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Analysis of the Flow of Viscous Fluid in Cylindrical Bifurcating Channel

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Abstract:- In this study of the flow of fluid in a bifurcating channel, an experimental method was adopted, where six (6) glasses of bifurcated tubes with angles (θ) measured from the centerline of the mother tube ranging from 5° to 30°. Also, four (4) fluid samples whose physical properties were presented in Table (1) were used. Each of the fluid samples were allowed to flow through the different bifurcated glass tubes and the time taken to recover the following designated volumes of 100ml, 200ml, 300ml, 400ml and 500ml to be recovered into a beaker is recorded, then the volume flow rate, the flow velocity and the Reynolds number for each of the fluid sample were computed and the results presented. A critical examination of the profiles of results presented in Figure (1) – (4) shows that as the bifurcating angles increases, the time taken to recover the designated volume of water increases, i.e as the bifurcating angle increases the volume flow rate decreases for all fluid samples. Similar results were also observed for the flow velocity, the trend of the results displayed on the graphs shows decrease in the flow velocity as the angle of bifurcation decreases for all fluid samples. For Figure (5) to (10) the pattern of results obtained from the graphs shows that the flow rate for the various samples decrease as the density increases from water to groundnut oil. Same pattern of result was also obtained for the Reynolds number.

Keywords:- *Bifurcation angle, Viscous fluid, Reynolds number Flow rate.*

I. 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 arteries, rivers to domestic and industrial piping network. For example, the drainage system, electrical circuit, domestic and urban water distribution as well as recovery and distribution of hydrocarbon products. Due to the relevance, several studies have been conducted in the literature for over ten (10) decades. For instance [1] studied the effect of flow splitting on separation and stagnation in a model asymmetric vascular bifurcation. Dye injection was used to study the flow pattern of water flowing from a main-limb to the sidearm that is bifurcated at an angle of 15° from the axis of the main-limb. At a characteristic flow Reynolds number, the boundary layer separation at the wall of the main-limb was studied using the Laser Doppler Anemometer (LDA) to measure the velocity at the wall.[2] were able to demonstrate how unique symmetric flow exiting at a small Reynolds number becomes unstable at a large Reynolds number. They were able to obtain eight asymmetric solutions and predict the existence of seven unstable solutions. For a sufficiently high Reynolds number, a time-periodic solution and a Hopf bifurcation were deduced. They were also able to show a rich and unexpected structure to the solution of the Navier-Stokes equation at a Reynolds of a few hundred.[3] studied flow through bifurcated arties 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 are associated with the development of atherosclerotic plague and hemodynamic factor such as shear stress and particle residence time with some implications. [4] 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.[5] 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. [6] conducted and experimental study of the transportation of the wetting liquid plug in a bifurcating microfluidic channel at a constant pressure, they concluded that Poiseuille’s law can be used to estimate the viscous dissipation of the bulk flow, while Bretherton and Tanners law modeled the additional dissipation occurring at the rear and front surface. The experiment further reveals a threshold magnitude of the pressure for a flow behavior through a T-Junction, below this threshold pressure values, the plug remain block at the entrance, and above the threshold pressure value, it bifurcates as it rupture’s or split into two daughter plugs depending on the pressure applied and the initial length of the plug. [7] presented the result of an experimental investigation of a bifurcation phenomenon for a laminar and time-dependent flow through a circular pipe with a sudden expansion, and the flow state was examined using a powerful Magnetic Resonance Image technique. They were able to deduce steady state symmetry breaking bifurcation at critical value of the Reynolds numbers. An asymmetric steady state arises at the bifurcation point, hence making way to the time-dependent and periodic motion as the flow rate is increased further.

II. MATERIALS

Four different types of fluid namely vegetable/peanut oil, crude oil, diesel and water (H2O) in the experimental analysis. The viscosity and room temperature of the fluid samples are as follows

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

Table 1: Some physical properties of the fluid samples

The above stated fluid samples were selected as a representative sample of various groups or categories. Here diesel is refined hydrocarbon fluid, peanut oil is a representative of vegetable oil, crude oil is for unrefined fluid and water generally is a polar solvent.

III. DESIGN AND FABRICATION OF FLOW CHAMBERS

The structural design of the chamber is shown in the figure 2. It consists of a reservoir and the bifurcating channel made of glass tube. The reservoir was constructed from a glass still pipe and the mechanical section of the engineering workshop at the University of Port Harcourt, while the bifurcating glass tube of various bifurcating angles (10º, 20º, 30º, 40º, 50º and 60º) were fabricated at the glass section of the same university workshop.

A. *Eperimental 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 mother tube connected to the tap valve of the reservoir and the bifurcated ends of the tube decline at an angle were its is kept at a height of about 2ft above the surface of the ground. The two daughter channels of the bifurcated tube are then connected to the beakers for the recovery of the fluid samples.

A. *Eperimental Procedure*

The experimental process begins 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 begins 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, Peanut oil and Crude oil their respective timing recorded and the average computed.

IV. RESULTS AND DISCUSSIONS

A. *Water Sample*

The flow of some selected fluid samples with characteristic properties of density, viscosity and specific gravity through various angles of bifurcated cylindrical glass channel, were studied under a constant temperature and pressure condition. Using some realistic values of these selected fluid properties, with the following angles of bifurcated cylindrical glass channels of 10º, 20º, 30º, 40º, 50º and 60º. the result presented in Fig. 2 for water sample shows a linear increase in Time (*T*) as the Volume (*V*) of water recovered increases from 100ml, to 200ml, 300ml, 400ml and a slight decrease in the gradient of the trend from 400ml to 500ml for the cylindrical bifurcated angle of 10º. For the bifurcation angle of 20º, a linear increase in Time is seen from 100ml to 400ml and a slight increase in the gradient from 400ml to 500ml. the profile of results obtained for the water sample reveals that for small angles of bifurcation, as the volume of water in the reservoir decreases, the flow pressure at the outlet decreases which corresponds to the change in the gradient observed at the trend for higher recovery volumes of 400ml and 500ml. while for higher angles of bifurcation, pressure gradient in the flow due to the change in the volume of water in the reservoir does not show any change in the Time even for low flow pressure and high recovery volume. The closeness of the trends for this profile of result shows that there is not much effect of bifurcation on this fluid sample.

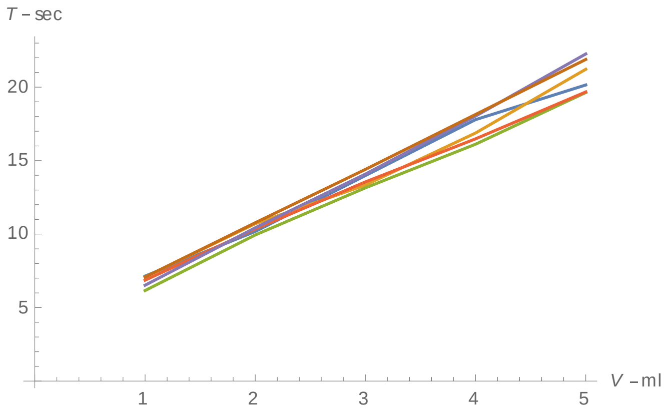

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Fig. 1: The dependence of Volume of fluid samples upon time

B. *Groundnut Oil Sample*

The effect observed for peanut oil in Fig. 3, shows an overlapping trend for 10º, 20º, and 30º angles of bifurcation as recovery volume increases from 100ml to 400ml, and a sudden increase in the gradient of the trend from 400ml to 500ml for 20º angle of bifurcation. And increase can be seen in the spacing in the trends and the gradients of each of the trends from 300ml to 500 ml for 40º and 50º, from 200ml to 400ml, and from 400ml to 500ml for 60º angles of

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bifurcation. The profile of result obtained for this fluid samples shows that the pressure gradient due to the change in the volume of this fluid sample in the reservoir does not affect the flow rate at 10º, 20º and 30º angles of bifurcation, but shows significant effect for 40º, 50º and 60º angles of bifurcation. The spacing of the trends for the higher angles reveal that the effect bifurcation is more significant for higher angles of bifurcation.

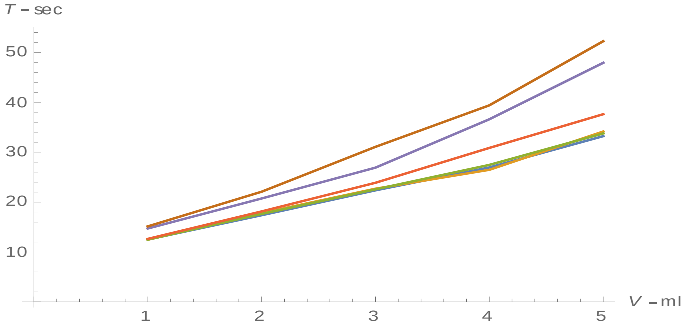

Fig. 2: The dependence of Volume of fluid samples upon time

C. *Crude Oil Sample*

Crude oil shows in Fig. 4, a linear increase in time as the volume of fluid to be recovered increases. The profile also shows an increase in gradient of the time taken as the pressure of the flow begins to drop due the change in the volume of the fluid sample in the reservoir for designated recovery volume of 300ml, 400ml and 500ml for higher angles of bifurcation.

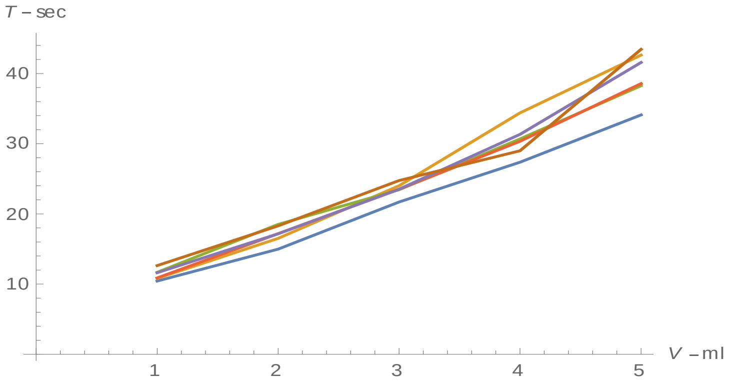

Fig. 3: The dependence of Volume of fluid samples upon time

D. *Diesel Sample*

For realistic values of the properties of diesel, the profile of result of Fig. 5, shows a linear increase in the time as the designated volume decreases as the angle of bifurcation increase for this fluid sample, which implies that as the pressure of the flow decreases due to the decrease in volume of the fluid, the flow rate also decrease as the bifurcating angle increases for this fluid sample.

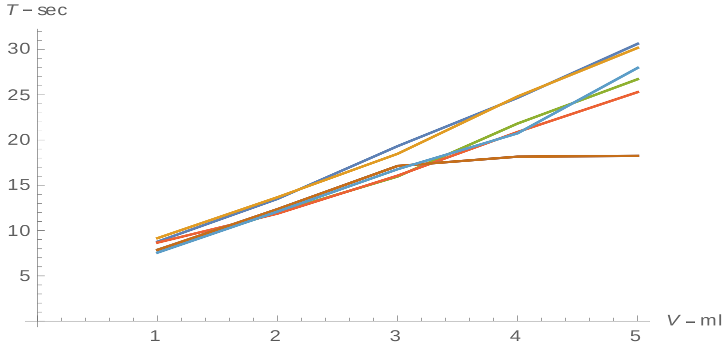

Fig. 4: The dependence of Volume of fluid samples upon time

E. *Profile of the flow rate of the selected fluid sample through an angle of bifurcation*

The profile of results presented in the figures [5, 6, 7, 8, 9, 10] which compares the flow time through the various angle of bifurcation for each of the fluid samples. The result shows that as the density of the selected fluid samples increase from water, diesel, crude oil and peanut, the time taken to recover the designated volume of the selected fluid sample also increases for 10º, 20º, 30º and 40º angles of bifurcation.

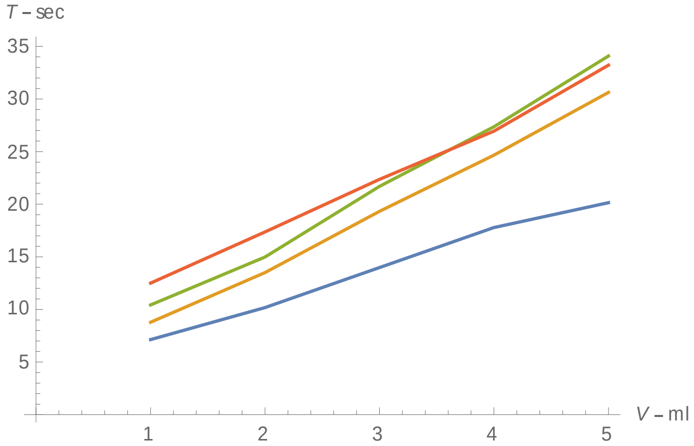

Fig. 5: flow rate of the selected fluid sample through an angle of bifurcation

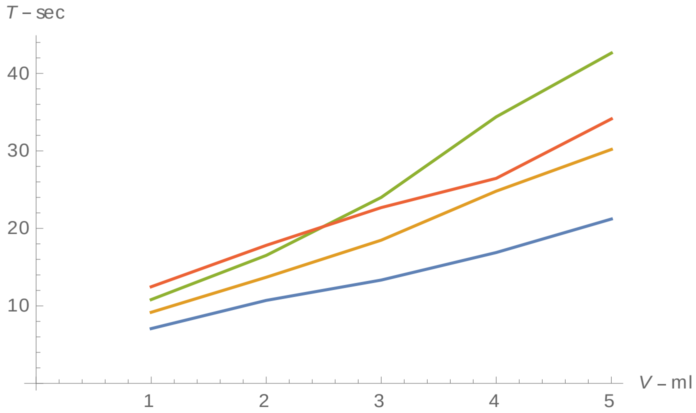

Fig. 6: flow rate of the selected fluid sample through an angle of bifurcation

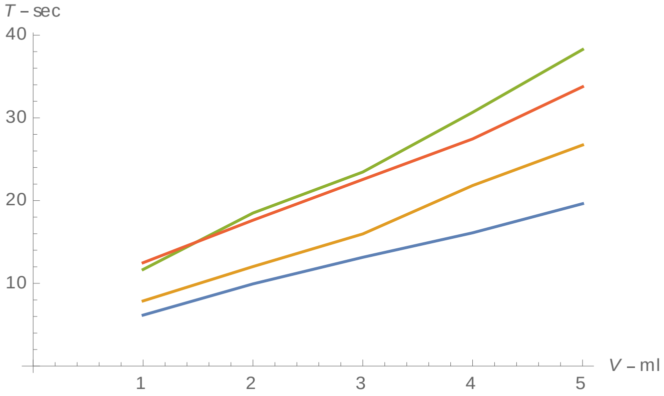

Fig 7: flow rate of the selected fluid sample through an angle of bifurcation

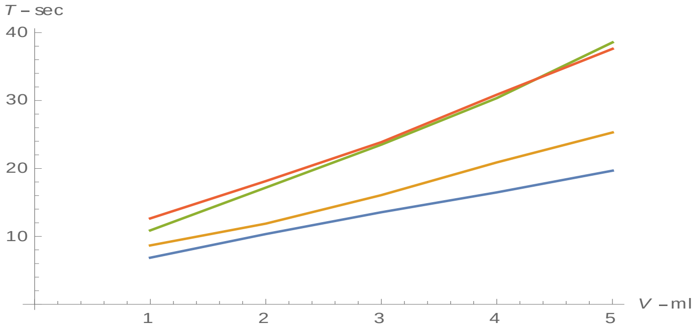

Fig 8: flow rate of the selected fluid sample through an angle of bifurcation

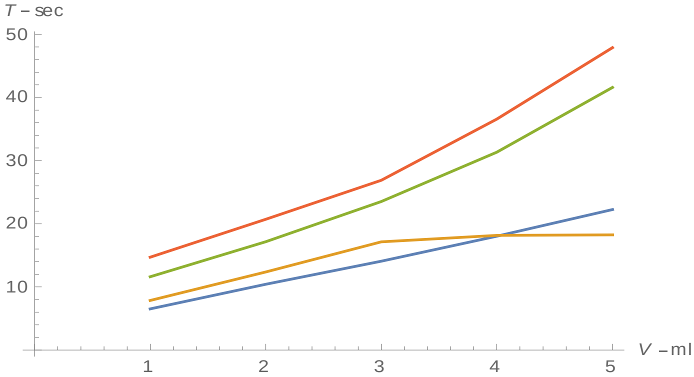

Fig. 9: flow rate of the selected fluid sample through an angle of bifurcation

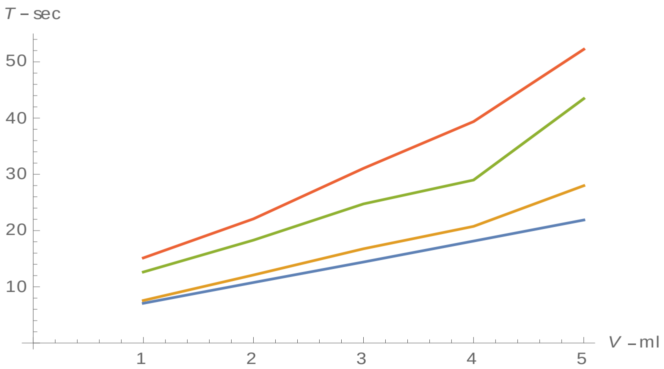

Fig. 10: flow rate of the selected fluid sample through an angle of bifurcation

V. CONCLUSION

The angles of bifurcation reduce the flow rate of the fluid samples flowing through it, thereby making the fluid samples to attain quickly a lamina flow state.

VI. ACKNOWLEDGMENT

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