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# Numerical simulation of blood pulsatile flow in a stenosed carotid artery using different rheological models

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ABSTRACT

Symmetrical 30–60% stenosis in a common carotid artery under unsteady flow condition for Newtonian and six non-Newtonian viscosity models are investigated numerically. Results show power-law model produces higher deviations, in terms of velocity and wall shear stress in comparison with other models while generalized power-law and modified-Casson models are more prone to Newtonian state. Comparing separation length of recirculation region at different critical points of cardiac cycle confirms the necessity of considering blood flow in unsteady mode. Increasing stenosis intensity causes flow patterns more disturbed downstream of the stenosis and WSS appear to develop remarkably at the stenosis throat.



## 1. Introduction

The intimal thickening of stenotic artery is known as a beginning step of atherosclerosis. Atherosclerosis is a common dangerous disease and a major cause of death in many countries. Because of the significant role of blood parameters in the formation and progression of the disease, it is essential to know how blood behaves in stenosed arteries. There are a large number of investigations which have led to understanding of the flow disorders due to stenosis related to many theoretical and experimental studies. Deplano and Siouffi (1999) considered a model of stenosis both numerically and using a Doppler ultrasonic velocimeter. They reported that velocity field is highly dependent on flow wave form, particularly downstream of the stenosis. Ojha et al. (1989) obtained velocity profiles for the pulsatile flow through tubes with mild to moderate stenosis severity using the photochromic tracer methods. Tang et al. (2001) experimentally simulated blood flow in carotid artery with fluid-wall interaction. They measured non-linear stress–strain relationship and expressed that stress distribution has a much localized pattern and both maximum tensile stress and maximum compressive stress occur inside the stenotic section. Lee (1990), Siegel et al. (1994), Reese and Thompson (1998) reported their numerical results for Newtonian flow through axially symmetric stenoses under steady flow conditions. Considering pulsatile flow, Buchanan et al. (1999) reported that different flow patterns formed for the highest Womersley number (the ratio of transient inertial effects to viscous effects) under consideration ($W_o = 12.5$). Long et al. (2001) simulated pulsatile blood flow in three axisymmetrical and three symmetrical stenosed tube models with different levels of stenosis severity. They focused on the flow separation zone (FSZ) and the wall shear stress (WSS) distributions for all models. Liao et al. (2004), Toufique Hasan and Dipak Kanti, 2008 investigated the effect of constriction ratio of stenosis, Womersley number and Reynolds number on the flow behavior through stenosed arteries. All of these researches neglected non-Newtonian property of blood.

Taking the non-Newtonian properties of the blood into consideration, Tu and Deville (1996) simulated the blood flow through stenoses using Herschel–Bulkley, Bingham and power-law fluids in a rigid circular tube with a partial occlusion. They acclaimed that the disturbances are stronger by their vorticity intensity and persist after the geometrical obstacle especially for severe stenoses. Chan et al. (2007) compared Carreau and power law models with Newtonian model for a 45% stenosis with a trapezoidal profile and concluded that in terms of velocity, pressure and WSS, Carreau model has very little difference while power law model has much more significant vortices and smaller WSS. Sankar and Lee (2009) solved the flow through mild stenosis using Herschel–Bulkley model. They found that, the plug core radius, pressure drop and wall shear stress increase with the increase of yield stress or the stenosis height. Shaw et al. (2009) investigated Casson fluid flow through a stenosed bifurcated artery and observed that in both the femoral and coronary arteries the variation of axial velocity and the flow rate with yield stress is uniform.

In the current study, pulsatile flow through an axisymmetric artery is conducted using Newtonian, power law, generalized power law, Carreau, Carreau–Yasuda, modified-Casson and Walburn–Schneck as molecular shear thinning viscosity models which are among most reputable models to simulate artery blood flow.

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