Effect of Types of Fluids on Fluid Flow Characteristics in Bifurcated Vessel using CFD Simulation

Yogesh Dewang[1] & S K Panthi[2]

[1]Department of Mechanical Engineering, LNCT Bhopal 462021, India
[2] CSIR- Advanced Materials and Processes Research Institute, Bhopal 462 026, India

The present study focuses on the CFD analysis of bifurcated blood vessel using ABAQUS /CFD 6.14 software in order to investigate the effect of types of fluids on resultant velocity and axial velocities of flow. It has been found that out of resultant velocity and axial velocity in three mutually perpendicular directions, types of fluids have significant influence on velocity in z-direction. A significant increment of nearly 45 % in maximum velocity in z-direction has been obtained from benzene to Newtonian blood.

Introduction

Bifurcated vessel is a fluid flow vessel divided into two branches, such as blood vessel, or a tooth that has two roots. Bifurcations are very common in blood vessels and in the bronchial 'tree' of the lungs. In past various researchers contributed in the domain of analysis of fluid flow problems using CFD. Malek and Hoque[1] developed theoretical formulation based on stenosis and hematocrit effects and found that resistance of flow increases with increment in stenosis height. Kumar *et al.*[2] utilized the technique of CFD for carrying out simulation for assessing the effectiveness in predicting the behaviour of blood flow in arteries. Jieyan[3] developed CFD tools and related models for simulation of pulsating blood flow aortic aneurysm (AAA) and stent graft. Khan *et al.*[4] conducted CFD simulation for hemodynamic simulation studies to gain a better understanding of functional, diagnostic and therapeutic aspects of blood flow and found that by considering blood as Newtonian or non-Newtonian has no significant effect on the results for measurement of wall shear stress as the primary consideration. Panta *et al.*[5] utilized CFD simulation for analysis of different human aortic models including straight, bend, T-shaped and the main arterial branching areas and found that turbulent flow with complaint muscle boundaries will provide more realistic results compared to the clinical studies. Ganesan and Mayakrishnan[6] used Computational Fluid Dynamics (CFD) in the analysis of blood flow. The objective of the present work is to study the effect of different types of fluid on resultant and axial velocities of fluid within a bifurcated blood vessel through CFD simulation using commercially available ABAQUS/CFD 6.14.

Methodology for CFD Analysis of Bifurcated Blood Vessel

In the present analysis CFD simulation is carried out to investigate the effect of different types of fluid on resultant velocity and axial velocities of flow in bifurcated vessel. Newtonian blood, Non-newtonian blood, water and benzene are considered as four different fluids considered in the present analysis. Density and viscosity are the two major properties are majorly considered during CFD analysis. Carreau-Yasuda constitutive law is utilized for defining non-Newtonian model for blood. Material properties of different types of fluids used in this study are given in the Table 1. Proper boundary conditions and initial conditions are applied on the inlet and two outlets of the

Table 1 — Properties of fluids used for CFD simulation[7].

S. No.	Name of fluids	Density	Viscosity
1.	Newtonian blood	1E-9 tonne/mm^3	2.5E-9 MPa-s
2.	Non- Newtonian blood	1E-9 tonne/mm^3	Carreau-Yasuda
3.	Water	1E-9 tonne/mm^3	1E-9 MPa-s
4.	Benzene	0.876e-9 tonne/mm^3	0.601 E-9 MPa-s

***Corresponding author (E-mail: sanjaypanthi@ampri.res.in)

bifurcated vessel. Meshing of bifurcated vessel is carried out using two different mesh sizes of different global mesh size of 0.3 (fine mesh) and 0.7 (coarse mesh).

Results and Discussion

Effect of types of fluids on maximum resultant velocity

Figure 1 shows the effect of different types of fluids namely Newtonian blood, Non-Newtonian blood, water and benzene on maximum resultant velocity in a bifurcated blood vessel. It is gathered from the Fig. 1 that the maximum resultant velocity is highest for the case of Newtonian blood, second highest for the water and third highest is for benzene and least maximum resultant velocity is for the non-Newtonian blood. It can also be recognized from the figure that there is percentage reduction in maximum resultant velocity of   nearly 4 % (while considering mesh size = 0.7) from Newtonian blood to non-newtonian blood. The results obtained for different mesh sizes for this case are quite comparable and negligible effect due to mesh size.

Effect of types of fluids on maximum axial velocity

Figure 2 shows the effect of different types of fluids on maximum axial velocity in x-direction. It is gathered that highest maximum axial velocity in x-direction is for both water and benzene at a mesh size of 0.7. Second
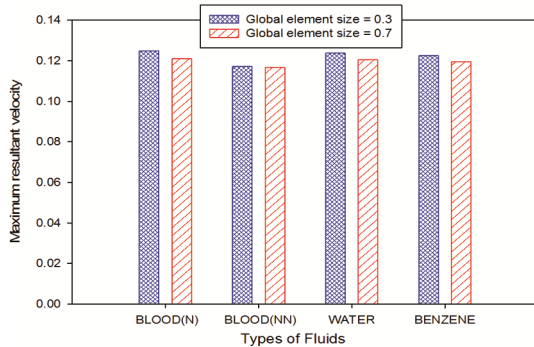
highest maximum axial velocity in x-direction is coming for the Newtonian blood while least maximum axial velocity in x-direction is coming for the case of non-newtonian fluid. It is found that there is an increment in maximum axial velocity in x-direction from non-newtonian blood (least) to Benzene (maximum) by nearly 8 %.

Figure 3 shows the effect of different types of fluids on maximum axial velocity in y-direction. It is found that highest maximum axial velocity in y-direction is obtained for benzene. Second and third highest maximum axial velocity in y-direction is obtained for water and Newtonian blood. The least maximum axial velocity in y-direction is obtained for non-newtonian blood. It is found that there is an increment in maximum axial velocity in y-direction from non-newtonian blood (least) to Benzene (maximum) by nearly 9%.

Figure 4 shows the effect of different types of fluids on maximum axial velocity in z-direction. It is found that the maximum axial velocity in z-direction is highest for the case of Newtonian blood. Second and third highest maximum axial velocity in z-direction is obtained for the non-newtonian blood and water. The least maximum velocity in z-direction is obtained for the
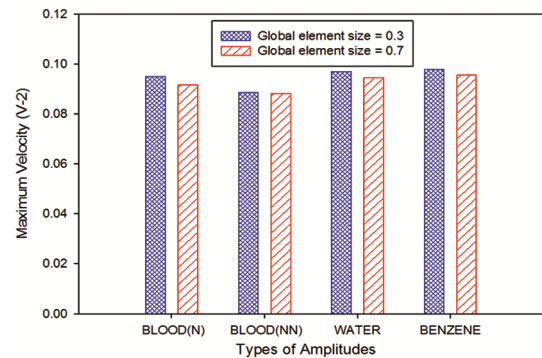

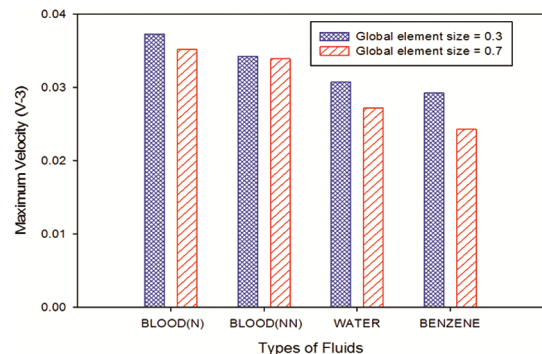Fig. 1 — Effect of types of fluids on maximum resultant velocity.

Fig. 2 ——— Effect of types of fluids on maximum velocity in x-direction.

Fig. 3 — Effect of types of fluids on maximum velocity in y-direction.

Fig. 4 — Effect of types of fluids on maximum velocity in z-direction.
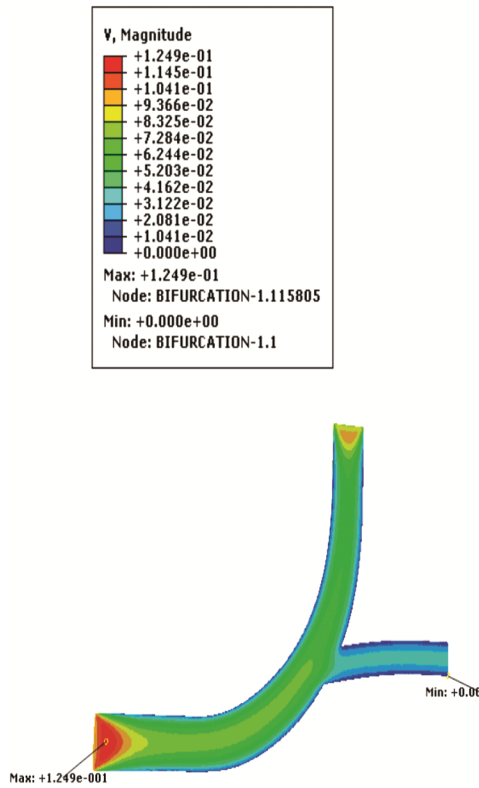
case of benzene. A significant increment of nearly 45 % in maximum velocity in z-direction is obtained from benzene to Newtonian blood case.

Contour plots: Effect of types of fluids

The following section shows the contour plots of resultant velocity and axial velocities in x, y and z-direction. Figures 5 to 8 show the contour plots of

Fig. 5 — Contour plot of resultant velocity for Newtonian blood.
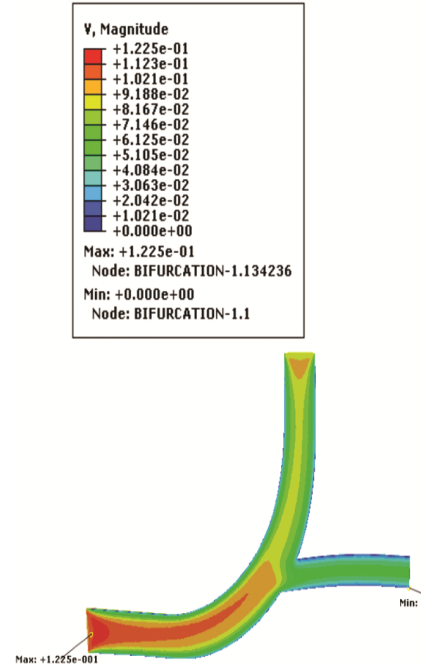

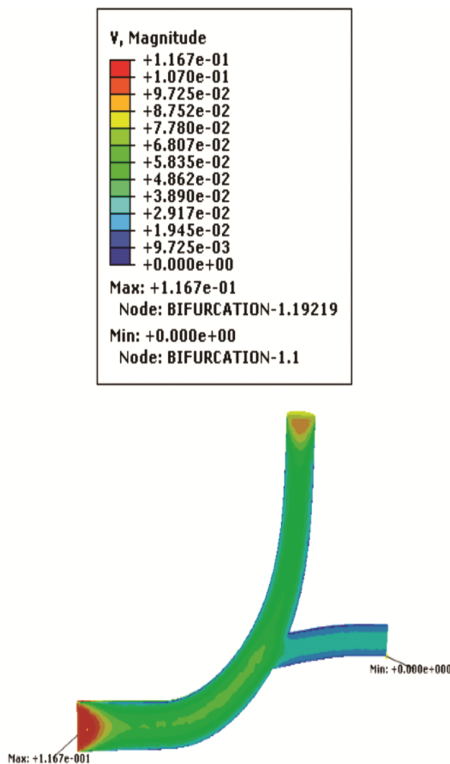Fig. 7 — Contour plot of resultant velocity for benzene.

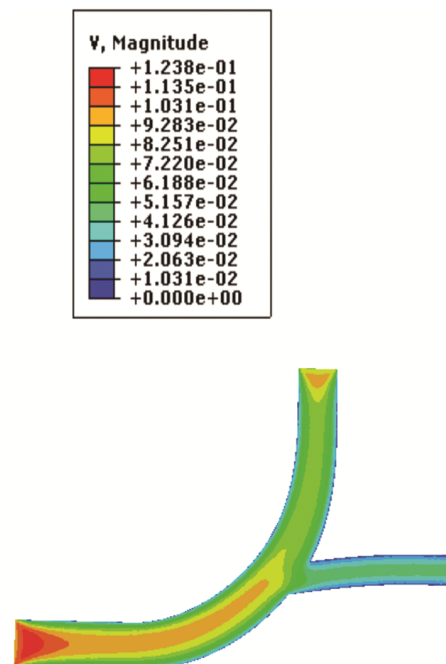Fig. 6 — Contour plot of resultant velocity for Non-Newtonian blood.

Fig. 8 — Contour plot of resultant velocity for water.

resultant velocity for Newtonian blood, non-Newtonian blood, benzene and water.

Conclusions

In the present research work, CFD analysis of bifurcated blood vessel has been carried out to investigate the effect of four different types of fluids on the fluid flow characteristics. It is found that the maximum resultant velocity is highest for the case of Newtonian blood, second highest for the water and third highest is for benzene and least maximum resultant velocity is for the non-Newtonian blood. It is also recognized that there is percentage reduction in maximum resultant velocity of nearly 4% (while considering mesh size = 0.7) from Newtonian blood to non-newtonian blood. It is found that there is an increment in maximum axial velocity in x-direction from non-newtonian blood (least) to Benzene (maximum) by nearly 8%. It is found that there is an increment in maximum axial velocity in y-direction from non-newtonian blood (least) to Benzene (maximum) by nearly 9%. A significant increment of nearly 45% in maximum velocity in z-direction is obtained from benzene to Newtonian blood case.

References

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