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Flow Velocity Gradient of Refined Hydrocarbon and Viscous Fluid in A Single Stage Symmetrical Bifurcated Channel

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ABSTRACT: A single stage bifurcated system in its wide spectrum of applications in the petroleum and gas processing industry, chemical industry and civil engineering industry, in the distribution and recovery of processed and unprocessed fluid and materials. Considered in this experimental investigation of the impact of a single stage symmetrical bifurcated system on the flow of viscous fluid and refined hydrocarbon to truly establish a relationship between specific dimensions ofsymmetrical bifurcatedflow channels and the physical properties of various classes of fluid samples. Peanut oil and diesel were selected to respectively represent viscous fluid and refined hydrocarbon, as they are allowed to flow through some selected angles of a single stage symmetrical bifurcated channel until designated volumes of each of the fluid samples are recovered into a recovery beaker. Profile of results presented from the experimental study reveals a trend with a sharp negative velocity gradient for small flow time corresponding to smaller recovery volume and a much lower velocity gradient for relatively higher flow time for higher recovery volume for less viscous and dense diesel oil representing refined hydrocarbon and a more viscous and dense peanut oil represented by the trend with a lower negative velocity gradient. The implication of the results obtained is that bifurcated systems offer flow stability in a continuous flow situation, and also observed from the results is the confirmation of the existence of velocity gradient between opposite wall of the branched channels, which further reveals where the flow state will eventually begin to graduate into turbulence. The study can be extended by investigating the impact of two-stage or multiple level bifurcated network system on flow structure and stability, and how the pressure based on the level of fluid in the reservoir is related to the flow velocity and stability.

Keywords; *Flow velocity, Symmetrical Bifurcation, Viscous fluid, refined Hydrocarbon*

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INTRODUCTION

Bifurcation is the branching of the main channel also called the mother channel into two more channels called the daughter channels. The importance of the geometrical system of bifurcation has been sighted almost in all physical environment ranging from engineering, hemodynamics in human physiology, fluid transport phenomenon, multi distributor system, transportation of water and nutrients in plant, in electrical circuits design, and in astrophysical environment. Research in the field of bifurcation has attracted great interest in the past two decades, a host of literatures on the various application, and geometrical consideration of bifurcated system have been developed in order to greatly understand the dynamical state of where they are found. Bifurcated systems have offered a lot of solution in the distribution of fluid in green plant, human arterial system, etc. In a bifurcated system, it can be easily seen that the angle of bifurcation can be resolved into vertical and horizontal distance/component and the total length of a bifurcated system, and it further depends on the angle of bifurcation. Hence, the flow distance considered in this study, depends on the angle of bifurcation which will further determine the time of flow through each of the lengths, for polar solvents and unrefined hydrocarbons.Using the PIV technic [1] experimentally studied the flow dynamics in perpendicular branched channels of rectangular cross-sectional area, and in their result as they were able to explain how heat transfer process is affected by the flow. [2] visually examine the operation of the break-ups of viscous fluid droplets, and they were able to obtain an explain of the phenomena that is linked with the compression, transition of viscous fluid droplets as well as the pinch-off regime of viscous fluid droplets through the symmetrical bifurcated micro-channel. [3] considered bifurcation in irrigation and drainage management system, waste-water treatment system, as they investigate flow bifurcation in river open channel, and the results they obtained in this study according to the dimensions of the channels geometry, shows that the out flow from the branched channel depends on the linkage parameters to the main channel, and the outflow velocity increases with decrease of the inflow velocity of the main channel. [4] considered river Tigris of Iraq in their study of river bifurcation on deposition and scouring zone. Hydro-morphodynamic simulation was done using numerical model, and the location of enhancement of flow velocity distribution and depth is concluded to be the most effective location. [5] in the examination of the 3-dimensional flow characteristics of branched cylindrical channel for a fully developed laminar flow situation, a 3-dimensional code was used to numerically analyze where they were able to show the existence of two domains of distinct distribution of flow at the outlet which depends on the flow Reynolds number, whose results further presented shows a periodic characteristic, as the flow Reynolds is increased, hence resulting into a swirling flow behavior. [6] discovered how the total force at the junction point of the bifurcated led to the deformation accounted for in their numerical study of the 2-dimensional study of the bifurcation of elastic capsule. The deformation at the junction point is confirmed in this study to be a function the bifurcation angle, and the deformation is further shown to be greater for fluid with higher viscosity.[7] investigated the use of both Y-shaped and T-shaped symmetrical bifurcated network channel, with angles ranging from 30o to 180o in sorting deformable cells of specific types, using the custom computation technic and numerical simulation they were able to establish a relationship between the critical bifurcation angle, cell size, cytoplasmic-viscoelasticity, cortical tension, and flow velocity. Their paper further the cell trapping for white blood cells and tumor cells which is seen to be most efficient for Y-shaped angle of 120^o. [8] 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, while [9] conducted a comparative analysis of the flow of polar solvent and unrefined hydrocarbon, and results of the study presented show flow properties peculiar to the category of fluid select for the experimental study.

The work aims to carry out a comparative study on the flow behavior of viscous fluid and refined hydrocarbons in a cylindrical bifurcated channel, where peanut oil and diesel oil respectively representing these two 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 angles of bifurcation.

MATERIALS

Peanut oil, and diesel oil are the fluid samples selected to represent their respective 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, coconut oil, chicken oil etc. whose viscosity is usually in multiples of ten (10). Diesel represents thecategory of processed hydrocarbons. Table 1 presents some the physical properties of the selected fluid samples.

Table 1: physical properties of the selected fluid samples

Fluid Sample	**Density *ρ(kg/m³)***	**Viscosity *μ(cP)***	**SG (*kg/cu.m)***
Diesel	894.33	0.89	885.00
Vegetable oil	919.70	34.6	0.92

DESIGN AND FABRICATION OF FLOW CHAMBER

Experimental setup

- Beakers (Two 500ml)
- Peanut oil (8litres)
- Diesel fuel (8litres)

The reservoir is kept at a vertical height of 4ft from the horizontal surface of the earth, and one end of the mainchannel is connected to the tap valve located at the bottom of the reservoir and the symmetrical bifurcated ends of the channel declining at an angle is properly positioned where the fluid samples can easily be recovered in the beakers.

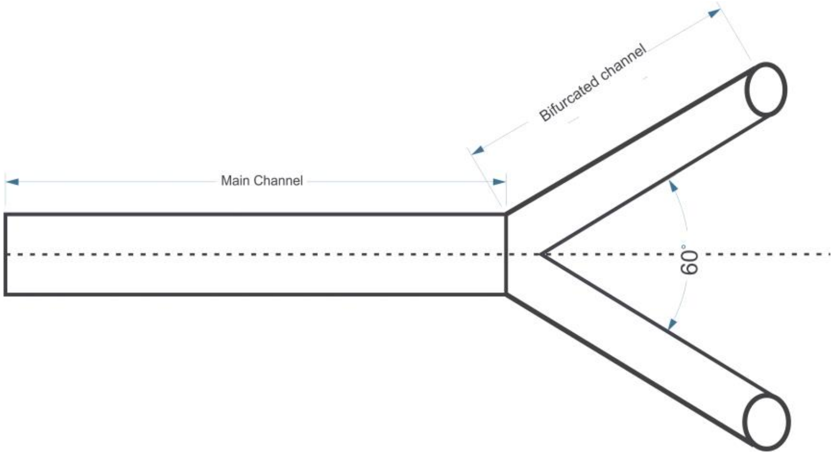

Figure 1: Channel geometry of Symmetrical Bifurcated System

The two daughter channels of the bifurcated tube are then connected to the beakers for the recovery of the fluid samples.

Experimental Procedure

The experimental procedureas presented in [10, 12],is carried out repeatedly volume after volume beginning from 100ml, 200ml, 300ml, 400ml to 500ml for every single stage symmetrical bifurcated tube, also beginning from 10^o, and is further repeated 20^o, 30^o, 40^o, 50^o and 60^o. the entire experimental procedure is repeated again for the selected fluid samples beginning with peanut oil and diesel oil. It should be mention here that after the recovery of each designated volume, the volume of the fluid sample is returned back into the reservoir before repeating the process for the net volume.

RESULTS AND DISCUSSION

Considering the physical properties of the fluid samples presented in table 1, selected for this experimental investigation and the selected angles of a single stage symmetrical bifurcated network system of figure 1. The result of the data obtained for diesel for the perpendicular and parallel components of the symmetrical Y-shaped channel were respectively presented in figures 2 and 3. While figure 4 presents the profile of results that shows the trend of the parallel and perpendicular components of the volume-dependent velocity components. Figures 5 and 6 contains the profile of results the comprises the trends representing the flow velocity of peanut oil through the selected angles of the symmetrical single stage bifurcated channel. While figure 6 present the profile of results that compares the parallel and perpendicular velocity component of peanut oil for the selected angles of the symmetrical single stage bifurcated channel. from the centerline of bifurcation as shown in the figure 1, (5^o, 10^o, 15^o, 20^o, 25^o and 30^o) of bifurcation for the designated volumes of 100ml, 200ml, 300ml, 400ml and 500ml.

Diesel

The trends of the volume dependent velocities of the component perpendicular to the main flow axis is presented in Figure 2, which shows the trendlines represents how the flow velocity increases as the angle of the single stage symmetrical bifurcated system increases from 5^o, 10^o, 15^o, 20^o, 25^o and 30^o for 100ml, 200ml, 300ml, 400ml and 500ml recovery volume. Which implies that increasing symmetrical bifurcation angles, which means decreasing total flow length of the pipe from the reservoir, further implies that less time will be required to recover the same volume of fluid samples for higher angles of bifurcation. Comparing the result obtained with the results obtained by [Egbo et al (2022)], we observed the following initial & final values of flow velocity of water 0.13 - 0.05, 0.15 – 0.06, 0.25 – 0.10, 0.23 – 0.11, 0.19 – 0.07, and 0.13 – 0.07, and the initial and final velocity values of crude oil were observed to be within the range of 0.09 – 0.03, 0.10 – 0.03, 0.13 – 0.05, 0.15 – 0.06, and 0.14 – 0.08 compared to the initial and final values obtained from diesel oil for 5°, 10°, 15°, 20°, 25° and 30° single stage angles of symmetrical bifurcation.

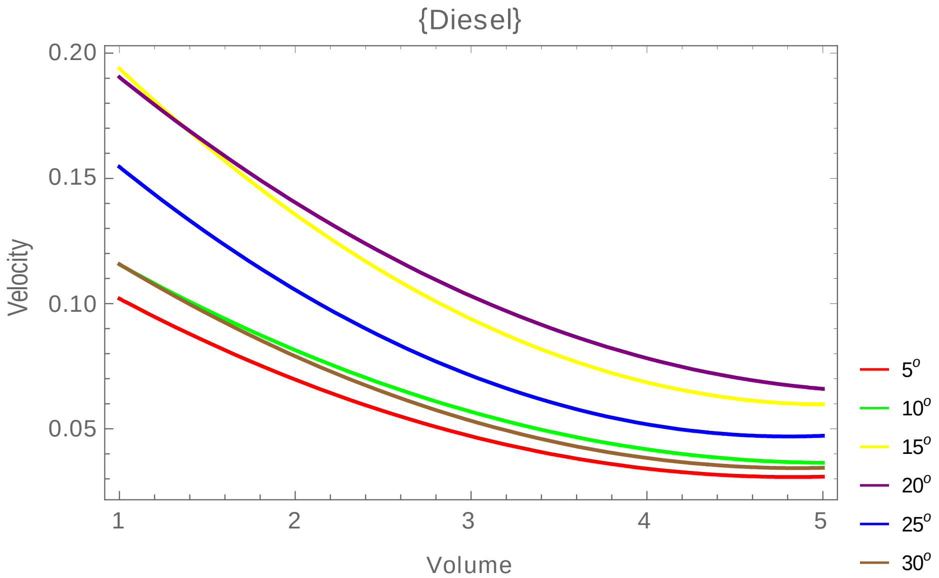

Figure 2: Dependence of vertical-velocity component on volume for diesel oil

Figure 3 presented result of the component parallel to the main axis, the trends in the result which roughly corresponds with the order of the increase in the angles of bifurcation. It can be roughly seen that increasing angles of symmetrical bifurcation is corresponds to the decreasing velocity values for split angles of 5°, 10°, and 15°, while as the flow becomes more stability the trends for the selected angles is seen to be in the order 25°, 20°, and 30°. Comparing the results of this study with the results obtained by [Egbo et al (2022)], which shows the following range of velocity values 0.20 – 0.08, 0.13 – 0.05, 0.16 – 0.05, 0.21 – 0.10, 0.26 – 0.10, 0.19 – 0.07 and 0.14 – 0.05, 0.09 – 0.02, 0.08 – 0.03, 0.13 – 0.05, 0.13 – 0.04, 0.11 – 0.04 for water and crude oil respectively compared with the flow velocity values 0.16 – 0.06, 0.10 – 0.03, 0.13 – 0.04, 0.17 – 0.06, 0.21 – 0.07 and 0.18 – 0.05 of diesel oil. Comparison of the respective range of values of the selected angles shows that the velocity values of diesel oil fall in between the values of water and crude oil respectively, which is a consequences of the physical properties of the fluid.

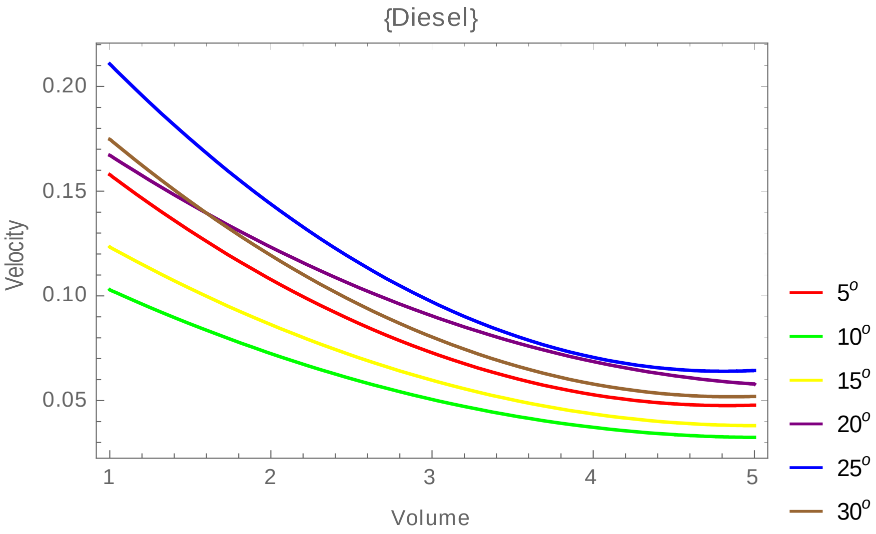

Figure 3: Dependence of parallel-velocity component on volume for diesel oil

Peanut oil

Figure 4 presents the profile of result for the component perpendicular to the main flow axis shows a pattern that shows the velocity through each angle of the single stage symmetrical bifurcated system, the profile further reveals how the velocity increases with increasing angle of bifurcation. Also comparing the range of the velocity values 0.07 – 0.03, 0.09 – 0.04, 0.13 – 0.06, 0.13 – 0.05 and 0.06 – 0.02 for the selected respectively with their counterpart in the profiles of results obtained in [Egbo et al (2022)] water 0.13 - 0.05, 0.15 – 0.06, 0.25 – 0.10, 0.23 – 0.11, 0.19 – 0.07, and 0.13 – 0.07, and the initial and final velocity values of crude oil were observed to be within the range of 0.09 – 0.03, 0.10 – 0.03, 0.13 – 0.05, 0.15 – 0.06, and 0.14 – 0.08, further reveals how the results obtained in this study is shown to be relatively more stable which is as a result of the physical properties of the fluid sample.

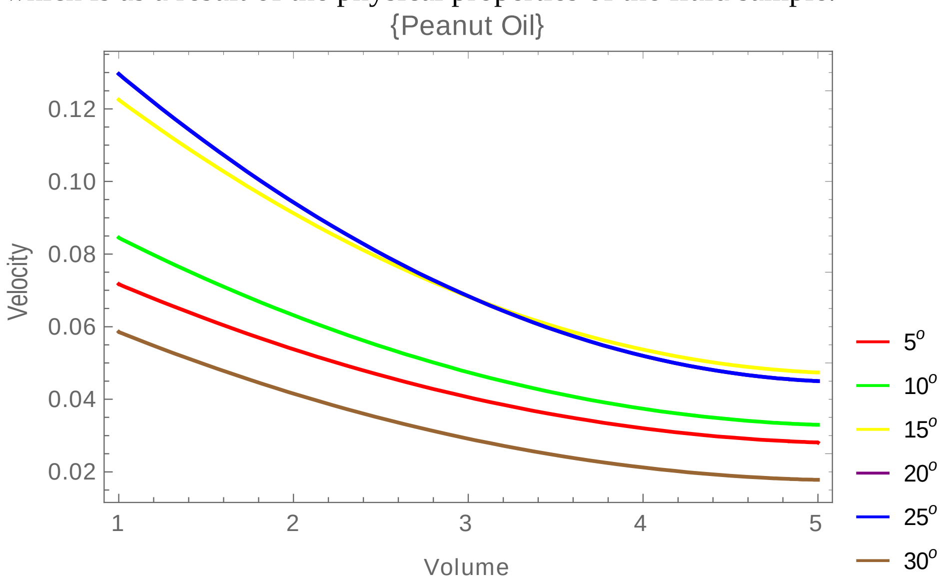

Figure 4: Dependence of vertical-velocity component on volume for vegetable oil

In the profile of figure 6 that presents the trends of velocity component of the axis parallel to the main flow channel, and the trend of result shows that the flow velocity decreases as the angles of the symmetrical bifurcated system increases, also comparing the range of results obtained for this component 0.11 – 0.04, 0.08 – 0.03, 0.08 – 0.03, 0.11 – 0.05, 0.11 – 0.04, and 0.09 – 0.05 with the range of values 0.20 – 0.08, 0.13 – 0.05, 0.16 – 0.05, 0.21 – 0.10, 0.26 – 0.10, 0.19 – 0.07 and 0.14 – 0.05, 0.09 – 0.02, 0.08 – 0.03, 0.13 – 0.05, 0.13 – 0.04, 0.11 – 0.04 obtained by [Egbo et al (2022)] for water and crude oil respectively. The results obtained here also confirms the significance of viscosity, density and other physical properties of a fluid on flow stability.

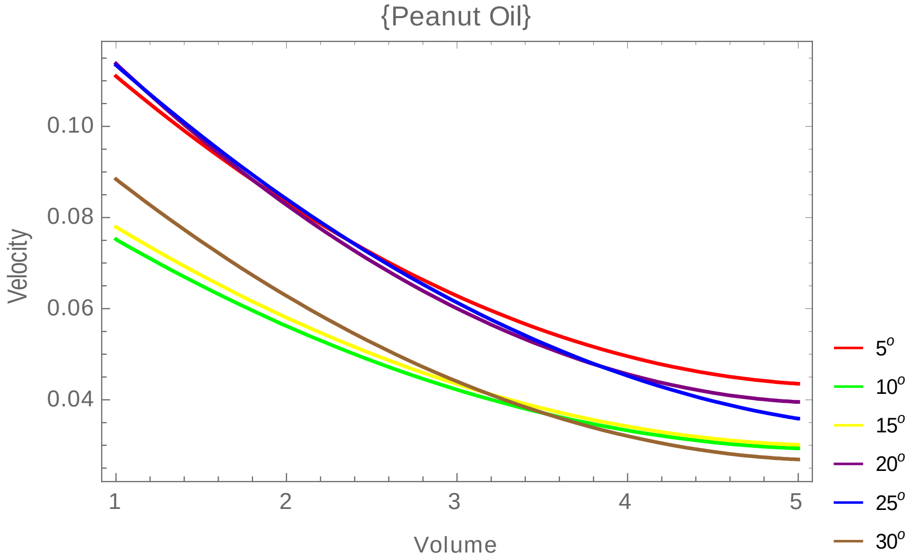

Figure 5: Dependence of parallel-velocity component on volume for vegetable oil

Results of the comparation of the velocity components of the single stage symmetric bifurcation for each of the angles is presented in figure 6 for water and figure 7 for peanut oil. Critical observation of the results on the velocity axis reveals how the physical properties of the selected fluid is the determining factor of the flow velocity of fluid in a symmetrical network channel. The blue and purple trends in the results are the perpendicular and parallel components of the flow velocity, the patterns of the trends which is similar to the ones obtained by [Egbo et al, 2022] which confirms the existence of velocity difference at direct opposite walls of a branched tube of a symmetrical bifurcated network system.

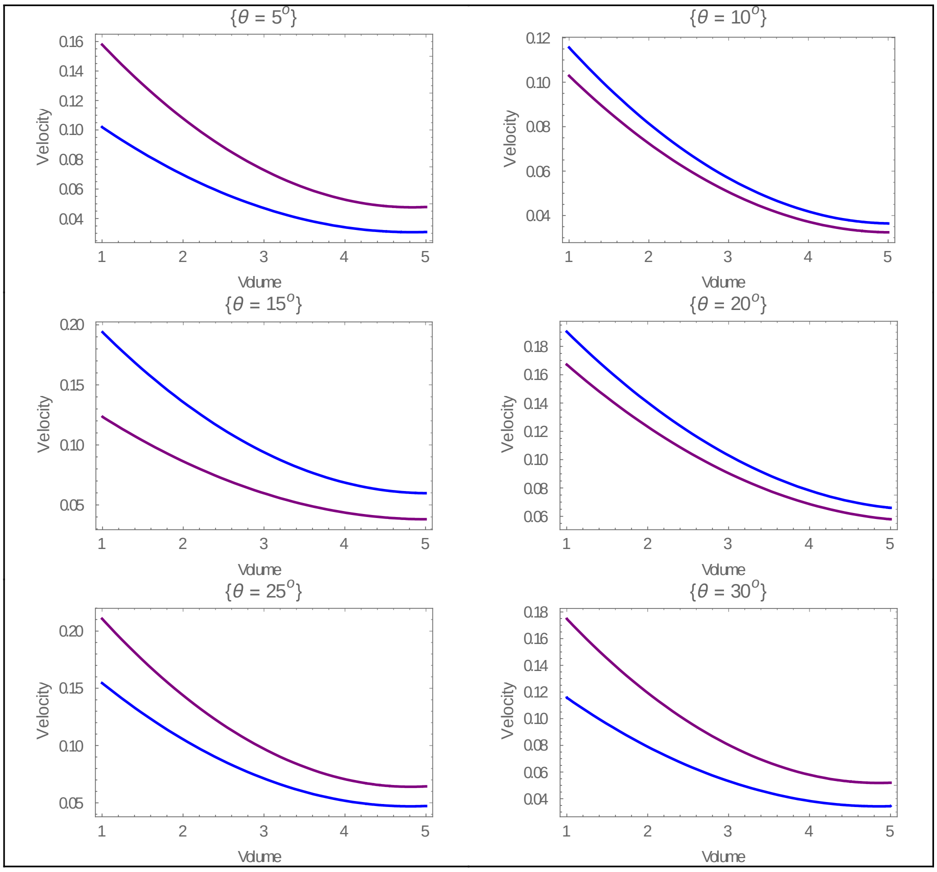

Figure 6: Dependence of vertical and parallel velocity component on volume for diesel oil

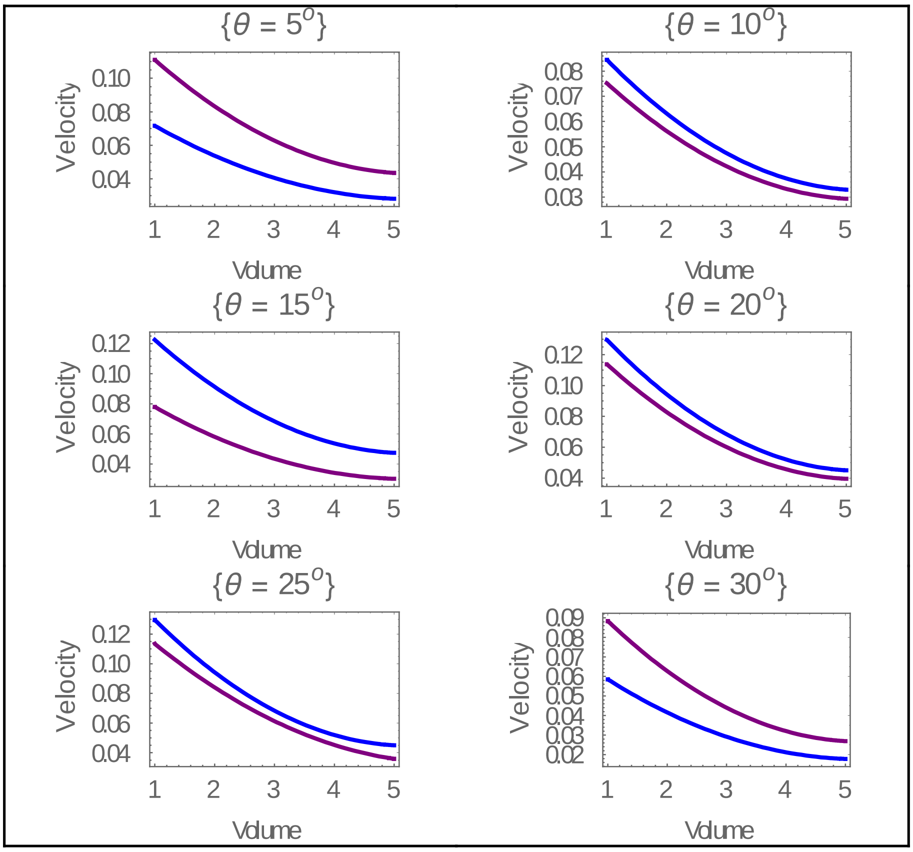

Figure 6: Dependence of vertical and parallel velocity component on volume for peanut oil

CONCLUSION

The flow patterns revealed by the volume-velocity trends depends ultimately on the geometric dimension of symmetrical bifurcated network system. The velocity gradient of the trends is determined by the physical properties of the fluid samples, as diesel with density and viscosity of 894.33 and 0.98 is observed to have a higher velocity gradient than peanut oil of density and viscosity 919.70 and 34.6 respectively. We further conclude that the impact of symmetrical bifurcation on fluid flow can be truly seen for higher recover volume or in a continuous flow situation. There exists an outward pressure at the junction of symmetrical bifurcation inline with [6] which appears at second flow regime defined by the relatively low velocity gradient of 500ml to 300ml.

RECOMMENDATIONS

The study can be extended by investigating the impact of two-stage or multiple level bifurcated network system on flow structure and stability, and how the pressure based on the level of fluid in the reservoir is related to the flow velocity and stability.

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