with various physical properties in s geometrical bifurcated is also considered by [10,11]. Egbo C. A. and Abbey T. M (2021), conducted an experimental study on the flow of viscous fluid in a cylindrical bifurcating channel, and they were able to show how bifurcation affects the flow rate of the selected fluid samples and how it makes the fluid samples flowing through it to maintain stability.

The aim of the current work is to do a comparative analysis of the flow structure of polar solvent, refined hydrocarbon, unrefined hydrocarbon and vegetable oil in a cylindrical bifurcated channel, where water, diesel, crude oil and peanut oil respectively representing this categories of fluid are allowed to flow through selected angles of bifurcation, and the length of the bifurcated channel resolved into vertical and horizontal component which are then used to obtain the total length of the flow channel, furthermore, relationship between the flow velocities of the fluid samples through the cylindrical bifurcated system and the selected recovery volumes will be established with regards to the physical properties of the fluid and the geometric angles of bifurcation system.

2 MATERIALS AND METHOD

2.1 Materials

Water, diesel, peanut oil and crude oil are the fluid samples selected to represent fluid samples within category of fluid samples with similar physical properties such as density and viscosity and chemical properties such as chemical composition and structure. As peanut oil represents vegetable oil such as olive oil, carrot oil, coconut oil, avocado oil etc whose viscosity is usually in multiples of ten (10). Water, represents all polar solvent, diesel represents the refined hydrocarbons while crude oil represents the unrefined hydrocarbons. Table 1 presents some of the physical properties of the selected fluid samples.

Table 1: physical properties of the selected fluid samples

Fluid Sample	Density ρ *(kg/m^3)*	Viscosity μ *(cP)*	SG *(kg/cu.m)*
Water	997.00	1.00	1000.00
Diesel	894.33	0.89	885.00
Crude oil	920.00	3.28	847.00
Vegetable oil	919.70	34.6	0.92

Design And Fabrication of Flow Chamber and Bifurcated Cylindrical Glass tube

Experimental setup

- Beakers (500ml) two
- Peanut oil (8litres)
- Crude oil (8litres)
- Diesel fuel (8litres)
- Water (8litres)

The reservoir is kept at a height of about 4ft from the surface of the ground, with the main tube connected to the tap valve of the reservoir and the bifurcated ends of the tube decline at an angle where it's is kept at a height of about 2ft above the surface of the ground.

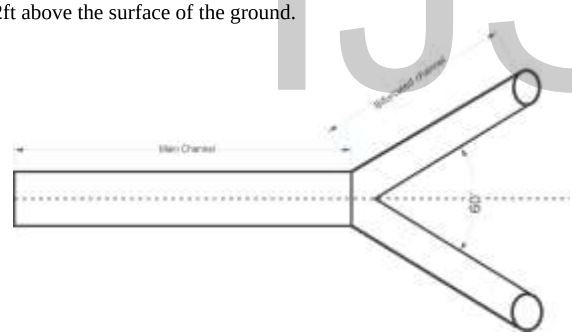

Figure 1: Geometry of a Symmetrical Bifurcated System

The two daughter channels of the bifurcated tube are then positioned to enable recovery of the fluid samples in the beakers.

When fluid flowing continuously from the main channel down to the point of bifurcation, and the fluid experiences a resistance to this continuous flow that tends to oppose the continuity of this flow state, in accordance with the second law of motion. For the purpose of this experimental investigation, the resistance which may depends explicitly on the vertical component of bifurcation measured from the centerline of the main channel is obtained, and used to compute the total flow length given by.

$$L_{\perp} = L_1 + L \sin\theta \quad (1)$$

the its horizontal counterpart given by

$$L_{\parallel} = L_1 + L \cos\theta \quad (2)$$

with their respective velocities are

$$V_{\perp} = L_{\perp}/t \quad (3)$$

$$V_{II} = L_{II}/ t \quad (4)$$

2.2 Experimental Procedure

The experimental process began by loading the reservoir with a fluid sample while the tap valve is closed, in this experiment we started with water. While the valve remained closed the beakers are positioned at the recovering end of the two bifurcated channels glass tubes. The timing of the experiment began as soon as the tap valve is opened to the extreme, and stops when the designated volume of the fluid sample is recovered, for the first cycle a volume of 100ml is required to be collected. The process is repeated for the recovery of 200ml, 300ml, 400ml and 500ml for the water sample. And the entire experimental procedure is expected to be repeated for diesel, crude oil and peanut oil and their respective timing recorded and the average computed.

3.0 Results and Discussion

The properties of the fluid samples selected for this experimental investigation is presented in Table 1, and the geometric dimension of the bifurcated cylindrical channel is presented in figure 1, the flow velocity is computed based on the expressions presented in equation 3 and 4, the profiles of results for water diesel, peanut oil and crude oil samples are presented in figure 2 and 3, 4 and 5, 6 and 7, as well as 8 and 9 respectively, the result compares the flow velocity of the samples through the specified geometric angles of bifurcation, figure 10, 11, 12 and 13 respectively presents the velocity profiles of the vertical and horizontal of water diesel, peanut oil and crude oil, while figures 14 and 15 both compares the respective profiles of the vertical and horizontal velocity components of the fluid samples for the selected angles of bifurcation.

The results for water show's a relatively high velocity gradient for smaller recovery volume of 100ml, 200ml and 300ml is observed for all fluid samples as the volume recovered increase between 400ml to 500ml a low and stable velocity gradient is also observed from the trendline, which implies that the flow will tends to be more stable in a continuous flow situation, further implication of the results observed is that, in a continuous flow situation the angles of bifurcation will always tend to stabilize the flow velocity of the selected fluid samples. It is also observed from figure 2, 4, 6 and 8, that the flow velocity increase for bifurcation angles of 10^o, 20^o, 30^o and 40^o, and decreases for 50^o and 60^o angles of bifurcation which could be as a result of the adhesive force between the glass tube and the water samples becomes more significant at these angles. Whiles on the horizontal component presented in figure 3, 5, 7 and 9, a decrease is observed in the flow velocity for bifurcation angles of 20^o, 30^o and 40^o and increases for 50^o and 60^o angles of bifurcation.

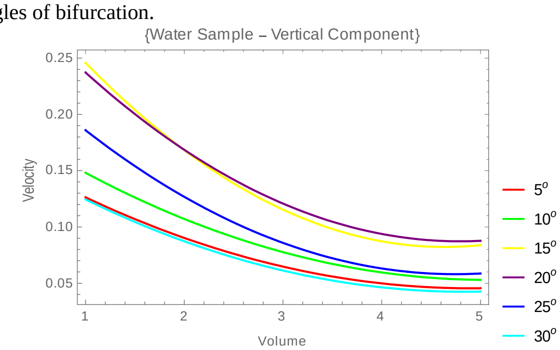

Figure 2: Impact of vertical component of bifurcation on flow through a cylindrical channel

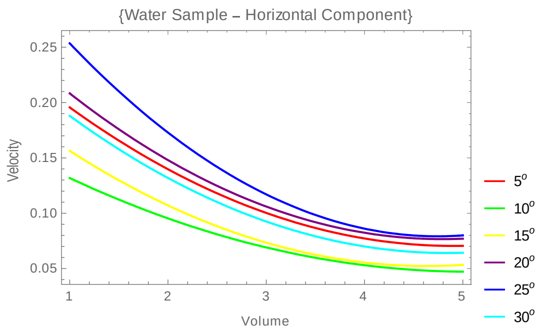

Figure 3: Impact of vertical component of bifurcation on flow through a cylindrical channel

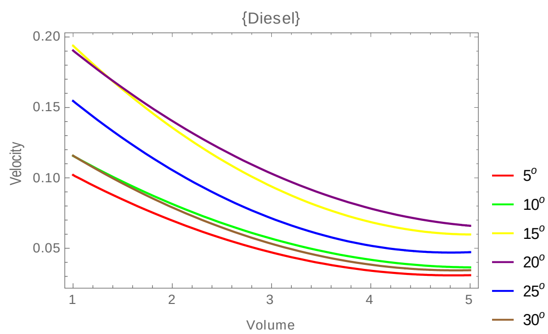

Figure 4: Impact of vertical component of bifurcation on flow through a cylindrical channel

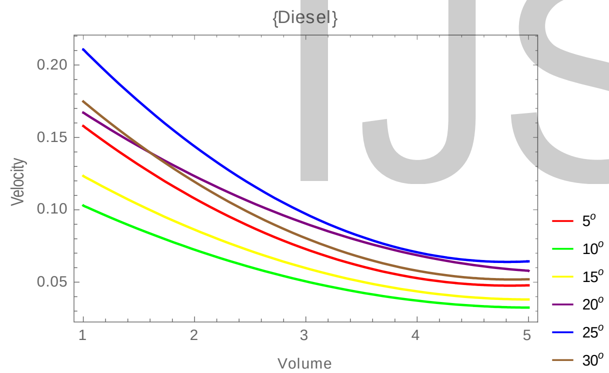

Figure 5: Impact of vertical component of bifurcation on flow through a cylindrical channel

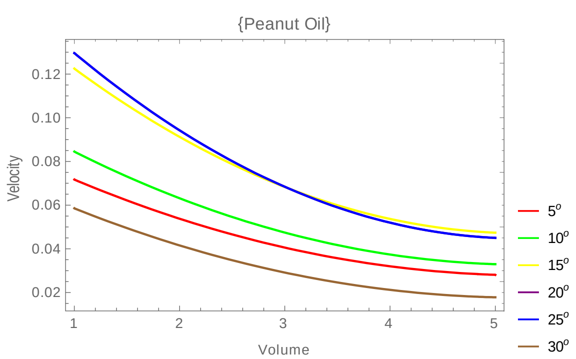

Figure 6: Impact of vertical component of bifurcation on flow through a cylindrical channel

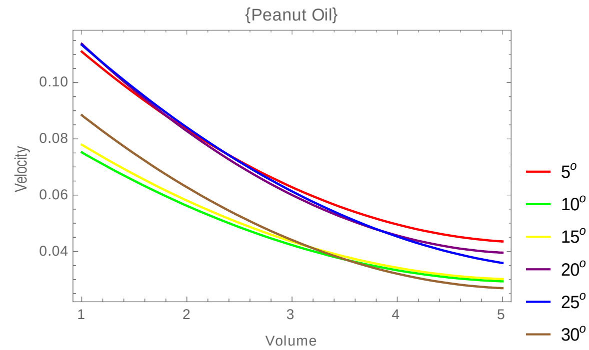

Figure 7: Impact of vertical component of bifurcation on flow through a cylindrical channel

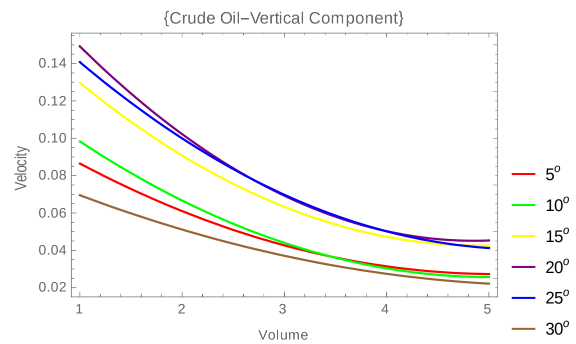

Figure 8: Impact of vertical component of bifurcation on flow through a cylindrical channel

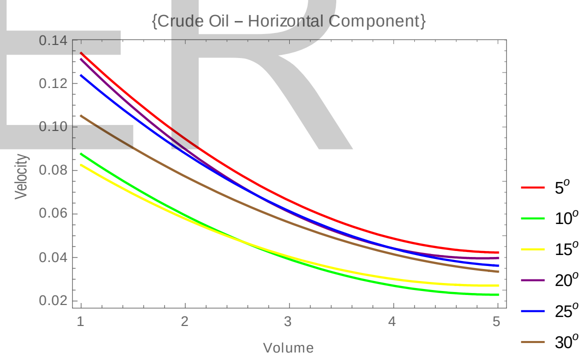

Figure 9: Impact of vertical component of bifurcation on flow through a cylindrical channel

The flow discrepancy between the vertical and horizontal component of bifurcation is presented in the volume-velocity profile of figures 10, 11, 12, and 13, for water, diesel, peanut oil and crude oil, shows a relatively low velocity gradient for the vertical components for bifurcation angle of 5°, 25° and 30° except for 20° in peanut oil is included shows a higher velocity gradient for the horizontal component, which imply that the vertical component of bifurcation is majorly responsible for the stability offered by bifurcation for this angles, and further implication is the likely appearance of skin friction at the left wall of the bifurcated channel that bifurcated to the right, which will consequently be the site where the flow structure will begin to change from laminar to turbulent if the flow velocity is further increased. While for bifurcation angle of 10°, 15°, 20° measured from the centerline, the horizontal component shows a lower velocity gradient, which will further account for the stability of flows through the bifurcated channel.

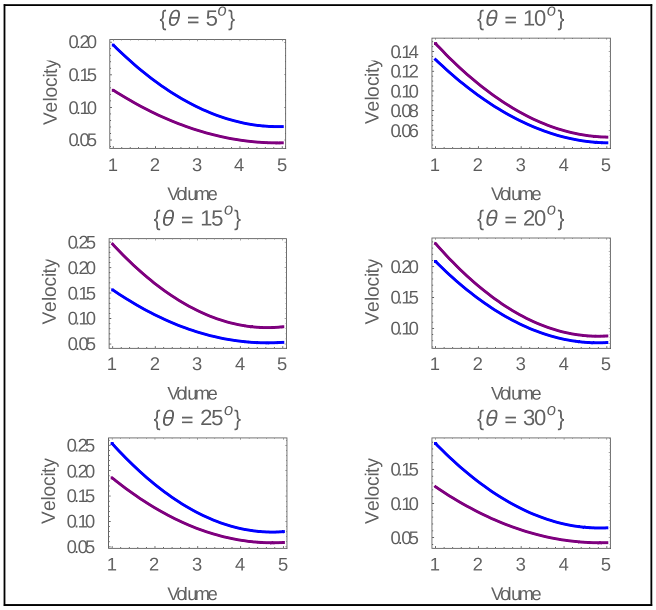

Figure 10: (Water) vertical and horizontal components of the velocity in the Y-shaped channel

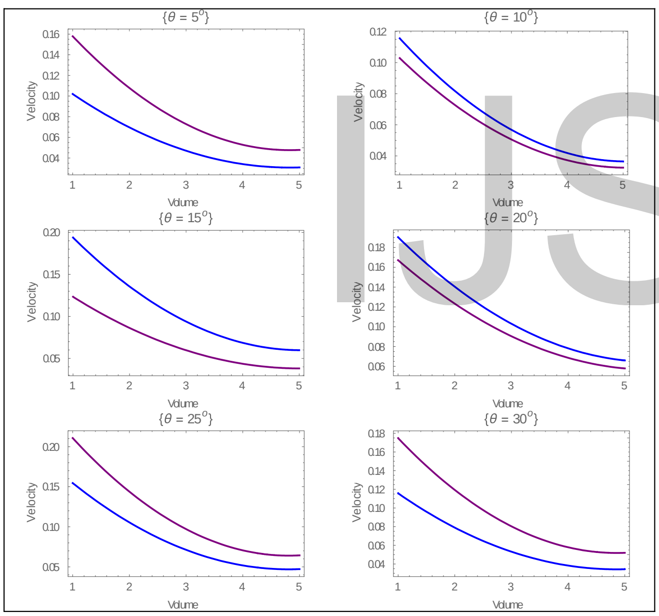

Figure 11: (Diesel) vertical and horizontal components of the velocity in the Y-shaped channel

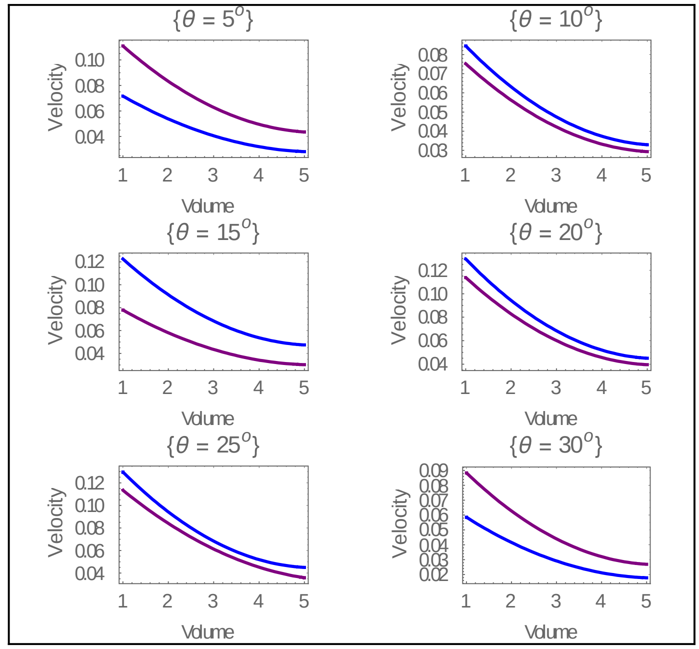

Figure 12: (Peanut oil) vertical and horizontal components of the velocity in the Y-shaped channel

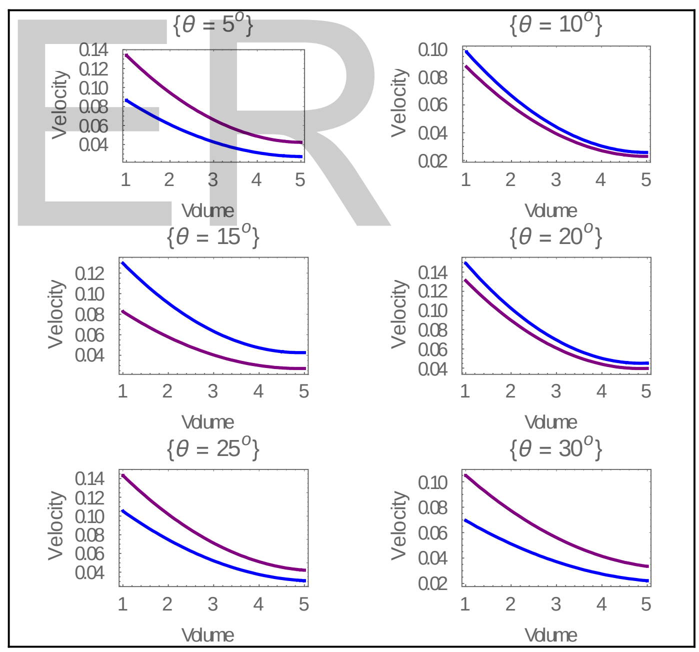

Figure 13: (Crude oil) vertical and horizontal components of the velocity in the Y-shaped channel

The impact of the selected angles of bifurcation for water, diesel, crude oil and peanut oil presented in figure 14 and 15 shows a high velocity gradient for water across all the angles selected, while diesel, crude oil and peanut oil are respectively observed to be in order of decreasing velocity gradient for the selected angles of bifurcation. When the result is compared with the physical properties of the fluid presented in Table 1, it can be observed that the viscosity of the respective fluid samples relates proportionally to the velocity gradient, and hence the flow stability through the geometric bifurcated system.

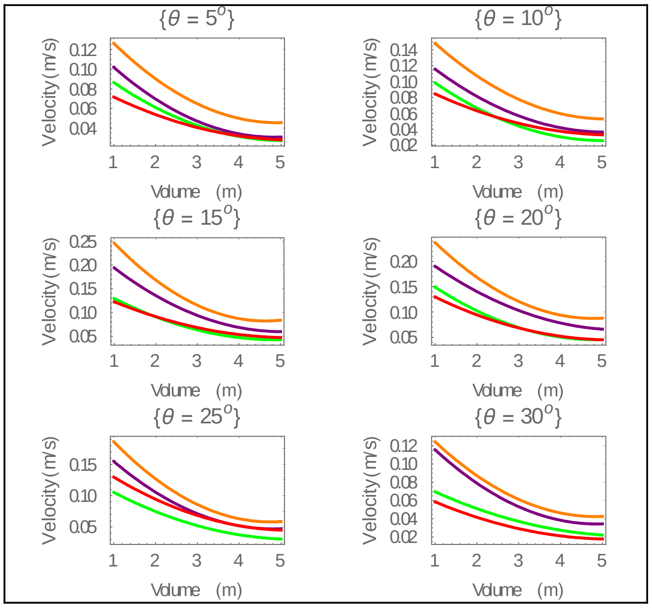

Figure 14: Vertical Components of velocity profile of the selected samples

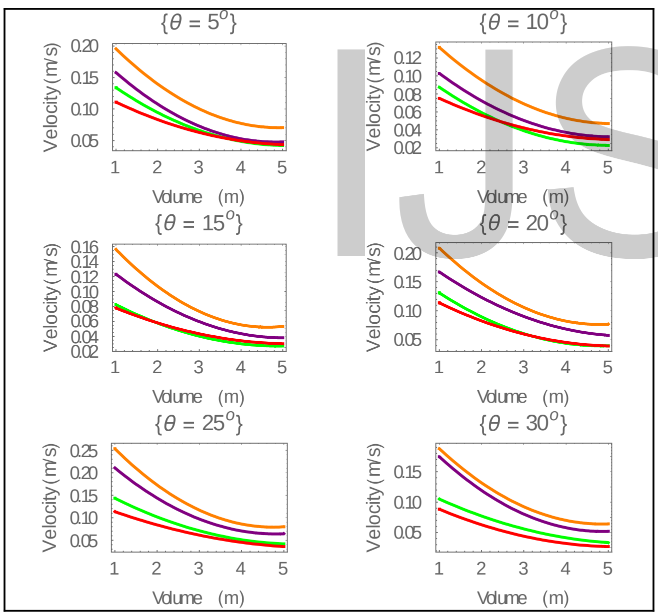

Figure 15: Horizontal components of velocity profiles of the selected fluid samples

4.0 CONCLUSION

Velocity difference is observed between opposite walls of the bifurcated channels, the side of the wall with higher velocity is the site where skin friction is created, which will further lead to the change in the flow structure of the fluid from laminar to turbulent flow structure.

For water samples which represent the polar solvents, the velocity gradient increase as the vertical distance increases (that is, increasing angle of bifurcation), and the decreases for as the horizontal distance decreases (for the increasing angle of bifurcation).

For crude oil which represents the unrefined hydrocarbons, the velocity gradient also increases as the vertical distance increases, i.e. increasing angle of bifurcation, and decreases for decreasing horizontal distance.

Bifurcation of a single channel into two channels separated by an angle stabilizes the flow of more viscous fluid such as vegetable oil and unrefined hydrocarbon much more than refined hydrocarbons and polar solvents, and this stability depends on the angles of bifurcation.

5.0 ACKNOWLEDGEMENT

I really appreciate the assistance of Mrs Ijeoma Nwoka and Mrs Nengiboofori Orupabo although the development of this manuscript.

6.0 REFERENCE

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