Summary

The present investigation deals with (a) the theoretical modeling on blood flow (b) for, steady and pulsatile behaviour of blood flow in a (i) stenosed artery, (ii) catheterised stenosed tapered artery and (iii) catheterised stenosed artery respectively, (c) with the flowing fluid blood, behaving as both Newtonian and non-Newtonian fluids, (d) for three different types of stenosis development at an artery wall and (e) subject to a velocity slip condition at the flow boundary. The aim of the present work is four fold viz.,

(i) To study the Newtonian and non-Newtonian behaviour of blood flow through a catheterized constricted tapered artery.

(ii) To study the role of velocity slip at the stenotic wall and at the catheterized wall (for one-layered flow) and at the interface (for two-layered flow).

(iii) To study the effect of externally imposed body acceleration on the flow of blood in a constricted tube.

(iv) To study the combined effect of slip, stenosis size, non-Newtonian character of blood and externally imposed body acceleration.

A mathematical model has been developed here for each flow situation.

Chapter 1 accounts for a general introduction, involving general and relevant information about cardiovascular system (cvs), its primary components, their composition and role in blood flow, review of literature accommodating theoretical models and experimental observations, a summary of the present work and the list of communications, prepared from this theoretical investigation.

Chapter 2 deals with the flow of blood (behaving as a Newtonian fluid) in a catheterised tapered artery with the unbecoming growth of a stenosis, subject to the presence of an axial velocity slip at the flow boundary. A slip condition in axial velocity in three flow situations viz., slip at the stenotic wall, at the catheter wall and at both the walls, has been employed in three cases (I-III) which are taken care of separately in three models (M1, M2, M3). Governing equations of the fluid flow have been integrated, under the boundary conditions considered. Analytical expressions for different flow variables have been obtained, a second representation of these
variables, are also presented and their variations with different flow parameters are depicted in figures. It is observed that velocity and flow rate, as expected increases with a velocity slip at wall but wall shear stress and apparent viscosity reduce due to an introduction of a velocity slip. It is also clearly understood from this chapter that increase in the size of stenosis and tapering angle of the artery, reduce axial velocity and flow rate but improve wall shear stress and apparent viscosity.

In Chapter 3 the flow of blood (behaving as a Power-law fluid) in a catheterised tapered artery with the formation of a stenosis, subject to the presence of an axial velocity slip at the flow boundary is considered. A slip condition in axial velocity at the stenotic wall, at the catheter wall and at both the walls, has been employed in three successive cases (I-III) which are taken care of separately, in three models (M1, M2, M3). Governing equations of the flow are integrated with the boundary conditions as considered in the investigation. Analytical expressions for different flow variables, as well as their dimensionless forms have been obtained and their variations with different flow parameters, are shown in figures. It is observed that velocity and flow rate as before increases with a velocity slip at wall but wall shear stress and apparent viscosity, decrease due to the introduction of a velocity slip. It is also clearly understood that increase in the size of stenosis and tapering angle of the artery, reduce axial velocity and flow rate but indicate a rise in both wall shear stress and apparent viscosity. Further, an increase in the fluid behaviour index (n) increases the axial velocity but decreases both the flow rate and apparent viscosity.

Chapter 4 addresses the two-layered steady flow of blood, behaving as a Newtonian fluid of different viscosities, in both core and peripheral plasma layer through a uniform catheterised artery with three different types of stenosis viz. mild, moderate and severe growths. An axial velocity slip is introduced at interface of two fluids. Governing equations are solved with the help of boundary conditions, employed in this investigation. Analytic expressions for axial velocity, flow rate, wall shear stress and apparent viscosity, have been found out, a second representation of these variables are also obtained and their variations with various flow parameters, are presented graphically. It has been observed that an employment of a velocity slip condition at the interface, plays an important role, in enhancing both velocity and flow rate and in reducing the resistance to flow.
Chapter 5 deals with pulsatile motion of blood (behaving as a Newtonian fluid) inside a uniform artery with the growth of a mild stenosis, under the influence of a periodic body acceleration. An axial velocity slip has been considered at the stenotic wall. Governing equations are solved by using a perturbation technique and the expressions for axial velocity, flow rate, wall shear stress and apparent viscosity, are obtained. Variations of these flow variables, due to different flow parameters, are represented graphically. It is observed that both the axial velocity and the volumetric flow rate increase with an increase of a velocity slip but decrease with an increase in height of a stenosis. Further, rise in the body acceleration enhances both the axial velocity and flow-rate. It may be worthwhile to notice that an employment of a velocity slip at the boundary wall, will accelerate both the speed and the flow rate on one hand and retard, the resistance to flow and apparent viscosity on the other.

Chapter 6 deals with pulsatile motion of blood (behaving as a Bingham plastic fluid) inside a uniform artery with the formation of a mild stenosis, under the influence of a periodic body acceleration. An axial velocity slip condition has been considered at the stenotic wall. Governing equations are solved by the help of a perturbation technique for obtaining expressions for axial velocity, flow rate, wall shear stress, apparent viscosity, plug core velocity and plug core radius. Variations of these flow variables with variations in flow parameters, are presented graphically. It is observed that both the axial velocity and the volumetric flow rate, increase with an increase of a velocity slip but decrease with the increase in height of a stenosis. Further, rise in the body acceleration enhances both the axial velocity and flow-rate. Flow rate decreases with an increase in yield stress while it increases with the increase in velocity-slip. Plug-core radius is seen to be decreased by an increase in stenosis size.

In the present investigation, flow is regarded as both steady and pulsatile and motion as unidirectional. The results obtained theoretically, are in agreement with other theoretical works and experimental observations, reported in literature.

In this modeling, we have investigated the annular blood flow, enclosed between a uniform or a tapered artery and a catheter, in view of its physiological importance and pressure-flow relationship. Also, pressure-flow relation is seen to be altered in stenosed arteries and that in case of an annular flow in a catheterised constricted artery significantly changes. Likewise, resistance to flow also changes considerably.
However, the situations can be improved, by the employment of a velocity slip at the boundary. In the present analysis, we have shown that the presence of an apparent slip at the flow boundary, accelerates the speed and the rate of flow on one hand but decelerates the resistance to flow and apparent viscosity, on the other. Therefore, in case of an arterial blockage at one or more places, slip at the wall may play a vital role as slip can increase the speed and reduce the resistance to flow. Also, in this investigation blunting in velocity profiles and increase in viscosity with a decreasing tube radius, have been observed. This indicates that the present modeling can explain two blood flow anomalies viz., blunted or flat velocity profiles and Inverse Fahraeus Linqvist Effect (IFLE). In this work, vanishing in velocity profiles, have been clearly indicated. Thus the fluid dynamical phenomena like critical or stagnation points, separation in flow leading to back flow and re-attachment point could be explained with the help of the present investigation. The present model could be used as a base or device in understanding the cardiovascular, cerebrovascular, renal, hematological, arterial etc. diseases.

Finally, the theoretical analysis as developed in the present investigation, can be improved further if two-dimensional motion of blood flow with both radial and axial slips at the flow boundary, is considered. It is strongly felt that such kind of a model could play a vital role in the diagnosis and prevention of many arterial and cardiovascular diseases. We intend to pursue such kind of models in our future course of study. The results obtained from the current work, would be helpful in designing of in-silico fluid modeling modules.